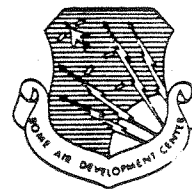


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FEASIBILITY STUDY ON FULLY AUTOMATIC HIGH QUALITY TRANSLATION

University of Texas

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

FEASIBILITY STUDY ON FULLY AUTOMATIC HIGH QUALITY TRANSLATION

Dr. Winifred P. Lehmann
Dr. Rolf Stachowitz

University of Texas

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FOREWORD

This is the Final Report, in two volumes, for the Feasibility Study on Fully Automatic High Quality Translation, by the University of Texas, Linguistic Research Center, Austin, Texas, for Rome Air Development Center, Griffiss Air Force Base, New York, under contract F30602-70-C-0129, Job Order No. 45940000. Zbigniew L. Pankowicz (IRDT) was the RADC Project Engineer.

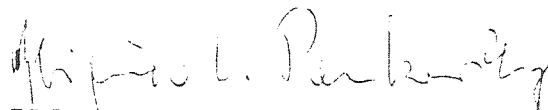
As the appendices indicate, the study brought together specialists in the areas involved in machine translation. The report summarizes their findings. Participants in the study were provided with a preliminary statement of the initial part of this report, except for the conclusions and recommendations, and were asked to send their comments and revisions. These were incorporated in this report, except when they did not seem in keeping with the general conclusions of the various other participants. There were few strikingly diverse points of view.

The authors are grateful to the participants, and to the sponsors who made the study possible.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

Approved:



ZBIGNIEW L. PANKOWICZ
Technical Evaluator

Approved:



FRANZ H. DETTMER
Colonel, USAF
Chief, Intel and Recon Division

FOR THE COMMANDER:



FRED I. DIAMOND
Acting Chief, Plans Office

ABSTRACT

This report presents the results of a theoretical inquiry into the feasibility of a fully automatic high quality translation (FAHQT), according to Bar-Hillel's definition of this term. The purpose of this inquiry consisted in determining the viability of the FAHQT concept in the light of previous and projected advances in linguistic theory and software/hardware capabilities. The corollary purpose was to determine whether this concept can be taken into consideration as a legitimate and justifiable objective of R&D. The effort was supported by 20 expert consultants from the various universities and research centers in the U.S.A. and abroad. Conclusions and recommendations are presented on pages 44-50 of the report. Individual contributions of participants and consultants reflect a wide range of opinions concerning the prospects of FAHQT in intermediate and long range of R&D.

TECHNICAL EVALUATION

The objective of this theoretical inquiry is to examine the controversial issue of a fully automatic high quality translation (FAHQT) in the light of the past and projected advances in linguistic theory and hardware/software capability. The principal purpose of this study is to determine whether the concept of FAHQT is justifiable as a long range R&D proposition. The study is also concerned with the intermediate range alternatives to FAHQT, i.e., machine translation forms that are adequate to the user's needs with or without post-editing. Machine aided translation, based on the automated dictionary look-up, is excluded from the study in consideration of the fact that this by-product of machine translation R&D is well within the current state-of-the-art.

In the context of FAHQT, "full automation" implies that the entire translation process is autonomous in the computer without pre-editing of the source language text and post-editing of the target language output. "High quality" seems to be undefinable in an absolute sense. In referring to machine translation of 100% quality, Bar-Hillel (1) introduced the following qualification.

"When I talk about "100%", I obviously have in mind not some heavenly ideal of perfection, but the end product of an average human translator. I am aware that such translator will on occasion make mistakes and that even machines of a general low quality output will avoid some of these mistakes. I am naturally comparing averages only".

Thus viewed, even the concept of 100% quality is not equatable with the error-free performance in either form of translation. Understandably enough, participants and consultants failed to reach a unanimous agreement as to the definition of "high quality" in machine translation. This is reflected on p. 48, quote, "There is apparently no absolute standard. Rather, standards must be defined with reference to specific users and specific purposes". In the absence of absolute and universally valid quality criteria, the user of machine translation can be legitimately considered an ultimate judge of its quality. This viewpoint was first expressed by Reitwiesner and Weik (2) as early as in 1958.

According to Lamb (3), "all translation can be viewed as human translation since machine translation is nothing but another kind of human translation". It follows from this observation that the fundamental constraints on machine translation parallel those imposed on human translation. Assuming the well-known limits of translatability, this seems to imply that either form of translation is a priori constrained. In summarizing the problem of translation equivalence between SL (source language) and TL (target language),

Catford (4) draws the following conclusion.

"The limits of translatability in total translation are, however, much more difficult to state. Indeed, translatability here appears, intuitively, to be a cline rather than a clear-cut dichotomy. SL texts and items are more or less translatable rather than absolutely translatable or untranslatable. In total translation, translation equivalence depends on the interchangeability of the SL and TL texts to (at least some of) the relevant features of situation-substance".

Ray (5) recognizes the fact that "every translation necessarily involves some distortion of meaning". However, as is reflected in his statements below, this deficiency is not only manageable, but even unimportant in the practice of translation.

"The translation operation is, like the limit operation, possible only under such conditions as "sufficiently" and "arbitrarily", that is, only by the exercise of some evaluative judgement, however little. Since distortion of meaning cannot be avoided, the problem becomes one of confining it to allowable measures of allowable kinds in allowable places along allowable directions".

"..., while no two languages will match exactly in the total range of possible discourse, there are infinitely many specific limited ranges of discourse where the distortion of meaning can be legitimately dismissed as of no account".

The feasibility of FAHQT must be, therefore, considered within the limits of translatability, i.e., taking into account the constraints on the total translation. Since the concept of high quality is untenable in the absolute sense, the question of what is feasible in the context of FAHQT is quite probably more meaningful. It would be patently unreasonable in this stage of R&D to postulate machine translation requirements beyond the limits of translatability imposed on human translation.

Machine translation research, based on puristic notions and oriented toward a global solution, was once compared to a search for the Holy Grail. This all-or-nothing attitude has probably caused as much damage to the progress of machine translation research as the early announcements of quick and easy solutions. Perfectionists in this area have generally tended to ignore the injunction by Lecerf (6) that "entreprendre la mise au point d'ensembles de traduction automatique, c'est avant tout accepter la contrainte du reel".

According to Ljudskanov (7),

"The widespread so-called 100 percent approach, along with the belief that MT presupposes the presence of a complete mathematical model of language in general and of the specific languages in particular, in practice amounts to equating the nature and extent of the knowledge of language in general, which is necessary from the point of view of theoretical linguistics, with the extent of knowledge necessary for the achievement of translation from one language into another. This approach also amounts to equating the description of communication in general with that of the translation process; it ignores the specific characteristics of the process as mentioned above and the general linguistic problems of the theory of translation (both HT and MT) in the general problem area of mathematical linguistics".

"....it can be asserted that the current critical state of MT research throughout the world, although much has happened that legitimately causes well-grounded anxieties and doubts as to its possibilities, is due to a certain degree to the maximalistic tendencies, however laudable they may be in themselves, of the global strategy. By giving due consideration to the particular characteristics of the translation process and of its study, as well as to the differentiation of the aims of mathematical linguistics from the theory of MT and of the fields of competence and performance from each other, research in this field would be channeled in a direction both more realistic for our time and more closely in accord with the facts".

The report highlights on p.4 an important, but often ignored, difference between scientific and technical translations and translations of literary and religious texts, in spite of its importance from the viewpoint of machine translation requirements.

"Even articles and monographs dealing with machine translation have failed to be adequately explicit about the special problems of translating technical and scientific materials by computer. Instead, they have confused the problem by comparing machine translation with the long-practiced human translation, by equating the problems of translating scientific materials with those involved in translating literary materials, and by using the same evaluation criteria for the results".

It is now a commonplace that the style of writing is of paramount importance in literary translation, whereas the accuracy constitutes the most important quality criterion in scientific and technical translations. According to Gingold (8),

"It is not the translator's job to abstract, paraphrase, or improve upon the author's statements. He cannot be expected to convert an article that is poorly organized and badly written in the original language into a masterpiece of English scientific writing. In technical translation, he must always be willing to sacrifice style on the altar of accuracy".

Savory (9) has expressed a similar opinion in his statement that "the translation of scientific work is an ideal example of translation of a writing in which the subject matter is wholly on the ascendant and the style is scarcely considered".

The report further emphasizes the crucial importance of timeliness in production of scientific and technical translations. According to the statement on p. 5, "...timeliness is of increasing importance to users of scientific translations. Even in a relatively unhurried field like linguistics, few articles retain their importance over a long period. Statements have been made repeatedly about the obsolescence of publications issued a few years earlier. The insistence among technical specialists and scientists for speedy translation contrasts markedly with the length of time permitted for completing literary translations". The requirement of timeliness was stressed elsewhere by Gingold (10), quote, "The delay between the appearance of the original journal and its English translation, which may be a year or more, is also a disadvantage, particularly to industry, where time is usually of great importance".

The principal findings of the study, as related to its objectives, can be summarized as follows.

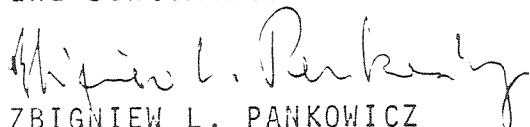
Computer hardware is no longer considered a crucial problem in machine translation. "Remarkable improvements, especially in rapid-access storage devices, have largely eliminated the problems caused by inadequate computers. Lexical items can now be retrieved as rapidly as were the major syntactic rules a decade ago. And with further improvements of storage devices in process, computers no longer pose major problems in machine translation". (p. 12). Developmental prospects in this area are very bright indeed, particularly with the advent of holographic memories. The impact of such memories on both linguistic and computational aspects of machine translation R&D is discussed in detail by Stachowitz in one of his contributions to the report ("Requirements for Machine Translation: Problems, Solutions, Prospects", pp*~~100-106~~). This contribution is considered significant because it provides a complete blueprint for a realistic implementation of a large-scale machine translation system.

Equally encouraging is the appreciation of advances in computer software. "Programming has evolved as rapidly as have computers... A key factor here was the enrichment of programming language data types which made possible efficient representation and manipulation of linguistic structures". (p. 13).

The report reflects a unanimous agreement of participants and consultants that "the essential remaining problem is language" (pp 14-15). It is, therefore, not surprising that linguistics has received much more attention in the study than computer hardware and software. Recommendations presented on pp 49-51 are exclusively oriented toward linguistic research in the context of machine translation.

The report points out that there is "no conflict between specialists in descriptive linguistics, linguistic theory and machine translation... As descriptive linguists improve their understanding of language, and the models by which to express that understanding, machine translation specialists will update their procedures and models". (p. 24). However, the report also reflects a difference of opinions between machine translation experts and linguists as regards the nature, orientation and scope of linguistic research involved in machine translation. It is further worth noting that some linguists participating in this study have not acknowledged Ljudskanov's caveat about "maximalistic tendencies of the global strategy".

The reader is referred to Conclusions (pp 45-48) and Recommendations (pp 49-51), summarizing the results achieved in performance of this study. Recommendation of support for research in machine translation is based on the fact that "quality translations can be achieved in the near future. This recommendation agrees strikingly with conclusions reached in a study carried out in the Soviet Union". (p. 49). Galilei's challenge ("Eppur si muove!"), aptly chosen as a motto in the Introduction to (11) by Kulagina and Mel'chuk, would be equally appropriate as an expression of views and sentiments embodied in the main part of this report.


ZBIGNIEW L. PANKOWICZ
Technical Evaluator

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1. Requirements of translation

With the increase in communication and in publication, translating has achieved a greater importance than ever before. Literary figures are engaged in translating from many exotic languages, as well as from the traditional languages of western culture. Symposia on translation have been held, resulting in the publication of monographs on the topic. Above all, scientists and technical specialists have come to demand translations. As one of the leading experts, Eugene A. Nida, has stated in his most recent contribution to the topic (Nida and Taber, 1969, 1): "Never before in the history of the world have there been so many persons engaged in the translating of both secular and religious materials." The book intimates that the requirements for translation will be increased.

Moreover, it describes more specifically and concretely than earlier discussions the steps that are involved in translation. Translation is defined (Nida and Taber, 1969, 12) as "reproducing in the receptor language the closest natural equivalent of the source-language message." And the paragraph continues: "this relatively simple statement requires careful evaluation of several seemingly contradictory elements."

For a fuller statement on the problem of translation, we refer to the important books by Nida and their bibliographies. His last book, however, contains further perceptive statements that are important to include here.

A section on "the old focus and the new focus" of translating (Nida and Taber, 1969, 1) states that "the older focus in translating was the form of the message... The new focus, however, has shifted from the form of the message

to the response of the receptor."

Further, "even the old question: Is this a correct translation? must be answered in terms of another question, namely: For whom?" After a brief answer, the section continues: "In fact, for the scholar who is himself well acquainted with the original, even the most labored, literal translation will be correct, for he will not misunderstand it." This statement is borne out by the reception to such translations at Oak Ridge, as reported by Zarechnak below.

The growing sophistication with regard to translation which is reflected in the book by Nida and Taber and in many recent publications calls for a new evaluation of the problem of machine translation, and a new statement on the current situation. The requirements for translation vary markedly from audience to audience. Even a glance at the Nida-Taber book, which concerns primarily human translations of the Bible, will disclose the difference between translation of religious and literary materials, and translation of scientific and technical materials.

For the translation of technical materials, the criteria of quality, speed, and cost have been used in evaluations. In the January Conference arranged under the Study, Bar-Hillel summarized his position on the improvements possible in machine translation in the foreseeable future using these three criteria. It is instructive to compare briefly these criteria with the objectives of Nida-Taber.

The primary concern of Nida-Taber is to "reproduce the message" of texts produced by cultures of the past for cultures of the present, often

radically different cultures, such as those of Africa and Asia. By contrast, the texts of interest to scientists and technicians share a common "culture," whether the texts are produced in Africa, Asia or in western countries. Zarechnak, who as director of Oak Ridge Russian-English translation is intimately acquainted with user needs of scientific translation, reports that American scientists readily understand translations of Russian scientific articles even when these are crudely rendered into English. Translations of technical materials accordingly face far fewer problems than do literary and religious translations.

This fact, obvious in any chapter of Nida-Taber, has often been disregarded when the requirements for technical and scientific translation have been discussed. Even articles and monographs dealing with machine translation have failed to be adequately explicit about the special problems of translating technical and scientific materials by computer. Instead, they have confused the problem by comparing machine translation with the long-practiced human translation, by equating the problems of translating scientific materials with those involved in translating literary materials, and by using the same evaluation criteria for the results. In his appended article Martin discusses the problem confronting the human translator of non-scientific material with respect to differences in cultural associations. The example he provides illustrates that some of these problems may not be encountered in technical and scientific materials.

Among the most striking contrasts are the disregard of cost and time in translating religious materials, as indicated briefly below.

The Appendix to Nida-Taber (1969, 174-188) deals with the "organization of translation programs." An organization consists preferably of three committees: (175) "1. the Editorial Committee, which has the basic responsibility for the work of translation,

2. the Review Committee, consisting of highly competent scholars whose advice and help is necessary, and

3. the Consultative Group."

After these three committees have made their contribution, a "stylist is called in" (1969, 186). This proposed organization, which is not untypical for academic projects designed to produce literary translations, provides perspective for the statements concerning post-editing of technical and scientific translations. Obviously, the length of time and the cost required to produce literary and religious translations are not factors of importance.

Yet timeliness is of increasing importance to users of scientific translations. Even in a relatively unhurried field like linguistics, few articles retain their importance over a long period. Statements have been made repeatedly about the obsolescence of publications issued a few years earlier. The insistence among technical specialists and scientists for speedy translation contrasts markedly with the length of time permitted for completing literary translations, and also with "the lag time (from receipt) in publication of the translated journals supported by NSF." This, according to a report of the National Academy of Sciences, (Languages and Machines, 1966, 17) "ranges from 15 to 26 weeks." This time span may be acceptable for archival purposes; for the requirements of scientists and technical specialists it may be burdensome.

Given a choice between overnight machine translation and human translation within two weeks, scientists at EURATOM invariably asked for machine translation. The need for virtually immediate translation is one of the major reasons for the concern with machine translation. In evaluating machine translation versus human translation, this reason may outweigh the difference in cost. And as Nida has pointed out, the parameter of "quality" varies considerably among the different users. Bar-Hillel, who some years ago coined the expression "High Quality Fully Automatic Machine Translation" now states in this appended article that he applied the expression in too absolute a sense. Further, that quality is related to the requirements of the user. This statement echoes the quotation from Nida-Taber on the shift of focus "from the form of the message to the response of the receptor." If technical experts and scientists have reasonable prospects of virtually immediate translation, the prospects may well be vigorously pursued, even if the translations will be more "labored" and "literal" than ordinary users permit for their religious and literary works.

In reviewing the prospects for machine translation, accordingly, the specific requirements must be considered as one of the major criteria. For technical specialists and scientists, translations must be consistent, reliable and timely, whether made by man or machine. Although the arrangements made for human translation are generally assumed to be known, and understood, a brief comparison of the current situation of human versus machine translation, and their prospects, may be useful before examining in detail the procedures involved in machine translation.

2. Translation: human and machine

The topic of machine translation is rarely discussed without reference to translation by man. In the comparison, several stereotypes have evolved. For clarity in dealing with the issue of machine translation these may be briefly noted.

The human translator is generally assumed to be highly skilled, both in the subject matter and in the source and target languages. Some commentators consider skill in the source language less essential than skill in the target language. Kay holds knowledge of the subject matter to be the most essential consideration. Accordingly, it will be no small task to provide machine translation systems with detailed information on scientific topics, and to program them to use this information. Human translators must also acquire knowledge of specific scientific and technical areas. With skills in the source and target languages, and control over the subject matter, the human translator is assumed to have great flexibility. Moreover, besides flexibility he provides immediate access to the text.

When, however, one considers the broad scope of scientific writing, and vocabulary, this ideal picture loses some of its attractiveness. The director of the translation service of the German government states flatly that no available dictionary is up-to-date. A translator dealing with German, one of the most thoroughly studied languages, would be unable to find any translation for thousands of technical terms. Others would have inadequate entries. Accordingly, technical terms might well be wrongly translated. A few moments of reflection by any specialist illustrates this problem of human translators.

One of the chief problems for any translator has to do with the changing meanings of supposedly standard technical terms. A simple area of linguistics, for example, is commonly subsumed under the terms: phonology, phonetics and phonemics. The term phonetics is generally used consistently. But among different authors the terms phonology and phonemics vary widely in their meanings. When such terms occur in texts translated by translation services, they are handled as though they had standard, fixed meanings. But for some writers phonology is used as equivalent to the term phonemics in other writers. Similar illustrations could be provided from any technical area, and all too easily supported by examples.

Without diminishing in any way the rôle of the human translator, we must conclude that adequate translation requires the organizational arrangements created to meet other contemporary technical problems. As noted above, an example of such an organization is proposed by Nida-Taber. If for a relatively unhurried problem in translation, teams of specialists are recommended, rather than individual translators, it is unrealistic to assume that an individual translator can deal with a broad scope of technical material. Moreover, even skilled human translators need retraining in expanding fields of science and technology if they are to keep up with new terms and new concepts.

To meet the problem, the German translation service has been compiling a large dictionary of technical terms and their standard translation. In this compilation, specific translations are fixed. The project, accordingly, is designed to standardize and normalize translations, as well as to provide assistance for human translators. Moreover, the dictionary is mechanized.

Eventually, any text to be translated is to be provided to the translator in a print-out having the translations of all terms in the dictionary, as well as the original. The translator's responsibility would then consist in framing the sentences in the target language. He would also determine the meanings of any new terms. In this way the dictionary would be expanded and updated.

The dictionary of the German translation service contains close to a million items. Problems which human translators face when using generally available dictionaries, which have far fewer entries, may be put in perspective by this resource. The arrangements for translators in the German translation service may also illuminate the requirements for computer-assisted translation.

It is occasionally proposed that computer-assisted translation is an attainable compromise, with better output than that from the individual translator and fewer awkward renditions than those provided by machine translation. Whatever one's reaction to this view, it should be noted that computer-assisted translation requires a large staff of research scholars, and a large computer facility. Kay, a proponent of machine-human translation, proposes an elaborate scheme to permit human beings to assist a system that is essentially a machine translation system. Under this scheme human beings would make decisions which the machine would be incapable of making and thus assure a high-quality output. His scheme envisions several native, possibly monolingual speakers of the source language, several monolingual speakers of the target language and one highly competent bilingual, to whom problems requiring knowledge of both languages would be shunted. In other words, the expenditure for staff

and equipment would not be small, actually larger than that for machine translation. Clearly, computer-assisted translation is proposed as a second choice, through desperation that machine translation is unattainable at present.

In contemplating machine translation, most observers have stereotypes which are as erroneous as are the stereotypes concerning human translators. The output of machine translation is supposed to be simply a printed document of some sort. Consideration of current computer technology however suggests a more likely output of a different kind. Many users of computers already have available display possibilities for research purposes, CRT's. If such research workers wish to secure a translation, little ingenuity would be required to provide it with great effect on the CRT, as described below.

The current arrangements at Oak Ridge, as described by Zarechnak in the January Conference, illustrate the potential output. Scientists at Oak Ridge who request a translation have the text keypunched and mechanically translated when computers are not fully utilized, typically at night. The translations are then available for them the following morning.

If, however, instead of a print-out, the translations were prepared for a running display on CRT's, both the original and the translation would be provided on the screen. The scientists would then be able to consult the original as well as see the translation. Tables and charts, often the most expensive sections to reproduce in translation, would need little attention under such a system. Zarechnak cited an instance at Oak Ridge where a

scientist detected an error by referring to a picture which accompanied the translation from the Russian. It turned out that the Russian original contained the error which was carried over into English. The availability of pictures, tables and charts thus provides a check on accuracy. Other advantages of displays of translations on CRT's will not be pursued further here. One obvious advantage is the speed with which the translations would be provided.

Among the advantages of machine translation is consistency. As in the German translation service, standard terms could always be produced. As a simple example, the German translation service decided to use Telefon rather than Fernsprecher; even the variant Telephon was considered erroneous. In much the same way, any technical term need never be varied, unlike the practice of many translators.

If the quality of such translations is to equal that of the most accurate human translations, a comprehensive dictionary and grammar are essential, as well as the necessary hardware and the software techniques. Achieving these has been the major goal of machine translation. In the next section we note the current status of these three requirements.

software developments.

Programming has evolved as rapidly as have computers. The early higher level programming languages were designed largely for application to numerical analysis oriented problems. Linguists who used computers were compelled to write their own assembly language programs. Eventually, in response to the needs of computational linguists, procedural languages such as COMIT were developed; in addition, other higher-level symbol manipulation languages such as LISP and SNOBOL proved useful for linguistic applications in mind. A key factor here was the enrichment of programming language data types which made possible efficient representation and manipulation of linguistic structures.

In time, procedure-oriented languages were used to produce programs of more general usefulness to linguists. Dictionary lookup and maintenance programs and context-free grammar parsing programs were followed by such programming systems as J. Friedman's transformational grammar tester and S. Petrick's transformational grammar syntactic analyzer. Systems such as these can be considered to be problem-oriented programming languages. The IBM natural language question answering project mentioned by Petrick in his appended paper uses Friedman's grammar tester system as well as a transformational syntactic analysis system that provides for a linguistically more realistic class of transformational grammars than could previously be accepted using its predecessor.

Certainly presently existing procedural and problem-oriented languages make the mechanization of many linguistic processes easier than was the case

a few years ago. The programming of many linguistic algorithms remains a slow and difficult task, however, as is the case for most complex algorithmic processes.

The scope of the programs necessary for machine translation may be noted by examining a flow-chart of the programs that had been projected, and in part completed, at the Linguistics Research Center. These were produced entirely from scratch. Because the basic programs furnished by computer manufacturers were so inadequate, the Linguistics Research Center programs were written in machine language. The expenditure of time was enormous. The magnitude of the problem may be noted if one compares the cost incurred by IBM in developing PL-1; the cost of it far surpasses the entire amount which was spent on machine translation from the beginning of machine translation research.

Gradually, adequate computer programs were devised for data processing. These now form the basis of programming systems used for machine translation. Like all programs, they need modification, and improvement, especially to speed up processing. The basic programs, however, are available and to them the additional programs needed for language processing can be added. Like computer equipment, programming systems will be improved. But in the same way, they no longer provide an obstacle to work in machine translation. Kay, an authority in the field of machine translation software, states flatly that "the real problems of machine translation are not in program writing; they are in linguistics."

All participants in the study agreed that the essential remaining problem

is language. Language has proved to be immensely complex, far more complex than linguists themselves had recognized. Moreover, as noted below, linguists do not agree on what constitutes complexity in language.

The fundamental linguistic problem for machine translation is often discussed in terms of deep or underlying structure. Numerous examples have been given to illustrate the problem; among the most commonly cited are the sentences:

1. He is easy to please
2. He is eager to please

Both sentences are alike on the surface. Yet their meanings differ, as the paraphrases indicate:

1. Someone pleases him readily
2. He pleases someone else with alacrity

Speakers of English interpret each sentence correctly. A machine using an inadequate model of English would not. It would take "he" to be the subject of the verb + adjective combination, and also of the infinitive; its analysis of sentence 1 would therefore be wrong. A literal interpretation would fail to determine the proper meaning of this sentence and many other sentences. By determining the deep structure the meaning can be more easily arrived at. Alternatively, "easy" may be provided with a feature which would transform "NP be easy to -Inf" to "it be easy to -Inf NP" in accordance with Harris' use of transformations.

Language is structured in this way in all its components, the phonological as well as the syntactic. In both of these components, it is a code,

rather than a cipher, system. The human brain knows how to interpret the code. If machines are to interpret language, they must be provided with a comparable capability. Engineers have been working on machine interpretation of the phonological system; it would be useful, for example, if telephone "dialing" could be done by voice, rather than manually. Engineers have not mastered the problem, however, even though they are aware of the basic difficulty.

The problem in the syntactic component of language has been one of the central issues for linguistics since the publication of Saussure's Cours in 1916 (though it was known earlier). Various labels have been given to the underlying structure. Saussure used the traditional philosophical terms: "form" for the underlying structure and "substance" for the surface structure. Recently the term surface structure has been used almost exclusively rather than substance, and deep or underlying structure rather than form.

In view of this structure of language, techniques must be devised to get from the surface structure to the deep structure. Recently linguists have proposed to do so by specifying the relationships between surface and underlying structure by means of transformations. Current linguistic descriptions state these relationships in such a way that the abstract underlying structures are transformed into the surface structures. That is to say, descriptive grammars start from deep structure and relate it to surface structure. If, however, transformations are applied in computer analysis of language, the deep structures must be primarily determined from the surface structures. Accordingly, for the computer, reverse transformations must be devised.

These would not simply be the obverse of transformations linking deep structure to surface structure.

The technique of using reverse transformations was explored almost a decade ago. But it was unsuccessful, primarily because the proposed transformations yielded too many underlying structures, including wrong ones for any given surface structure. In devising reverse transformations, the linguists had not been able to refer to lexical features. The system being developed at the Linguistics Research Center can make use of lexical features, and thus is meeting this problem. Descriptive linguists have also encountered the problem of producing too many alternatives by means of transformations, and are painfully aware of it. Transformations are now generally acknowledged to be too powerful (Bach; Peters and Ritchie, 1971).

This realization has important consequences for machine translation. The fact cannot be escaped that in machine translation, one must somehow determine the underlying forms of sentences. Further, the technique of using some relational formulae like reverse transformations is also clearly necessary. In considering linguistic techniques, the fundamental question is: how can these formulae be adequately restricted so that they yield only the specific underlying structure intended by the author, that is, the proper meaning?

Two devices must be used: the lexical elements must be described as precisely as possible, so that only the desired transformations apply; the transformations must be devised in such a way that their use is properly restricted.

Exploiting this understanding of the necessary procedures will require considerable work. The lexical analysis alone will be a huge task. It will,

however, lead to vastly improved general purpose dictionaries, and vastly improved understanding of language, with implications for various applications. Jakobson confirms the inadequate state of dictionaries in all languages. Developing the necessary techniques to arrive at underlying structures will also require considerable study.

Like programming techniques, and computers, the linguistic techniques will continue to be improved. Unlike them, the techniques are not yet available for any appreciable amount of any language. As stated above, dictionaries are inadequate. And the fullest account of the grammar of any language: Integration of Transformational Theories on English Syntax, by Robert P. Stockwell, Paul Schachter and Barbara Hall Partee, is generally considered premature. For these reasons, specialists state that linguistic analysis is now the major problem if machine translation is to be achieved. The state of linguistics is accordingly of vital importance for machine translation.

4. Contributions of linguistics to machine translation

Two important topics of recent linguistic research have been of major concern for machine translation, and have been in part prompted by work in machine translation: the problem of a universal base, and that of ambiguity in language. Views on each of these topics have changed considerably, even during the last decade. Linguists also differ in their views on each, as the following statement may indicate.

The assumption of a universal base receives support from the capability of speakers to translate. It is also supported by the capability of infants to learn any language, to learn it rapidly, and in accordance with well-determined stages. Whatever a baby's ancestry, it acquires the language it hears. Moreover, the stages of linguistic development are fixed for virtually all infants, regardless of their intelligence.

These observations are most plausibly accounted for if we assume some fundamental principles common to all language; further, that these somehow are related to the functioning of the brain. The principles are highly abstract. They permit certain linguistic structures and constrain others which are theoretically possible. As yet they are not by any means thoroughly explored. The term "universal" has been used for general characteristics of language; one example of a universal may be exemplified here, with two sentences and their variants.

- 1.a She regretted the fact that she had taken the book.
- 1.b She regretted the fact that she had taken what?
- 2.a She regretted that she had taken the book.

2.b She regretted that she had taken what?

2.c What did she regret that she had taken?

BUT NOT 1.c *What did she regret the fact that she had taken?

The impossibility of 1.c results apparently from a universal principle which blocks the extraction of an element out of a clause modifying a noun phrase.

This principle was formulated by Ross (1967, 66-70) as "The Complex NP Constraint." Since this principle applies to all languages which have been examined, it is assumed to be a universal characteristic of language.

Whatever the views which will be formulated concerning universals, this principle, like other universal principles that are being investigated, restricts the possible transformations for structures of language. Since language is governed by such constraints, the model which must be constructed to embrace all languages must have certain limits. Moreover, if only because of the finiteness of the human brain, grammars must be finite.

These observations lead to the conclusion that a mechanical translation system can be devised. Even more support is provided by the conclusion of much recent linguistic study that we may posit the existence of a universal base. For the surface structures of any language can be related to such a universal base. Since the universal base in turn can be used for deriving the surface structures of any language, the universal base can serve as the intermediate language between any source language and any target language.

The possibility of devising a translation system in view of the fact that a universal base may exist still leaves many problems. The surface structures of one language may map into the intermediate language differently from those

of the target language. For semantic distinctions which are overt in one language may not be overtly expressed in another language. Different languages may also represent differing "word views." We assume, however, that closely related languages, like English and German, are similar in expressing their semantic distinctions overtly and covertly, and even in their surface structures; accordingly, they are relatively easy to translate into each other. Moreover, languages strongly influenced by another language, as were the languages of western Europe by Latin, so that Whorf referred to them as Standard Average European, share many surface features. Accordingly, translation systems may be so designed that the description of any source language is directed at a specific target language. And in our current understanding of language, attempts to move directly from any source language to a universal base, in the hope of translating into any other language, are premature. For we must take into account the complex relationships between a given language and the universal base.

That linguists have not yet been able to determine the exact nature of a universal base does not present a problem for linguists who favor machine translation by means of an intermediary language. Garvin has stated (1970, 9-11) that an intermediary language need be nothing more than a series of symbolic notations to record the output of the recognition routine for the source language and to serve as input into the command routine for the target language.

Further, as mentioned in the preceding chapter, rigorous procedures for establishing relationships between surface structures and a universal base must be established. For example, as Ritchie and Peters (to appear in

Information Sciences) have demonstrated, the transformations characteristic of most generative grammars are so powerful that they permit the derivation of any structure. Consequently, in spite of their contributions to our understanding of language, they can make no claim on properties of grammars, on a universal base, or on what is going on in the brain. Current transformational grammars are accordingly inadequate devices for describing languages and also for use in machine translation systems, for which they produce far too many syntactic interpretations of any given sentence.

The production of devices to map surface structures stringently into underlying structures is one of the most serious concerns of current linguistics. Bach's paper noted above (1971) is an example. A device projected by Stachowitz has been described in RGEMT (1970). It makes use of an underlying form, the standard strings of a language. Associated with these strings are canonical forms, which represent the meanings of given sentences. "The language" of these is assumed to be "common to all natural languages" (Stachowitz, 1970, T-65). Fuller information on the model is given T-66ff. The quotation here may be adequate to indicate that the canonical forms correspond to a universal base. A description of translation as it is being pursued in accordance with this model at the Linguistics Research Center is appended (Stachowitz paper).

Of great importance for the Linguistics Research Center system is a well-designed lexicon. The intensive lexicographical work which has been going on at the Center for more than two years now has resulted in great amounts of syntactic information; the incorporation of semantic information is currently in progress. Because of their syntactic and semantic classification, the lexical

entries will limit the possibilities of relationship with canonical forms. In this way a proper match will be brought about between the lexical and syntactic elements of the source language and those of the target language.

The design of the lexicon has been vastly improved over dictionaries envisaged a decade ago. Without intending to dwell on the naivete of these and their proponents, reference might be made one further time to the saying which was supposedly quite ambiguous and accordingly a prime exhibit of the difficulties of machine translation: "Time flies like an arrow." When one notes that Austin's How to Do Things with Words was available at the time this saying was widely discussed, the singular limitations of a view of linguistics which could permit the citing of the proverb seem quite remarkable. For as Austin made clear, meanings cannot be determined from syntax alone. Additional publications, such as Speech Acts by John R. Searle (1969), make the simplistic attention of a decade ago to a highly limited type of syntax quite difficult to understand.

As linguists have improved their models of language, the problem of ambiguity has been reduced. It may be noted that the attention to the pragmatics of Peirce repeats a position held early in machine translation research. By attention to pragmatics, that is, to information on the "origin, uses and effects" of language, sentences belonging to the class of proverbs are not treated like sentences found in scientific exposition. Attention has also been focussed on such classes as illocutionary verbs, or on the characteristics of speech acts. Thus a sentence like: I pronounce you man and wife would not be treated as a simple declarative statement, with the meaning of "pronounce" in a sentence

like: They pronounce greasy with a voiced groove fricative.

While models of language in this way incorporate far more information about individual sentences than did the purely syntactic-based grammars of a decade ago, means must be devised to take account of the more accurate analysis of language which is now projected. Suggestions vary concerning the implications of these developments, as the following chapters will indicate. Some specialists consider machine translation unlikely unless at the same time automatic information and fact retrieval are made possible. Others hold that machine translation is not now, and may never be, contemplated for types of language outside technical and scientific documents; accordingly the "origin, uses and effects" of the material to be translated are determined, and investigators dealing with machine translation should direct their concerns at this restricted type of language.

Whatever steps are selected to employ findings of contemporary linguistics to carry out machine translation, it should be noted that specialists in machine translation have taken account of these findings. There accordingly is no conflict between specialists in descriptive linguistics, linguistic theory and machine translation, as Chapter 6 below will outline in further detail. As descriptive linguists improve their understanding of language, and the models by which to express that understanding, machine translation specialists will update their procedures and models.

5. Pertinent recent work in linguistics

Contemporary linguistics is concerned with all facets of language, its syntax, semantics, aberrant uses, uses in established social situations, its relation to other disciplines, such as logic and so on. This breadth of concern contrasts strikingly with self-imposed limitations of the recent past. It also leads one to examine the extent of concern of machine translation with these matters. For machine translation is an application of linguistics, like language teaching, design of communication channels, and the like. Each of these applications relies in part on disciplines other than linguistics. Each may or may not be involved with the various sub-disciplines of linguistics.

To what extent applications are intricately tied to the various concerns of linguistics is a highly important problem; for many of the most active theoreticians in linguistics deplore their inadequacy in understanding language. Some state that an understanding is not foreseeable for a considerable length of time, such as half a millennium. Moreover, there is no comprehensive linguistics theory. Most of the current efforts of linguists, even those who style themselves theoreticians, are directed at minutiae. These efforts, such as the repeated examination of quantifiers like some and any, are carried out chiefly to find support for new hypotheses. If adequate language teaching, or machine translation, or any other application of linguistics is so dependent on a thorough understanding of language that it must be deferred until linguists arrive at a satisfactory linguistic theory, anyone with an interest in these fields should be advised of his dubious expenditure of time, energy and funds.

In dealing with this important question, we may examine the concerns

of those linguists who are especially vocal about our lack of understanding of language. John Ross furnished an excellent example of these concerns in one of his presentations sponsored under the Study. It will be summarized briefly here to illustrate topics which engage the interest of linguists, and their possible pertinence for machine translation.

For some time linguists have been concerned with the role of quantifiers in language, such as some : any. Among such recent linguists are Brugmann, Jespersen, and Sapir. Their discussions have not solved all of the problems with quantifiers. Current concern extends beyond the simple cases, such as those included in Fowler (1965, 31): "Have you any bananas? No we haven't any bananas. But yes we have some bananas." This quotation implies that some is used in positive contexts, any in negative, even though it is provided in Fowler's discussion of any (= some) in positive sentences like: "Then, for the first time, she paid any attention to my existence." While Fowler's entries for any and some concentrate on stylistic matters, contemporary linguists deal with the syntactic and logical problems. For example, they may note that in addition to other restrictions that cannot be included here any is not used before verbs with negative implication, such as doubt, dislike, and predicate adjectives such as unkind. For example, the following sentence is impossible: *Anyone doubts that the earth is flat. But the following sentence is possible: Anyone would doubt that the earth is flat. Similarly, in contrast with the impossible: *Anyone is unkind the following sentence is possible: Anyone who fails to send his mother a card on Mother's Day is unkind. The precise constraints have not yet been defined.

One of the problems in this definition is the existence of two meanings of any, one illustrated in Ross's sentence:

Anybody could have shot Max

The meaning of any here might be made more precise by adding: whatsoever. This use of any is found only when possibility is involved; it is not used with must. A different meaning (some) is found in the question: Do you know any songs? If, however, stress were put on any, especially in a negative sentence, the "any...whatsoever" meaning would emerge.

Accordingly, as study of quantifiers has been pursued more extensively it is clear that a sentence like the following can have two meanings:

We do not believe that any catalyst could have precipitated the reaction

On one interpretation, this sentence could be roughly equivalent to: that some catalyst, that is, that a selected catalyst was involved. By another interpretation it would be equivalent to: that any catalyst whatsoever was involved, that is, that no involvement by a particular catalyst was possible.

This indeterminacy of usage in English presents a translation problem, for German, too, indicates slight differences of meaning with quantifiers such as irgendein 'someone, anyone'. These differences are especially important in the colloquial, as the following quotation from the Duden Grammatik (1959, 265) may indicate:

Irgendeiner muß es doch getan haben!

"Someone must surely have done it!"

Such usages are often found in conjunction with modals and adverbs, like doch in this sentence. For the examples of any which Ross cited, however, translation

would not be a problem inasmuch as the ambiguity in English is preserved when literal translation into German is carried out.

The use of any in such a relatively straightforward sentence is simply the beginning of Ross's interest. He has pursued the difference in uses of any in syntactic constructions illustrating general syntactic patterns or principles which he has investigated intensively. One of these is a "maximal domain of syntactic processes, "—in his word "island".

An island is subject to special constraints, as the impossibility of the following example indicates:

*Who do you believe their claim that Max fired?

If "their claim" were eliminated, the equivalent sentence is possible:

Who do you believe that Max fired?

By the use of claim, an island is created which does not permit the extraction of the object of fired. See Chapter 4 above.

In his discussion, Ross proposed that islands have an effect on the meaning of any, e.g.

We do not believe their claim that any catalyst could have precipitated the reaction

For Ross, any in such a context can only mean "any...whatsoever". Not all participants in the Conference agreed. Yet the situation is presented here nonetheless to illustrate the delicacy of concern which occupies current syntacticians. Readers may decide for themselves the importance of possible ambiguities in such sentences if machine translation were confronted with them.

the normal interpretation gets rejected as inappropriate). We accordingly get a non-colloquial translation which in terms of information conveyed remains adequate. Finally, the possibilities of human interaction to provide the required information on an ad hoc basis, either by intermediate discussion or by the kind of successive attempts editing discussed above may be of substantial help. Accordingly, the phenomenon ought to be rather the occasion for more intensive research.

Norman M. Martin
University of Texas at Austin

Another syntactic principle explored by Ross is in his words the domino effect. By this principle, selected elements like deny affect subsequent elements in the sentence. Thus, deny rules out the last of the following sentences even though the others are possible:

1. I deny that anybody said anything nasty
2. I deny that anybody said something nasty
3. I deny that somebody said something nasty
4. *I deny that somebody said anything nasty

In the same way, according to Ross, any cannot be used in lower clauses when some is used in upper clauses, as in:

Finding somebody under the bed is not easy for some people

That is, if the first phrase read: finding anybody under the bed, the sentence would be impossible, on Ross's view. On the basis of such patterns, Ross asserts that domino constructions disambiguate. Accordingly, the following sentence can only have the "any...whatsoever" interpretation:

We did not inform some researchers that any catalyst could have precipitated the reaction

From these examples, Ross concludes that in machine translation the sense of any would not be determined until the machine had searched for some in the same sentence. That is, machine translation would be faced with a large job. For the meaning of individual words could not be determined simply by examining the immediate contexts. Rather, entire passages would have to be examined. The problem would be compounded because linguists have not yet determined the extent to which individual areas contribute to disambiguating meaning; see Chapter 6.

Ross cites these and other problems in support of his contention that linguists have a highly inadequate view of language. The extent of his pessimism may be illustrated by his statement that the sentence: Birds sing is full of a host of unsolved problems.

As noted above, individuals will have to evaluate our current understanding of language and determine for themselves whether Ross's bleak characterization of the state of linguistics implies that machine translation now is impossible. The extent to which machine translation depends on the production of a comprehensive linguistic theory was discussed repeatedly during the Study. Obviously the sentence: Birds sing can be readily translated: Vögel singen, whether or not Ross's problems are solved. In much the same way, many complex constructions may be translated straightforwardly, especially between closely related languages.

It may not be presumptuous then to suggest on the basis of Ross's problem-riddled example that man and machine can happily embark on translation projects, even before current and future generations of linguists solve its momentous problems.

For students of translation, a second paper may furnish more comfort concerning the contributions of linguistics--the paper of Fillmore which undertook to determine the possibility of finding an unambiguous interpretation for the sentence: May we come in? Fillmore selected the sentence, partly because it is extremely barren in providing assistance to a hopeful interpreter. It contains no content word for the subject, as does the sentence: Birds sing, to delimit the meaning of actor. For like other auxiliaries, may has a broad

scope of meaning. Yet Fillmore demonstrated that proper use of all linguistics features leaves little question about the proper meaning of the sentence.

Since the paper is appended, it may be consulted for details. The general types of analytic techniques, as well as the types of "linguistic information" in this sentence pointed out by Fillmore will be summarized here. Moreover, in evaluating the implications of Fillmore's analysis for machine translation, it is important to note that he used only the written form of the sentence, excluding information that might be obtained from "any understanding of the voice quality of the speaker on the manner of utterance."

Identifying first the "syntactic information" in the sentence, Fillmore uses it to determine among the three possible functions of may the one which is appropriate in this sentence.

Next, examining the "illocutionary force of the question," Fillmore notes the information on deixis furnished by the pronoun and the verb come. The term "illocutionary force" refers in Fillmore's paper to the obligation which the question imposes on the addressee, that is, the obligation to exercise authority. The term "deixis" refers to the various aspects of the interpretation of sentences that relate to the speech act situation, such as person deixis, place deixis and time deixis. The possible meanings of come are restricted by its use in "a permission-seeking utterance."

Last, it may be noted that Fillmore determines the meaning of the sentence from its "surface structure." He has done so by using a comprehensive lexical description for each of the four words. The possible meanings of each

are restricted by the order of the sentence and by the selection of the other elements. That is to say, disambiguation was carried out by using two syntactic devices: order and selection.

In conclusion, Fillmore lists "the various kinds of facts which must... be included in a fully developed system of linguistic description." These are extensive. Yet such explicit linguistic descriptions permit a mechanical disambiguation, and interpretation, of a given sentence.

The effort required to produce these descriptions will, however, be enormous. An example of the analysis necessary for improved interpretation of sentences, which will be particularly important for information processing, is Karttunen's paper, "The Logic of English Predicate Complement Constructions." This paper, which is also appended, leads to seven classes of verbs, each indicating a commitment which "the main sentence carries along...with respect to the truth or falsity of its complement" and an indication of "what is implied." For example, the verb cause belongs to one of these classes which carries a commitment "true" for main as well as complement sentences. The seven classes of verbs arrived at in the paper identify meanings in much the same way as did the syntactic information in the sentence: May we come in?

Linguists accordingly are drawing nearer to lexicographical work of the past, as represented especially by Zgusta and Josselson in the Study. Since the use of lexicographical techniques for machine translation is discussed in the appended papers of Zgusta, they will not be further noted here.

Current linguistic description in this way is providing information on detailed lexical classes, as well as on syntactic constructions. These two types

of information about language, whether they be labeled syntactic or semantic, are leading to descriptions of language which are so precise that the sense of a sentence can be determined mechanically.

The generative semanticists, besides Ross, who participated in the Study: George Lakoff, Robin Lakoff and James McCawley, are also contributing insights which will sharpen our understanding of language. McCawley, for example, challenged the analysis of adjectives as reduced forms of relative clauses. In his presentation he cited examples, such as: He's an incredible fool which cannot be derived from: He's a fool who is incredible. Further, while the sentence John is an easy man to please is acceptable, the construction is unacceptable for a noun like that in the sentence: *John is an easy tool-and-die-maker to please. Such observations point out the necessity of distinguishing sub-classes of "adjectives" and carefully defining their uses in somewhat the same way as Karttunen and other linguists are distinguishing sub-classes of verbs.

These linguistic analyses will not however solve the problem of sentences which Austin labeled "performatives". One of the participants in the Study, Fraser, concerned himself particularly with the problems raised by Austin, and pursued by other philosophers such as Searle. As Austin pointed out, performative sentences contain "humdrum verbs in the first person singular present indicative active." An example is: "I name this ship the Queen Elizabeth." Few linguists are unaware of Austin's book How to Do Things with Words (1962). It is noteworthy that the book concludes with a sub-classification of the verbs discussed. There are five classes:

verdictives, 2) exercitives, 3) commissives, 4) behabitives and expositives. The example given above belongs to Austin's class 2. Like the work of the generative semanticists, Austin's leads to more precise lexical analysis.

Modestly, Austin does not claim to have produced a definitive classification, but includes in his final chapter the statement: (1962/68, 148) "Now we find that there was one further thing obviously requiring to be done, which is a matter of prolonged fieldwork." Generally, fieldwork is used by linguists of rank in non-literate cultures. Austin obviously recommends highly exacting analysis of the types discussed earlier in this chapter.

After Fraser's presentation, the problems raised for machine translation by illocutionary verbs were discussed, especially by Ross and Bar-Hillel. Like Fraser, Ross stated that a theory of speech acts is not essential for machine translation, inasmuch as its goal is the translation of technical materials. Agreeing with this view, Bar-Hillel added that nonetheless we need a great deal of pragmatic information.

This chapter was intended as a survey rather than as an evaluation of current linguistic work as pertaining to machine translation. Linguists are carrying on research into the narrower concerns of language, and those listed in the first paragraph of this chapter. Though not all of this work may be directly pertinent for machine translation, specialists in machine translation are profiting greatly from it. The implicit interest of this work--to analyze sentences so thoroughly that they can be interpreted from the linguistic information contained within them--is of great significance for machine translation.

To the extent that this interest is accomplished, machines will be able to translate.

6. Views of specialists concerning machine translation

One of the primary problems in presenting the views of specialists on machine translation results from the low level of research during the past five years. Few groups received any kind of support. The greater part of them could only update their previous systems, not introduce major innovations. In view of the low funding, research was severely restricted, generally devoted to improvements in the lexicon. This limitation in funding greatly restricted the possibility of carrying out new experiments, let alone that of producing improved translation systems which could meet some of the goals held out for machine translation. The views of specialists are accordingly based in part on assumptions framed some years ago when some long-range machine translation projects were able to carry out work in programming and in linguistic analysis, and to test their efforts by means of computer runs.

In his summary on the final day of the January Conference, Bar-Hillel concentrated on the linguistic situation. Noting that the primary considerations are quality, speed and cost, he expected improvements in speed and cost of output from advances in computer hardware and software; but their contributions to improved quality would only be external, for example as printouts would begin to approximate those produced by printing-presses. Essential for improving quality is improvement in linguistic theory and analysis.

Bar-Hillel's discussion involved arguments on a definition of quality, and on the receptivity of scientists to output from the translation systems which now are in use, notably the Georgetown system as used at Oak Ridge. This point will be discussed further below, in connection with Zarechnak's statements.

Bar-Hillel disagreed with Zarechnak's statement that the output was approximately 80% complete. His own estimate is around 35 to 40%. He assumes that sustained linguistic work during the next five years can raise this figure by 15%. And he considers this degree of accuracy less than that which sponsors demand. But as a perceptive participant at the Conference pointed out, Bar-Hillel's estimate has to do with readability. Zarechnak's on the other hand has to do with informativeness, as the reaction of the Oak Ridge scientists indicates.

Turning from this pessimistic estimate to possible palliatives, Bar-Hillel rejected the possibility of simplification of scientific texts by editors, and he also doubted that scientific texts presented many fewer problems than do general materials. Among the questions discussed during Bar-Hillel's summary were inadequate means devised to measure complexity. Fraser pointed out the difficulties involved in determining such means, for complexities may exist at the various levels of language, by no means in parallel ways. The question accordingly is another which has been raised in machine translation research.

In what he considers the present impasse, Bar-Hillel proposed that fully automatic machine translation must be sacrificed for the time being, and that instead efforts should be made to develop man-machine combinations for translation. He had no suggestion on the type of combination, but indicated that the most promising one would have to be determined by research. During the discussion Pankowicz pointed out that no translation, indeed no writing, is published without editorial intervention. Bar-Hillel envisages more "human

intervention" than is the normal practice in translation. He concluded by suggesting that determining a useful type of man-machine translation system would not be difficult.

However negative he is to fully automatic machine translation at present, Bar-Hillel recommends that further research be carried out. In his view, such work is intellectually respectable and challenging. It is of further interest to him because of its potential contributions to information retrieval.

Garvin is far less pessimistic about the prospects for machine translation. In his view, the basic problems involving linguistic analysis have been identified. What remains to be done is application, involving detailed lexical analysis. By Garvin's view, if adequate funding were provided, acceptable outputs of machine translation could be achieved in five to ten years.

Neither Garvin, nor any of the other participants, however, were able to define what is meant by acceptable translation. Moreover, Garvin believes that linguists must leave such determination to users. A similar position was maintained by Kay, who stated that "buyers" of translation are the persons best equipped to pass judgment on the acceptability of translations. A comprehensive judgment accordingly is unlikely until machine translation is carried out.

Garvin's views on the essential problems are indicated in his appended paper. For him too, the linguistic problem is primary. Moreover, a system must be prepared in accordance with an adequate model. He states further that all systems under development are of a tripartite design, but that grammar and computer programs may be linked. Specific problems, in his opinion, must be solved in terms of the overall system. There can be no hard and fast

rules, for example, for deciding whether to handle any particular topic in the grammar code or in the algorithmic portion of the system. Garvin is also flexible in his recommendations for performing analysis; he does not advocate rigid analysis from left to right, but rather selective analysis. As an experienced practitioner in the field, accordingly, Garvin believes in making use of any advantages which can be offered by linguist or programmer. The designer of a translation system relies on them for any possible assistance, but like any applied scientist he must decide when their contributions are useful in helping attain his ends.

Of particular interest is the IBM question answering system mentioned in Petrick's appended paper. This system is based on a generative transformational syntactic component that reflects current transformational theory to a reasonable extent. Deep structures are in some cases quite deep; certain nouns for example, are transformationally derived from underlying abstract verbs. The use of relatively deep structure facilitates semantic interpretation; this is accomplished through the use of a translation mechanism due to Knuth. (The task of relating these deep structures to surface forms is, to be sure, quite complex. Even relatively simple sentences may require as many as forty or fifty transformational applications.)

The syntactic analysis algorithm which is utilized is valid for a significant class of transformational grammars. This, together with the modular nature of the Knuth semantic interpreter, makes modification of both the syntactic and semantic components relatively easy.

It should be noted that the system being implemented at the IBM

Research Center is an experimental question answering system based on a restricted subset of natural English, not a machine translation system involving relatively unrestricted textual material in two or more natural languages. This choice of application was made because the Theoretical and Computational Linguistics Group at the IBM Research Center feels that the coverage of English presently attainable by any means is too small for the purposes of machine translation but perhaps not too small for applications which can tolerate artificially restricted input. It should also be noted that the IBM system is in an early state of development with the separate components (generative transformational grammar, syntactic analyzer, and semantic interpreter) yet to be integrated and put to use as a coherent whole.

By contrast, the system used for machine translation of Russian at Oak Ridge is essentially the GAT system developed at Georgetown University some years ago. The lexicon and syntactic rules are updated by Zarechnak constantly. But the basic system, based on a surface structure analysis, has been maintained. As indicated above, the system is frequently used. According to report, the output is valuable, though scientists must become used to its Russian-like syntax. If translation indicates that a paper is particularly valuable, a further effort can be made to produce a completely accurate version of the original. Zarechnak considers the output of great value to the Oak Ridge scientists. They must also find it useful, for numerous translations are produced on the initiative of individual scientists.

As several participants in the Study pointed out, a convincing analysis of the usefulness of machine translation will result only from a well-designed

experiment determining reactions to its output. Yet linguists have identified the stages of accuracy, in accordance with the levels of language which must be incorporated in a system, as shown in the examples below. It is unlikely that scientific or technical articles would contain such simple sentences. Yet on the assumption that no further linguistic information were available in the sentences to be translated, these examples illustrate successive degrees of sophistication in the development of machine translation and the expected quality at each stage.

Proceeding from the simplest system to one which approximates the information available to a human translator, we may propose the following progression:

- translation with:
1. Lexical information alone
 2. Syntactic information
 3. Semantic information
 4. Contextual information
 5. Pragmatic information

Each state incorporates all of the earlier stages.

The following examples indicate difficulties, and characterize inadequacies, which each type of system fails to resolve. If that type of system were used, these shortcomings would have to be removed by pre-editing or post-editing.

1. Lexical translation, with no access to syntactic information.

They milk cows.

Under such a system milk might be taken as verb or noun.

2. Syntactic translation, with no access to semantic information.

The conductor broke.

The conductor smiled.

Under such a system disambiguation would be impossible.

3. Semantic translation, without contextual theory.

We watched the conductor. He smiled.

We watched the conductor. It was on fire.

Here too disambiguation would be impossible.

4. A system making use of contextual information would be able to disambiguate the sentences given in 3, and other examples, such as the German verb beugen in the indicated contexts.

beugen = bend

= deflect (optics)

= inflect or conjugate (grammar)

5. A system with access to pragmatic information would provide for the German sentence "Eisenhower folgte Truman" the correct reading "Eisenhower succeeded Truman" rather than the equally correct alternate translation "Eisenhower obeyed Truman."

In accordance with this sketch of potential systems, we expect the highest quality from a system which is at stage 5, or possibly at stage 4. The requirements for these stages have not yet been handled in linguistic theory, and accordingly at present they are unattainable. To what extent a system at stage 3 will be able to translate scientific and technical materials acceptably will depend on testing of the output, and the receptivity of users after such a system

has been developed. Systems at this stage are now under development.

The questions raised in the Study are also of interest to scholars who could not participate, as a recent article by Kulagina, Mel'chuk and Rozentsevyg indicates. It is noteworthy that, like Bar-Hillel and other participants in the Study, the three authors concentrate on the quality to be achieved, assuming that cost and time can be adequately managed.

The authors express their views concerning the feasibility of machine translation with regard to the ALPAC report, especially its view that machine translation is at present impractical. They state: "We wish to declare decisively that this view has no real support: it is founded upon a failure to understand the problem in principle and confusion of its theoretical, scientific and practical aspects. The fact that machine translation has been ineffectual in practice to the present should, in our opinion, lead to an increase rather than a decrease in efforts in this area, especially in exploratory and experimental work. It is clear that no practical result can precede fundamental development of the problem, although the possibility is not excluded that useful practical results may be the product of early stages of research. There is not, and has not been, a crisis in machine translation as a scientific undertaking, a crisis which would be reflected in a lack of ideas and a lack of understanding what path to follow. Machine translation as a scientific undertaking...is continuing to develop actively. There are many interesting ideas and approaches which are far from being sufficiently developed and experimentally tested."

After making this critique of a negative approach, they state that a high-capacity, high-quality system can be established within about five years

if (a) the components produced under a system--dictionaries, grammars, algorithms--are prepared on the basis of available theoretical developments and experimental results, (b) goal-directed experiments are carried out (given an existing algorithm), and (c) research oriented toward a future modification of the system is carried out.

Having arrived at such a judgment, the authors suggest the establishment of an MT center comprised of a linguistic, a mathematical and a computer group equipped with the best computational equipment available. From such a center they expect not only contributions to machine translation, but also to automatic language processing in general. They also believe that if their recommendations are followed, machine translation on an operational scale can indeed be accomplished within their estimated deadline (+ five years).

The estimates, and recommendations, of this article coincide remarkably with those of some of the participants in the Study, notably Garvin. Readers may form their own judgments on the basis of the appended articles, not all of which agree in these estimates or recommendations. Like Garvin, Kulagina, Mel'chuk and Rozentsveyg have been involved in the theoretical and practical aspects of machine translation. Their views are accordingly based on intimate knowledge of the difficulties involved in attempting to achieve high quality machine translation.

Conclusions

1. A technological application drawing on three bases: computer hardware, computer software and linguistic analysis, machine translation today is confronted with fundamental obstacles only in the last. Advances in computer hardware and software have greatly reduced the earlier problems in these areas.

In spite of the progress that has been made in linguistic analysis, linguistic research has dealt primarily with syntactic analysis of individual sentences, and hardly at all with semantic problems and discourse analysis. As a result, current linguistic theory is inadequate for machine translation. For machine translation, semantic representations derived from syntactic structures in the source language must be associated with syntactic structures in the target language. See Katz-Postal, *An Integrated Theory of Linguistic Descriptions*, 1964, 166-172. To meet this problem, linguists must concern themselves with performance models and with semantic and discourse analysis. Moreover, comprehensive grammars do not yet exist for any language. Estimates of the availability of adequate grammars vary. Production of such grammars depends on the complexity of the model of language and on the research support provided. Some scholars participating in the Study suggest a date of five to ten years, a figure proposed also in a study carried out by Soviet specialists.

In view of the Peters-Ritchie results, it may be advisable to continue efforts with more restricted grammatical models which provide exact surface analysis based on syntactic and semantic features in the lexicon. Examples

are string analysis, the model used at the Linguistics Research Center, dependency theory of the Soviet type, and grammatical models whose transformational apparatus is more restricted than that of "standard" transformational grammars, for example, systems which use non-ordered or partially ordered transformations or equivalence transformations. Further, research in discourse analysis should be increased. Since the problems in machine translation are not the generation of coherent discourse but the carrying across of information, the achievement of translation would be considerably facilitated by such models. These problems may even be less pressing in actual practice because of the user reaction; that is, very often it may not be necessary for the system to represent all alternatives since the user will be able to provide the proper reading because of his access to information necessary for comprehension. Investigations on user-translation interaction should be carried out, especially in view of the highly divergent estimates of Zarechnak and Bar-Hillel. See also section 4, p. 46.

2. Like other technological applications, machine translation can be designed with various degrees of adequacy. The history of machine translation reflects this situation. The first attempts were primarily lexical. Syntactic analysis was then added. Currently semantic analysis is included for projected machine translation systems.

The improved understanding of language resulting from these progressively more comprehensive descriptions of language leads to improved translations. Translations based on semantic analysis will be correct when the information needed for disambiguation of a sentence is contained in that

sentence. When it is not, contextual and pragmatic information will be necessary.

3. Meaning is largely determined by the semantic readings of the lexical items in a sentence and the syntactic (semantic) relations between those items; these are presumably represented by the underlying structures of language. To arrive at the meanings of specific sentences, the underlying structure will have to be determined from the surface structure. In related languages, such as English and German, the relationships between surface and underlying structure are more similar than they are between less related languages like Russian and English or unrelated languages, such as English and Chinese. Accordingly, it will be simpler to devise translation systems for related languages. For the development of the technology of machine translation, systems designed for related languages are accordingly recommended at this time as an immediate goal. Medium-range goals (Russian-English) and long-range goals (Chinese-English) should also be planned.

4. The usefulness of translation depends on various factors: cost, timeliness, comprehensibility. In locations where imperfect, lexically-based machine translations are available, scientists have selected these over human translation when they could be made available the following day and human translations only after a week. In view of this situation, studies should be performed to measure the extent to which comprehensibility of a translation is dependent on the knowledge available to the actual user. Moreover, it should be noted that timeliness ranks high as a factor in translation. See also page 46.

Participants in the Study did not agree on what constitutes "high quality" translation. There is apparently no absolute standard. Rather, standards must be defined with reference to specific users and specific purposes.

Recommendations

1. On the basis of this Study it is recommended that support be made available for research in machine translation. The recommendation is made on the grounds that quality translation can be achieved in the near future. This recommendation agrees strikingly with conclusions reached in a study carried out in the Soviet Union.

Moreover, apart from attempts in information retrieval, machine translation is currently the only discipline which requires the study of problems beyond the sentence boundary. Because of the general lack of interest in these problems on the part of linguists, machine translation should be sponsored as an intellectual pursuit contributing to our knowledge of language.

2. For improved machine translation, research in the areas of descriptive linguistics, theoretical linguistics, comparative linguistics, stylistics, and evaluation of translation is necessary and should be supported.

2.1 Lexical research is necessary to determine the syntactic and semantic patterns of linguistic entities. Recent lexical research has indicated that entities such as verbs which have more than one meaning may have a particular meaning (1) only when they occur in specific syntactic environments whereas they have meaning (2) or further meanings when they occur in other specific environments. To illustrate the effect of only a trivially improved lexicon on translation, the report of an experiment conducted by Stachowitz in the spring of 1967 is appended.

2.2 Continued syntactic research, based on comprehensive lexical research, is essential. Fortunately a great deal of such research is being carried out, though eclectically, by linguists and their students in the normal course of their activities. Funding of such research should be increased, as well as linguistic study carried out in accordance with various approaches to language.

3. Theoretical research is essential, especially in view of the conclusions arrived at by Peters and Ritchie with reference to current transformational grammar. Various models based on differing grammatical assumptions and/or using less powerful transformations should be investigated. Among these are the string analysis of Harris, and models like those of the Russian linguists which are based on dependency grammars. See Conclusions, p. 44.

Besides encouraging research in discourse analysis and production of coherent discourse, the possibility of establishing a research area intermediate between sentence (constituent) analysis and contextual analysis should be investigated. This investigation would be concerned with notions like those proposed by Fraser on "usage of sentences."

4. Contrastive studies dealing with the lexical and syntactic structures of two languages, and with the similarities of mapping these structures into semantic representations should be carried out. Such studies should also be concerned with the ways in which covert and overt semantic distinctions are expressed in these languages, including their overlap.

The overlap of lexical, syntactic and semantic ambiguity between two

languages should be studied from the point of view of carrying source language ambiguity over into the target language.

5. Descriptive stylistic studies on the incidence of lexical, syntactic and semantic ambiguities in scientific texts and their resolution by means of sentence immanent, context immanent and context external information should be carried out, as well as contrastive stylistic studies on scientific texts in contrast with literary texts. Such studies should aim to determine the types of syntactic structures used in various "styles" of language and possible divergences between them.

6. Explicit study should also be made of the kind of information available to the user which is necessary for the understanding of material that is mechanically translated. Such studies should seek to determine the amount of knowledge available from the surrounding text, as well as the amount of world knowledge necessary for the understanding of individual sentences. These investigations would be designed to determine the amount of information which must be provided to the machine so that the output is intelligible to a specialist or a general user.

7. Since the results of linguistic research will contribute to advances in machine translation, support is also recommended for research on problems in linguistics.

APPENDIX I

Conferences at the Linguistics Research CenterJune 15 - 19, 1970

Martin Kay, W. P. Lehmann, Norman M. Martin, Jacob Mey, Stanley R. Petrick, Robert F. Simmons, Rolf Stachowitz, Donald E. Walker, Ladislav Zgusta, and the Linguistics Research Center staff.

September 30 - October 2, 1970

Emmon W. Bach, Charles Fillmore, Lauri J. Karttunen, W. P. Lehmann, John Lyons, Norman M. Martin, Jacob Mey, P. Stanley Peters, Robert F. Simmons, Rolf Stachowitz, and the Linguistics Research Center staff.

December 16 - 18, 1970

Emmon W. Bach, Lauri J. Karttunen, Robin and George Lakoff, W. P. Lehmann, James D. McCawley, Norman M. Martin, P. Stanley Peters, John R. Ross, Robert S. Simmons, Rolf Stachowitz, and the Linguistics Research Center staff.

January 11 - 15, 1971

Emmon W. Bach, Yehoshua Bar-Hillel, Paul L. Garvin, J. Bruce Fraser, Lauri J. Karttunen, Martin Kay, W. P. Lehmann, John Lyons, R. Ross Macdonald, Norman M. Martin, Z. L. Pankowicz, Eugene D. Pendergraft, P. Stanley Peters, Stanley R. Petrick, John R. Ross, Robert F. Simmons, Rolf Stachowitz, Rowena Swanson, Donald E. Walker, Terry A. Winograd, Michael Zarechnak, Ladislav Zgusta, and the Linguistics Research Center staff.

Visits of Individual Consultants

March - April 1970

Yehoshua Bar-Hillel

September 1970

Paul L. Garvin

April 1970

Roman Jakobson

February 1971

Harry H. Josselson

July 1970

J. Bruce Fraser

March 1971

Roman Jakobson

APPENDIX II

Papers of participants

Supporting papers. As the statement on work under the Contract indicates, participants in the Study presented papers or participated in informal discussions. Some of the presentations reflect views of the authors which are published elsewhere. Participants were not pressed to provide papers for the final report. Further, the views which are expressed in the accompanying papers are strictly those of each author. Some of the authors have modified their statements after taking part in one or more conferences. But each paper included here was provided by its author and is given without modifications in the form provided originally by its author.

Most readers of the Report are probably acquainted with the authors of the appended papers. It has seemed unnecessary to provide introductions to such outstanding figures in linguistics and related disciplines. The appended bibliography, which is highly selective, will provide further access to the authors and their views.

Titles of Papers in Appendix I

- Y. Bar-Hillel: Some Reflections on the Present Outlook for
High-Quality Machine Translation
- C. F. Fillmore: On a Fully Developed System of Linguistic Description
- P. L. Garvin: Operational Problems of Machine Translation:
A Position Paper
- L. Karttunen: The Logic of English Predicate Complement Constructions
- J. Lyons: The Feasibility of High Quality Machine Translation
- N. Martin: Philosophy of Language and the Feasibility of MT:
A Position Paper
- J. Mey: Toward a Theory of Computational Linguistics
- E. Pendergraft: Meaning Revisited
- S. Petrick: Syntactic Analysis for Transformational Grammar
Syntactic Analysis Requirements of Machine Translation
- A. Stachowitz: Analysis of Es liegt eine grosse Anzahl von Elementen vor
- R. Stachowitz: Lexical Features in Translation and Paraphrasing :
an Experiment
Requirements for Machine Translation: Problems,
Solutions, Prospects
- D. Walker: The Current Status of Computer Hardware and Software
as it Affects the Development of High Quality Machine
Translation
- L. Zgusta: Equivalents and Explanations in Bilingual Dictionaries
The Shape of the Dictionary for Mechanical Translation
Purposes

THEORETICAL STUDY EFFORT OF HIGH QUALITY TRANSLATION

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SOME REFLECTIONS ON THE PRESENT OUTLOOK
FOR HIGH-QUALITY MACHINE TRANSLATION

by

Yehoshua Bar-Hillel

Linguistics Research Center
The University of Texas at Austin

I shall take off from Josselson's recent report¹ on the progress of MT research in the 60's. By starting there, I shall be able to restrict myself to pointing out certain issues that seem to me not to have been adequately treated in the MT literature, including the most recent one.

For high-quality MT it is now probably generally recognized that reliance on the best available linguistic theories is a necessary but by no means sufficient condition. But for reasons I have discussed elsewhere at length, even the best modern linguistic theories do not treat adequately the pragmatic aspects of communication in natural languages. As a matter of fact, these aspects are simply not yet sufficiently well understood to receive a satisfactory explicit formulation, not even to the degree that the so-called semantic aspects have already received.

Applied linguistics, or the theory of linguistic performance, of which the theory of translation is a part, works with utterances and sequences of such as basic units. What a translation program is meant to provide a translation for is primarily utterances (written, printed or spoken), and only secondarily, if at all, sentences (or sequences of such); though, in some sense, translation of utterances may still be based on translation of sentences.

It is now almost generally agreed upon that high-quality MT is possible only when the text to be translated has been understood, in an appropriate sense, by the translating mechanism. A full understanding requires taking into account the pragmatic aspects of the text, such as by whom the text was produced, for which kind of audience it was meant, which kind of background knowledge the producer of the text assumed to be available to the audience, the time, the place, and other parameters of the situation in which the text was produced, etc.

In view of the present non-existence of an adequate theory of the pragmatics of communication in natural languages and the small likelihood that such a theory will be produced in the near future, the question arises to what degree disregarding the pragmatic aspects of the production of a given text will diminish the quality of its translation. There exists a good amount of published material on this matter, with regard to human translation, but so far we have little systematic insight and still less experimental evidence.

In principle, understanding a given text means, for instance, being able to tell which, if any, statements the producer of this text intended to make, which, if any, questions he intended to ask, which, if any, commands he intended to give, etc. In order to manipulate these statements, questions, commands, etc., e.g. in order to produce another text in a different language, by which the same statements can be made, the same questions asked, etc., it seems, in general, to be necessary to reformulate these statements, questions, commands, etc., in some constructed, non-pragmatic language, the so-called intermediate or pivot language. This issue has been adequately covered in the literature, and I have no new comments to make, except to state that in view of the enormous difficulties that stand in the way of such a language, any attempt for MT research to wait for the completion of this task would just mean the end of this research.

I am in no position to estimate to what degree a lowering of this aim would enable MT research to continue; a clarification of this issue would be vital. It is not inconceivable that a certain amount of experimentation could be performed with human translators who would be instructed to deliberately disregard some or all of the pragmatic aspects they

would usually take into consideration and to compare these outputs as to their degree of satisfactoriness for a variety of users in a variety of conditions.

In other words, it now seems more than ever that the ideal of obtaining MT of a general quality comparable to that of a good human translator has led to a dead end. It seems therefore to be mandatory to investigate, more thoroughly than before, the various possible substitutes: (1) Machine-aided human translation, (2) man-aided machine translation, (3) low-quality autonomous machine translation. These are all eminently practical matters that still have to be based, in some form, on linguistic theory, particularly on psycholinguistics, but will have to rely to a much higher degree on investigations of man-machine interactive systems and on the psychology of the behavior of humans in such conditions.

It seems, then, that we have turned full circle in MT research and are now approximately back where we started some 19 years ago. MT will probably have to rely on language-dependent strategies rather than on some highly developed theory, but it is quite clear that the detour has enormously helped clarify the issue, has dispelled any utopian hopes so that we are now in a much better position to attack this problem afresh.

Let me make a side remark. When I started using the term "high quality" a number of years ago, I was using it in a much too absolute sense which cannot be seriously justified. "High quality" has to be relativized with regard to users and with regard to situations. A translation which is of good quality for a certain user in a certain situation might be of lesser quality for the same user in a different situation or for a different user,

whether in the same or in a different situation. What is satisfactory for one need not be satisfactory for another. This remark, of course, is trivial as such, but its implications for MT might not have been always fully realized. It is therefore, for instance, not inconceivable that a translation program with an unsatisfactory output for a certain user under given conditions might turn out to be more satisfactory if the conditions are changed, for instance, if the user is allowed to ask back certain questions and the computer is programmed to answer these questions upon request. Again, clearly, much experimentation is needed to get more light on this issue.

Altogether, I am rather doubtful whether at this stage any further research on the possibilities of normalization, canonization, or other types of regimentation of the input to MT will prove to be useful. At any rate, this type of research, if at all, should not be undertaken by MT research groups but by linguists at large. The results, if any, of their research will have a much broader application than to the problem of MT alone. MT research should restrict itself, in my opinion, to the development of language-dependent strategies and follow the general linguistic research only to such a degree as is necessary without losing oneself in utopian hopes. Every program for machine translation should be immediately tested as to its effects on the human user. He is the first and final judge, and it is he who will have to tell whether he is ready to trade quality for speed, and to what degree.

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ON A FULLY DEVELOPED SYSTEM OF LINGUISTIC DESCRIPTION

by

C. F. Fillmore

Linguistics Research Center
The University of Texas at Austin

In this paper I offer a preview of the scope of linguistic description, insofar as the field of linguistics touches on questions of the meanings of sentences. I take the subject matter of linguistics, in its grammatical, semantic, and pragmatic subdivisions, to include the full catalogue of knowledge which the speakers of a language can be said to possess about the structure and structural affinities of the sentences in their language, and their knowledge about the appropriate use of these sentences. I take the special explanatory task of linguistics to be that of discovering the principles which underlie such knowledge. I will exhibit the range of information which speakers possess about the sentences in their language by examining, as thoroughly as I know how, one English sentence. The sentence I have chosen for this demonstration is simple and short and extremely easy to understand; it is the four-syllable question, MAY WE COME IN?

Instead of beginning with a set of observations about a particular utterance of our sentence, by a particular speaker, on a particular occasion, examining all of the social and psychological and acoustic and biological and physical aspects of the situation to which we can gain access, and speculating about which of these can be said to exemplify specifically linguistic facts about the sentence in question, I will conduct a thought-experiment that will be simpler and more limited and that will be guaranteed to point solely to linguistic information. The thought-experiment I have in mind is this: we are to assume that we know, about some real-world situation, only one single fact, and that is, that somebody uttered the sentence MAY WE COME IN? A qualification on the nature of that information is that we have it in a notation which fails to include any understanding of the voice quality of the speaker or the manner of utterance. We know

only that it was an utterance of the English sentence that we ordinarily have in mind when we write, MAY WE COME IN?

Our task is to make explicit everything that we know about the sentence as a linguistic object, and everything that we know, as speakers of English, about the situation, or class of possible situations, in which it was uttered. We will be interested, in short, in the grammatical form of the sentence, the meanings and grammatical properties of its words, and in the assumptions we find ourselves making about the speaker of the sentence and about the setting in which it was uttered.

Our account will exclude information about the range of possible phonetic realizations of the sentence, and we will furthermore disregard the uninteresting possibility that the sentence was uttered hypotactically: we will not bother with the infinite range of possible conditions for the utterance of this sentence that includes somebody responding to the request that he pronounce four English monosyllables, or a speaker of a foreign language imitating an English utterance he once overheard, or a librarian reading aloud the title of a short story.

Assuming that the sentence was uttered in conformity with the system of linguistic conventions whose character we are trying to make explicit, we will probably find ourselves imagining a situation involving: some kind of enclosure, call it E; at least three beings, call them A, B, and C; one of whom, A, is a speaker of English and is the utterer of our sentence; one of whom, B, is believed by A to be a speaker of English and who is the addressee of our sentence; and some other being, C, who is a companion of A. (I say "being" rather than "person", since C might be, for example, A's pet beaver.) We further assume that A believes that he and C are

outside the enclosure E, that A believes B to be inside E, that A is interested in the possibility of his gaining admission to E, in C's company, and that A believes that B has the authority--or represents somebody who has the authority--to decide whether or not A and C may enter E. We further understand that the uttering of this sentence is an act which socially requires B to do something--in particular, to say something--it being understood that what he says will count as authorizing or forbidding the move into E on the part of A and his companion C.

These, then, are the main things that we might find ourselves imagining, on learning about a particular situation that somebody has made the request, MAY WE COME IN?. This is the most straightforward understanding we might have of the appropriateness conditions for uttering our sentence. Actual situations in which the utterance is used may depart from this description in several ways and for several reasons: some of A's beliefs may be mistaken; A may be speaking insincerely; the number of A's addressees may be greater than one; and the number of A's companions may be greater than one; and other arrangements of the personnel are conceivable.

As linguists we need to ask what it is about the structure of the sentence MAY WE COME IN? that makes it possible for speakers of English to agree on the nature of the conditions in which it can be used. We may begin our analysis of the sentence with an analysis of its words, one at a time, beginning with MAY.

The only syntactic information we will need to appeal to is the information that the sentence is a question, that its subject is the pronoun WE, that its main verb is COME, that it contains, in association with this verb the modal auxiliary MAY, and that the verb COME has a directional complement IN. The word MAY, when used as a modal auxiliary, has three functions that will interest us here, and these

are separable as its (1) epistemic, (2) pragmatic, and (3) magical functions. In its epistemic function, it is used in connection with likelihood-estimating expressions such as HE MAY NOT UNDERSTAND YOU. In its pragmatic function, it is used in sentences utterable as parts of permission-granting or permission-seeking acts, such as YOU MAY COME IN NOW. In its magical function it is used in the expression of wishes, blessings and curses, such as MAY ALL YOUR TROUBLES BE LITTLE ONES or MAY YOU SPEND ETERNITY ROLLER-SKATING ON COBBLESTONES.

The magical function appears only in sentences with initial MAY, but there only if the sentence is not construed as a question. YOU MAY SPEND ETERNITY ROLLER-SKATING ON COBBLESTONES may count as a warning or a gloomy prediction, but not as a curse. Our sentence, MAY WE COME IN?, is a question and does not allow the magical interpretation of MAY.

The epistemic and pragmatic functions of MAY can be seen ambiguously in certain sentences, as for example in JOHN MAY LEAVE THE ROOM. The person who utters that sentence may either, in doing so, be authorizing somebody named JOHN to leave the room, or he may be expressing his belief in the possibility of that person's leaving the room at some time in the future.

The epistemic and pragmatic senses are not appropriate to every use of MAY, however; it happens that the two uses of the modal are associated with two grammatically quite distinct sets of contextual possibilities, and instances of ambiguity with respect to these two senses are instances of accidental overlap of these two context sets. I will content myself with merely giving examples: it is probably immediately clear that the permission-granting sense is completely

absent from JOHN MAY HAVE LEFT THE ROOM, and that the possibility-expressing sense is absent from MAY JOHN LEAVE THE ROOM? By that I mean that JOHN MAY HAVE LEFT THE ROOM does not permit a pragmatic interpretation, as, say, I HEREBY GIVE JOHN PERMISSION TO HAVE LEFT THE ROOM, and the question MAY JOHN LEAVE THE ROOM? does not permit an epistemic interpretation, as, say, IS IT POSSIBLE THAT JOHN WILL LEAVE THE ROOM?

These observations are to be accounted for by noting that the pragmatic sense of MAY simply does not show up with the so-called perfective construction, and that the epistemic sense does not show up in questions. It was because our sentence MAY WE COME IN? is a question that we knew it had to do with permission-granting.

The recognition that the sentence is a question, then, rules out, for interpreters of MAY WE COME IN? the possibility that MAY is used in either its epistemic or its magical senses. We are left with the assumption that it is used in its pragmatic sense, and therefore that it is used in a social situation involving permission-granting in some way. Permission-granting situations involve two parties, the person or persons accepted as having authority to grant the permission, and the person or persons whose actions are to be authorized. A sentence with pragmatic MAY may be uttered performatively, in which case the utterance is a part of a permission-seeking or permission-granting act, or it may be uttered non-performatively. In the latter case, it is a statement or question about somebody's having permission to do something. It is the non-performative use of pragmatic MAY which is taught in the classroom as the preferred way of speaking of permission-possession. This use is quite unnatural to most speakers of English and will be ignored here. For persons who have been influenced by the classroom tradition, our sentence has the possible interpretation HAVE WE BEEN GIVEN PERMISSION TO COME IN?, the interpretation, in other words,

which would be associated, in the speech of most of us, with the question CAN WE COME IN?. In what follows I will be disregarding the non-performative sense of pragmatic MAY.

In a performative utterance of a pragmatic MAY sentence, the possessor of authority is taken to be the speaker if the sentence is an assertion, the addressee if the sentence is a question. Thus, the speaker of JOHN MAY LEAVE THE ROOM is, in saying the sentence, authorizing John to leave the room. The sentence we are examining, however, is a question, and in uttering a question with pragmatic MAY, the speaker is acknowledging the addressee's authority with respect to the permission-granting gesture. This alternation of the authority role between the speaker of an assertion and the addressee of a question must be accounted for in terms of general principles of conversation and general principles in the logic of questions and answers.

Without touching on the details, it is at least clear, for the rules of two-party discourse, that the speaker and addressee roles alternate in ways exhibited in such exchanges as I DID A GOOD JOB / NO YOU DIDN'T or HAVE YOU SEEN HIM? / YES, I HAVE. In general, if A asks B a question, A acknowledges B's authority to answer the question, and B in trying to answer the question, acknowledges that acknowledgement. Any of the ways in which the A's sentence assigns separate roles to speaker and addressee must have those assignments reversed in B's contributions to the same conversation. In a sentence like JOHN MAY LEAVE THE ROOM, the speaker of that sentence is the authority with respect to the permission-granting act which a performance of that sentence may constitute. If that sentence is, as it is, an authorized answer to the question, MAY JOHN LEAVE THE ROOM?, it follows that the addressee of the question has the same role as the speaker of the corresponding assertion.

So far, then, we have seen how a speaker of English is able to reach certain conclusions about our sentence: from the fact that it is a question and contains the modal MAY, (1) it involves the permission-granting sense of MAY, and (2) it is the addressee of the sentence who is taken as having the right to grant the desired permission.

Recall that I have pointed out that assertions containing pragmatic MAY could be uttered as, or as a part of, or as constituting, permission-granting acts. Because of that fact, my use of the term 'assertion' was not quite appropriate--though I will not abandon it since I have not found a suitable alternative. An utterance of YOU MAY COME IN is not merely a statement declaring or asserting that some state of affairs exists--it is rather an instance of a type of utterance that has some sort of extra-linguistic validity as defined in particular sorts of social situations. It is a sentence, an utterance of which, under an appropriate set of conditions, constitutes an illocutionary act of the type that we have been referring to as permission-granting. A sentence like THE CAPITAL OF FRANCE IS PARIS cannot, in any perfectly straightforward way, be uttered as one step in a socially dynamic situation, but the sentence YOU MAY COME IN can.

We must ask, then, just what is the illocutionary force of the question MAY WE COME IN?. This question imposes on the addressee the obligation to exercise his authority. An utterance of the question, under the conditions mentioned above, is an illocutionary act whose effect is to get the other party to perform a related illocutionary act; an utterance on B's part of the answer YES or the answer NO to this question will be taken as an authorizing or as a forbidding act respectively.

I have mentioned several times the role of speaker and addressee as factors to deal with in the interpretation of utterances, and I have referred to the fact that in two-party conversations, the identity of the speaker and the addressee will systematically alternate. Aspects of the interpretation of sentences that relate to the speech act situation are known collectively as deixis, and reference to the participants in a speech act are covered by the term person deixis. When explicit reference is made in an utterance to the speaker and the addressee of the utterance, the English pronouns I and YOU are used; but we have seen from the analysis of assertions and questions with pragmatic MAY that not every appeal to the participants in a speech act involves the presence of one of these words. Other forms of deixis, soon to be mentioned in another context, are place deixis, involving reference to the location of the speech act participants (as seen in such words as HERE and THIS), and time deixis, involving indication, direct or indirect, of the moment of the speech act (as seen in such words as NOW and TODAY).

We turn next to the person-deictic pronoun in our sentence, the word WE. The traditional grammatical term for a linguistic form which identifies the speaker of a sentence is "first person", and the traditional label for pronouns of the type of English WE is "first person plural". This characterization is, of course, rather odd. If we identify the "first person" as the speaker--the one who pronounces the sentence containing the "first-person" form--then the description "first person plural" makes sense only in the case of choral recitation, speaking in unison. The English word WE has, actually, a quite different use. It identifies a group of individuals including the speaker of the sentence; it refers, in other words, to the speaker of the sentence and somebody else.

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In many languages a distinction is made in their so-called "first person plural" forms depending on whether the group does or does not include the addressee of the sentence. Such languages distinguish an inclusive form, designating the speaker and the addressee (and maybe others), from an exclusive form, designating the speaker and one or more beings not including the addressee.

Linguists find it necessary to speak of the inclusive and exclusive uses of the English pronoun WE. In translating from English into a language which makes this distinction explicit, one needs, obviously, to assign one or another "inclusivity" value to each instance of the pronoun. In descriptions of the speaker/addressee alternation in conversations, different values of WE must be assigned to the first contribution to each of the following conversational exchanges: DID WE MAKE A MISTAKE?/YES, WE DID. DID WE MAKE A MISTAKE?/YES, YOU DID.

In the sentence MAY WE COME IN?, it is clear that the WE is exclusive, and that was in fact the reason we were forced to imagine three beings in the situation calling for this particular utterance. The individual we have been calling C is the "somebody else" included in the scope of WE and distinct from the addressee, B. In the permission-granting situation, the person with authority and the person or persons seeking permission, are necessarily distinct, as we have seen. Since in a question with pragmatic MAY the addressee is the one with the authority, the addressee cannot be included in the scope of the subject expression.

So far, this is what we know: from the fact that our sentence is a question having MAY as its main modal, we know that it has to do with a permission-requesting situation; from the fact that it is a question rather than an assertion,

we know that the addressee is assigned the authority role; from a general understanding of permission-granting situations, we know that the person having authority is distinct from the persons who need and seek permission to enter, and therefore that the pronoun WE is used in the sense which is exclusive of the addressee.

We turn now to the third word, the word COME. We notice first of all that it is an action verb, and therefore the activity it identifies qualifies as something for which it makes sense to speak of granting permission. If our sentence were something like MAY WE UNDERSTAND YOUR PROPOSAL?, we would have had to reject it as a well-formed pragmatic-MAY question, since one does not speak of needing permission to understand something. As an action verb, furthermore, it is not an "achievement" verb. If our sentence were MAY WE SUCCEED ON THIS PROJECT?, it would have to be rejected as a pragmatic-MAY question, since SUCCEED, as an achievement verb, refers to carrying out an activity which leads, fortuitously, to a particular consequence; and one does not speak of needing permission to have good luck.

The verb COME, secondly, is lexically simple with respect to the type of activity it designates. In this way it is unlike a verb like SWIM, which has associated with it both the idea of motion and an understanding of the manner of motion. If our sentence were MAY WE SWIM IN?, we would have had to point out that this sentence can be used under two distinct conditions in a permission-seeking situation. Suppose, for illustration, that the speaker and his companions were swimming in a body of water that entered a cave, and they were addressing a person guarding the entrance to the cave. In that case, there is no question of their needing permission to swim, they are asking for

permission to move into the cave while swimming. The sentence, in that case, would have heavy stress on IN. Suppose, on the other hand, that the speaker and his companion have already been granted permission to enter the cave, and they wish to know whether they may do this by way of the stream, that is, by swimming, rather than by using some other means. In that case, it is understood that they have permission to move into the cave, and what they are seeking is permission to do this by swimming. In that case the sentence would have heavy stress on SWIM. The verb COME, I suggested, does not have this sort of lexical complexity, and so there is not the same sort of ambiguity with respect to which aspects of the situation are those for which permission is needed.

The verb COME, however, has other sorts of complexities. The description of the presuppositional structure of this verb requires reference to all three types of deixis-- person, place, and time.

For speaking of temporal matters in the semantics of natural language sentences, it is necessary to distinguish-- on the simplest level--the time of the speech event, on the one hand, and what we might call the time of focus, the time that is being referred to or focused on in the sentence. We can see how both of these types of references can figure in the description of a single sentence by considering a sentence like JOHN WAS HERE LAST TUESDAY. The time of focus is identified by the phrase LAST TUESDAY, and the time of the speech act is involved in the interpretation of the word HERE: HERE is the place where the speaker finds himself at the time of his pronouncing the sentence. (Even for fairly simple cases, it is necessary to distinguish more than just these two temporal reference points, but for the points I have in mind, these two will do.)

The role of deictic categories in the interpretation of sentences with COME may be observed with sentences of the form "X" CAME TO "Y" AT "T", where "X" is the moving entity, "Y" is the destination, and "T" is the time of focus. (Here, "T" is taken to be in the past, just for the sake of simplicity.) It happens that sentences of the form "X" CAME TO "Y" AT "T" are appropriate just in case any of the following conditions obtains:

- 1) the speaker is at Y at the time of the speech act
- 2) the addressee is at Y at the time of the speech act
- 3) the speaker was at Y at T
- 4) the addressee was at Y at T

To see that this is so, take JOHN, THE OFFICE, and YESTERDAY MORNING as values of "X", "Y" and "T" respectively. A sentence like JOHN CAME TO THE OFFICE YESTERDAY MORNING is appropriate under any of the four conditions just indicated. It is a sentence I can say appropriately if I am in the office when I say it, if you are in the office when I say it to you, if I was in the office yesterday morning when John came, or if you were in the office yesterday morning when John came. (There are uses of the verb COME in pure third-person narrative which are not covered by the description, and there are personal identifications with places distinct from physically being in a place for which COME is nevertheless appropriate; but on these matters the reader's indulgence is requested.)

Limitations on these appropriateness conditions appear when we substitute for the "X" and "Y" of the formula expressions of person deixis and place deixis respectively. For example, if I say I CAME THERE YESTERDAY MORNING, it is not possible that I am "there" now, because THERE is by definition a place where I am not now located; and it is also not possible that I was already there yesterday morning when I came.

But now what are we to say about our sentence, MAY WE COME IN? We have seen, from the fact that we are dealing with permission-granting MAY in an interrogative sentence, that our pronoun WE is exclusive of the addressee. That same conclusion could also have been reached by noticing its occurrence with the verb COME. COME is a verb of locomotion which indicates a change in location from some point of origin to some destination, this latter conceived of as a place where the speaker or the hearer is at the time of the speech act or was at the time of focus. In a permission-seeking utterance with the modal MAY, there is lacking a definite time of focus, and that leaves open only those possibilities that refer to the participants' location at the time of the speech act. Since the pronoun WE has to include the speaker and does not have to include the addressee, we are forced to include that WE is exclusive; since the addressee must be at the place of destination in order for the use of this sentence to be appropriate, he cannot be included in the group seeking to move toward that destination. Again our analysis supports the picture we had at the beginning, of A, on the outside, speaking on behalf of himself and C, also on the outside, and addressing the insider B.

The verb COME, like its partner GO, is one of the few verbs of motion in English that require a destination complement in syntactically complete sentences. In our case the destination complement has the form IN, which we may take as an ellipsis for IN(TO) THE PLACE, or the like. The particle IN ascribes to the destination the information that it is some sort of enclosure. That information, together with the change-of-location interpretation required of the verb COME, is what imposes the understanding that the moving entities have as their point of origin a location which is not within that enclosure. Notice that quite

different assumptions about the relative position of speaker and addressee would have been taken if the sentence had been MAY WE COME UP? or MAY WE COME THROUGH? or the like.

So far we have examined certain properties of the individual words of the sentence. In doing that we have fairly exhausted, because of the simplicity of the sentence, whatever there is to say about its grammatical structure as well, at least its "surface structure". There are current arguments in support of the claim that the deep structures of sentences will correspond to their fully specified semantic descriptions--including an account of their illocutionary force--but since my effort here is to uncover and detail such a semantic description, it will not be necessary to adjoin to my discussions any specific claims about the nature of the deep structure.

The illocutionary act potential of the sentence must be studied in the context of the systems of rules or conventions that we might choose to call discourse rules, a subset of which might be called conversation rules. We have seen, in what has already been said about the illocutionary force of our sentence, that it is not to be construed as a request for information, but as a request for the addressee to "perform" in some way. It is usable as a way of getting the conversational partner to perform the needed permission-granting (or, of course, permission-denying) act. In the sense that a question like SHALL WE COME IN? is an utterance spoken to get one's interlocutor to issue an order, the question MAY WE COME IN? would be spoken to get the addressee to grant permission. Because of its role in a changing interpersonal situation, a complete description of the sentence must specify the various social conditions which must be satisfied in order for it to be used appropriately. For various reasons, these may be stated as belief conditions which must be satisfied by the utterer of a sentence in order for us to acknowledge

that he has uttered the sentence in good faith. We have agreed, for example, that the speaker must believe that his interlocutor is inside E, that he and his companion are outside E, and that his interlocutor is a person capable of authorizing admission into E. By viewing these as belief conditions, we are able to recognize various ways in which the sentence may be uttered deviantly. It may be uttered mistakenly, in case the speaker's beliefs are incorrect; or it may be uttered insincerely, in case the belief conditions are not satisfied.

The speaker may be mistaken in his belief that he is outside the enclosure E; he will realize his mistake if his question is answered, WELL, IT LOOKS TO ME LIKE YOU'RE ALREADY INSIDE. He may be mistaken in his belief about the location of the addressee; he will realize that if he hears, from an unexpected direction, the reply, YOOHOO, HERE I AM. GO RIGHT ON IN. He may be mistaken in his beliefs about the relative social positions, with respect to this activity, of himself and his addressee. It may not be necessary for him to receive permission to enter, as he will find out if the answer is, OF COURSE. The person he is addressing may not have the authority to admit him, as he will learn if he hears the answer, DON'T ASK ME.

The sentence can be used "insincerely" in either of two ways. It may be used politely, in which case the assumptions associated with the sentence about the social dominance (on this occasion, at least) of the addressee, are intended as a polite social gesture; or it may be used ironically, as in cases where the suggested dominance relation is clearly contradicted by the realities of the situation. An example of an ironic use can be seen in a situation in which a prison warden addresses the question to a prisoner in his cell, or in the case of a pair of aggressive encyclopedia salesmen who have already entered the living room.

The conversation rules of a language govern not only the conditions under which it is appropriate to perform a permission-requesting utterance of the type we have been examining, but they must also determine the principles by which a speaker of English is able to recognize appropriate responses to the request. If the question is used in absolutely its most straightforward way--a rare occurrence, I would guess--the normal appropriate answers would be merely YES, YOU MAY or NO, YOU MAY NOT. Such an answer merely acknowledges that B does indeed have the requisite authority and that he does or does not tolerate the entering into his territory of A and C.

If, however, the question was asked in the way it was asked out of politeness, as an instance of the sort of social gesture that occurs in conversations between equals or near-equals, and if B recognizes and wishes to return the gesture, he would say something like YES, PLEASE DO or COME IN, BY ALL MEANS. These answers, having the form of imperatives, have associated with them some of the conditions appropriate to imperative sentences--one of these being that it is in the speaker's interest to have the addressee act as commanded. Thus, on being asked whether one would tolerate admission into a room, the person who responds with YES, PLEASE DO shows that he not only tolerates but desires such a move.

From observations such as these, it is now obvious that the rules of conversation must not only specify the appropriateness conditions for an utterance and the nature of the most straightforward appropriate second-speaker responses to utterances, but must be capable of making use of certain logical operations by which it can be shown that something equivalent to a straightforward response is deducible from the actual occurring response. In particular, such

principles would include the information that desiring implies tolerating, that necessary implies possible, etc.

Let me now summarize the various kinds of facts which must, I suggest, be included in a fully developed system of linguistic description.

The linguistic description of a language

- (1) must characterize, for each lexical item in the language
 - (a) the grammatical constructions in which it can occur,
 - (b) the grammatical processes to which it is subject in each relevant context,
 - (c) the grammatical processes which its presence in a construction determines, and
 - (d) information about speech act conditions, conversation rules, and semantic interpretation which must be associated in an idiosyncratic way with the lexical item in question;
- (2) it must provide the apparatus which characterizes
 - (a) the grammatical structures of sentences on the "deep" or abstract level, and
 - (b) the grammatical processes by which abstract linguistic structures are processed and become surface sentences;
- (3) it must contain a component for calculating the complete semantic and pragmatic description of a sentence given its grammatical structure and information associated with each lexical item;
- (4) it must be able to draw on a theory of illocutionary acts, in terms of which the calculations of (3) are empowered to provide a full account of the potential illocutionary force of each sentence;

- (5) it must be able to draw on a theory of discourse which relates the use of sentences in social and conversational situations; and
- (6) it must be able to draw on a theory of "natural logic" by means of which such judgments as the success of an argument or the appropriateness of elements in conversations can be deduced.

OPERATIONAL PROBLEMS OF MACHINE TRANSLATION:
A POSITION PAPER

Paul L. Garvin

State University of New York at Buffalo

The late Uriel Weinreich in the first of his lectures in the Trends in Linguistics lecture series at the Indiana University Linguistic Institute on July 13, 1964 referred to machine translation as "linguistics' most conspicuous and expensive failure."¹ Two years later the Automatic Language Processing Advisory Committee of the National Academy of Sciences, National Research Council in what has since become known as the ALPAC Report (1966: 24) stated that "No one can guarantee, of course, that we will not suddenly or at least quickly attain machine translation, but we feel that this is very unlikely."

In the light of these two highly authoritative statements of position, and in view of the abrupt reduction of funding for machine translation research, is it at all reasonable to discuss operational problems of machine translation these days? The answer is of course that if one is to talk about machine translation at all, it must be in terms of some reasonable operational objective, since research without such objectives will at best be related to machine translation only indirectly. The question as to whether or not such objectives are reasonable depends in this author's opinion upon the researcher's basic orientation: with a predominantly theoretical orientation, machine translation research will clearly be close to pointless; with an operational orientation, on the other hand, machine translation research will not only be interesting and valuable in its own right, but will also constitute one of the few available conclusive means of verification of the findings of linguistics (cf. Garvin 1962: 387).

This paper will attempt a survey of the major controversial issues in the field of machine translation, all of which, in the light of the above discussion, are considered operational. These issues are considered to fall into three basic categories: linguistic problems, design problems, and bread-and-butter problems.

LINGUISTIC PROBLEMS

The Role of Linguistics Theory in Machine Translation

It is a commonly held view among linguists, both the few who are interested in machine translation and the many who are not, that any application of linguistics--and in the linguist's view this certainly includes machine translation research--must be based primarily on a strong linguistic theory. (For a recent statement of this view see Bar-Hillel 1970). This is essentially a capsule view of the theoretical orientation. While nobody will deny that any applied work must have a sound theoretical basis, from an operational standpoint there are a number of things seriously wrong with an over-emphasis on theory.

(1) Machine translation is considered primarily an operational rather than a theoretical problem. Consequently, an application of sound linguistic research methods is more important than a further elaboration of linguistic theory.

(2) Most strong linguistic theories are essentially generative in nature. However, the basic problem in machine translation is not a generative but a recognition problem. Recent research in psycholinguistics has confirmed an opinion long held by this investigator, namely that a recognition problem cannot be resolved by simply reversing a generative system.

(3) The kind of questions that arise in machine translation research are not necessarily the kind of questions that are most popular among linguistic theorists. More specifically, the basic problems of ambiguity resolution are different in machine translation from the formulation they have received in

recent explanatory linguistic theories.

(4) It is an old operationalist adage that one can best learn by doing. This is particularly true in the case of machine translation where the machine manipulation of linguistic data forces the investigator to recognize a great many inaccuracies and intuitive shortcuts that are usually glossed over in theoretical linguistic research. Thus, rather than relying excessively on the contributions of linguistic theory to machine translation research one should expect significant contributions to linguistics from research on machine translation.

Nature of Models

Linguistic models can be categorized as strong or weak, depending on whether or not they have strong or weak formal pretensions. Current trends in linguistics favor strong models; this is of course based on an epistemological attitude that is oriented towards the elaboration of theory rather than of method. In line with the discussion in the preceding section, it is here considered that, particularly for purposes of an application such as machine translation, weak models are to be preferred to strong ones. The reason is that strong models are considered to prejudge the direction of research in a situation in which there are too many unforeseen and as yet insufficiently known factors. Clearly, there have to be grammars of both the source and target languages at the base of any machine translation system. Equally clearly, however, these grammars need not be formal grammars; as a matter of fact, in this author's opinion descriptive grammars are strongly preferable to formal grammars for purposes

of machine translation because they are much better able to account for the indeterminacies of natural language structures which, as was so well stated by Charles F. Hockett recently, are essentially ill-defined systems (Hockett 1968: 44-45). Descriptive grammars can best be developed in a primarily method-oriented, rather than a primarily theory-oriented, frame of reference. As a matter of fact, in such a frame of reference conventional grammars may be used as a reasonable point of departure, with the necessary modifications introduced as the requirements of machine translation become apparent in the process of the development of experimental systems. Operationally oriented machine translation research both in the United States (cf. Garvin forthcoming) and in the Soviet Union (cf. Bel'skaja 1969) has done just that. This author has made strong claims on behalf of his proposed version of an operational machine translation system (Garvin 1967); it is not known how far along comparable Soviet versions have progressed.

Aspects of Linguistic Structure

All linguists seem to agree that the system of language is hierarchically structured. That is, they all look upon the system of a language as having different levels, or strata, or components. From a machine translation standpoint, of course, it is most important to know which distinctions between different aspects of language are relevant for the development of machine translation systems. The least significant seems to be that of phonology and grammar, since no machine translation system to this author's knowledge is concerned with phonology at all. The most important is the distinction between

grammar and lexicon, since all machine translation systems known to this author make some distinction somewhere between a dictionary lookup based on the lexicon and an algorithmic portion based in part on the grammar.

Linguistic approaches differ in regard to whether or not the lexicon is considered a part of the grammar or a dimension separate from it. In either case, the lexicon and the grammar (or the remainder of the grammar) are kept clearly separate by most linguists. The difficulty in machine translation is that the lexicon and the grammar cannot be hermetically sealed off from each other. The dictionary and the algorithmic portion correspond only roughly to lexicon and grammar respectively; the dictionary, after all, contains a grammar code which is based on the grammar, and the algorithmic portion serves to resolve not only grammatical but also lexical ambiguities. Nevertheless, an understanding of the differences between lexicon and grammar is essential for a proper operational assessment of all the variables that enter into the design of a machine translation system.

Related to the conception of levels or strata of language is the methodological problem of conducting the analysis "from the bottom up" or "from the top down". In the first case, the minimal units of language are considered as the input into the analysis and the output yields the maximum units which are, for all practical purposes, the sentences of the text. In the second case, the input are the sentences and the output is a decomposition of the sentences into their constituents. Clearly, since in machine translation the grammatical information is transmitted to the algorithmic portion from the dictionary by a lookup of individual textwords, and since therefore the initial input elements

into the algorithmic portion are the "bottom units", a "bottom to top" approach is the most operationally efficient one for machine translation.

DESIGN PROBLEMS²

Sensing Units and Translation Units

This is one of the oldest and also most important problems faced in the design of machine translation systems. Sensing units are linguistic units which the computing equipment can read, that is, for all practical purposes, strings of letters separated by spaces and/or punctuation marks. Clearly, these correspond only partially to the translation units, that is to say, the grammatical and lexical units that must be manipulated in order to effect translation. The problem consists in providing the machine translation system with a capability for transforming the sensing units into appropriate translation units. In a sense, the entire recognition problem in machine translation is a consequence of this difference between sensing units and translation units. Were it not for that, the brute force conception that machine translation can be effected by a large enough dictionary with some adaptations to make room for syntactic and semantic differences between the two languages, would indeed be adequate. And, needless to say, everyone who has had any experience with the field knows that this is not so.

Intermediate Language

There has been a good deal of discussion in the machine translation literature about the presumed advantages of an intermediate language (for an

example of this, cf. Andreyev 1967). It has, for instance, been asserted that with the help of an intermediate language one could ultimately accomplish translation from any one of a number of different languages into any one of a number of other languages much more economically than by designing a corresponding series of translation systems for the different conceivable language pairs. Some have gone so far as to give a mathematical expression to this theoretical economy. From an operational standpoint, of course, the real problem is whether or not machine translation of any satisfactory quality can be achieved at all, rather than how it can be achieved most economically for an indefinite number of language pairs.

Nevertheless, the question of intermediate language deserves serious consideration, from an operational as well as from a theoretical standpoint. Some authors, such as Andreyev (ibid.), have talked about an intermediate language as if it were a real language such as English or Russian. That is, translation would be done from the source language into an intermediate language conceived of as a real language, and then back out of the intermediate language into the target language. If the intermediate language is so conceived, then this means encumbering the translation process by an additional step: instead of translating in a one-step process directly from the source language into the target language, it becomes a two-step process in which translation is first effected from the source language into the intermediate language, then from the intermediate language into the target language.

If on the other hand the intermediate language is not conceived of as a genuine language with all the appurtenances, then the conception of an intermediate

language becomes much more rational from an operational standpoint, and also much more trivial from a theoretical point of view. In that case, the intermediate language is nothing more than a series of symbolic notations to record the output of the recognition routine and to serve as input into the command routine by which the text in the target language is to be generated. This, as was said, is operationally effective--it is also operationally necessary, because there must be some way in which the information gathered by the recognition routine is stored and transmitted out into the command routine. The use of the term intermediate language then becomes trivial, because this information store will certainly not have the language-like qualities which the term implies. It is further conceivable from an operational point of view, although certainly premature at the present state of machine translation research, that the same information store can be filled by a number of different recognition routines for different languages, and in turn feed into a number of different command routines for different target languages. The information store then will be combined with a kind of switchboard that will direct the appropriate recognition routine into the store and make sure that the output of the store is fed into the appropriate command routine. Thus, the theoretical efficiency talked about in the preceding paragraph is conceivable, but in a sense which for the current state of affairs is operationally trivial.

Total Accountability

Many linguistically oriented researchers in machine translation have claimed that in order for machine translation to be possible, it is necessary

to account for all of the linguistic conditions that exist in a language. Some, such as Bar-Hillel (1970) have gone even further and claimed that not only linguistic conditions, but also pragmatic conditions have to be accounted for in order to make machine translation of the desired quality possible.

From an operational standpoint, this is an inappropriate identification of the aims of exhaustiveness in linguistic research with the aims of machine translation. Clearly, only those linguistic conditions which have a bearing on the translation process need be accommodated in a machine translation scheme. Thus, most of derivational morphology, although of great interest to the linguistic researcher, is essentially irrelevant to the translation process, since derived forms can be entered into the machine translation dictionary with their appropriate translations without going through the trouble of underlying analysis. Similarly, it is certainly not to be expected of a machine translation system any more than of a human translator to translate unambiguously passages which are inherently ambiguous in the source language. Likewise, no machine translation system should be expected to account in its entirety for those pragmatic factors which under ordinary circumstances would remain obscure to the human peruser of the source language text.

Morphological Analysis

Quite a few linguistically oriented machine translation researchers have given a great deal of attention to automatic morphological analysis as part of the machine translation process. This analysis has been primarily concerned with attempting to determine morpheme boundaries within printed words; some

researchers have limited themselves to separating inflectional endings from the base portions of the words, while other researchers have gone further than that and also included the segmentation of derivational morphological material. One of the reasons given for this has been the requirement of total accountability which was discussed in the preceding section. Another, operationally more valid, reason has been that separating inflexional endings from base portions, while it may encumber dictionary lookup, saves a great deal of storage space in the dictionary portion of the program. The reason given for segmenting derivational material has been that it facilitates the recognition of neologisms. Clearly, the latter two reasons apply primarily to "highly inflected" languages such as Russian or German.

As far as the segmentation of inflectional morphemes is concerned, which some machine translation groups have called "stem-affixing", this is a perfectly reasonable space-saving procedure when it comes to high frequency regular inflectional patterns. In the case of the so-called exceptions, particularly when the irregularities involve changes in the base portions of the words, no operational gain is derived from the segmentation of inflectional morphemes from base portions.

As far as the segmentation of derivational elements is concerned, the advantages derived from the facilitation of the recognition of neologisms have to be weighed against the disadvantages of introducing an additional elaborate systems task into the design. In this author's opinion, the segmentation of compounds into their components may well be extremely useful in the recognition of neologisms. On the other hand, the segmentation of derivational

morphemes from the remainder of the base portions of the words is both operationally more cumbersome than the segmentation of compounds, and less likely to yield results in the correct recognition of neologisms. It is, after all, well known that the lexical meanings of derived words, particularly in the Slavic languages, are often not predictable from the sum of the meanings of the derivational morpheme or morphemes and the remainder of the base portion.

Grammar Code and Algorithmic Portion

Most workers in the field of machine translation agree that grammatical information is stored in the form of grammar codes in the dictionary of the system; the term grammatical information is here used loosely to include whatever lexical and other semantic information is available to the program. This information is then called by the algorithmic portion of the system for further processing to effect the required recognition of the source language input and subsequent generation of the target language output. This raises the question as to how much information is to be stored in the grammar code, and how much of the recognition and subsequent generation task therefore is to be left to the algorithmic portion. The current trend in much of linguistic theorizing has been to emphasize the significance of rules; this means, from a machine translation standpoint, that a great deal of the recognition burden is placed on the algorithmic portion, with only as much contained in the grammar code as is considered theoretically desirable. Since, however, a table-lookup operation is significantly easier to perform than an algorithmic

one, there is a distinct operational advantage in maximizing the grammar-coded information and minimizing the role of the algorithmic portion. This does not of course mean that under any circumstances the role of the algorithmic portion becomes as trivial as some early machine translation researchers have assumed it to be. The other question, namely, whether or not the algorithmic portion should contain a separate table of rules, will be discussed in a subsequent section on bipartite and tripartite design in machine translation.

Content of the Grammar Code

One of the lessons learned by all machine translation research groups has been that the amount and type of grammatical information contained in conventional grammars is wholly inadequate for machine translation purposes. At least the following types of information have been found essential for most full words in a language such as Russian: (1) Word class information. This includes not only indication of the conventional word class, but requires a reformulation of word class distinctions in terms of syntactic functioning of Russian words. Thus for instance, instead of including participles under verbs as one of their forms, as is done in many traditional grammars, participles are considered a special type of attributives with the particular function of having the potential for governing dependent structures. Thus participles are included in a category of governing attributives together with a number of adjectives that are functionally equivalent to them, and are not included in the same class with verbs. Similarly, infinitives are considered a separate word class because, unlike finite verbs, they do not ordinarily have subjects, and unlike gerunds which likewise do not have subjects, they may serve themselves

as subjects of Russian clauses. (2) Agreement information. This has to include information with regard to modifier-head-type agreement, as well as information as to whether or not the agreement is of the ordinary type (as for Russian adjectives) or of the exceptional type (as for Russian numerals).

(3) Modifiability information. This information has to state what dependent words a given word may be modified by. That is, in the case of nouns, what adjectives may modify a given noun; in the case of adjectives, what adverbs may modify a given adjective; etc. (4) Complementation information. This information concerns the type of complements which may be associated with a given verb, noun, or other Russian word that may have a complement in association with it. Thus, verbs or nouns of location may have certain types of complements of place accompanying them; verbs or nouns of time may have certain complements of time accompanying them, etc. (5) Governor class information. For those words which may be governed by other words, information in regard to the particular kinds of words which may govern them: for instance, in the case of adjectives, the kind of nouns to which they may be modifiers; in the case of adverbs, the kind of adjectives to which they may be modifiers. (6) Government information. Those words which govern dependent structures, the kind of dependent structures which they may govern. For instance, the kind of case a verb or noun may govern, whether or not more than one dependent structure may be governed and in which case each of the possible dependents will stand, whether or not there is prepositional government (which preposition and demanding which case), etc. (7) Subject class information. For verbs, the class of subjects which a given verb may take, such as animate, inanimate, human, etc. (8) Object class information. The same type of

information as for subject class, except of course, concerning the object which a given verb or a given governing attributive may take.

The above includes only a part of the kind of information required for a complete grammar code. Much of this information is commonly considered semantic rather than grammatical; much of it has to do with not only the syntactic recognition of the sentence but also with the recognition of semantic compatibilities. A great deal more information is needed if in addition to this type of recognition correct choices are to be made in the case of multiple meaning.

Bipartite versus Tripartite Design³

The issue here is whether or not the rules of the grammar of the source language should be contained in a table to be called by a parsing algorithm, or whether these rules should be written into a more elaborate algorithm of which they become an organic portion. In the first case, the machine translation program would essentially consist of three portions: a dictionary, a parsing algorithm, and a table of rules--hence, the term tripartite. In the second case, the machine translation program will consist of only two portions: a dictionary, and a translating algorithm--hence, the term bipartite.

The main arguments in favor of a tripartite design are: (1) that it allows the processing by one and the same parsing algorithm of more than one table of rules; thus, if any corrections in the grammar are to be made, this involves only a relatively simple updating of a given rule table, and does not require any revision of the algorithm itself; (2) the labor of the programmer

who is responsible for the parsing algorithm can be kept separate from the labor of the linguist who is responsible for the table of rules. In theory, these two advantages appear to be overwhelming. In practice, it turns out that the fundamental problem in the automatic recognition of grammatical structure of text is the correct sequencing of the application of the rules of the grammar which are supposed to effect the recognition. In this author's opinion, such a sequencing of the application of different grammatical rules can be effected only by making the rules of the grammar an organic part of the algorithm; this is the only way to insure that a given rule will be called only after all the conditions that are necessary for its operation have been previously recognized by other rules of the program, and that such a recognition has been effected in the correct order.

This requirement of sequencing of rule application is based not only on the recognition that the grammar of a language is hierarchically structured, that is, that there are levels to be gone through. It is also based on the recognition that in addition to the levels of the language, there is also an operational order in which grammatical and other information becomes available to the program. Thus, once again, it is apparent that the operational requirement does not parallel the theoretical desiderata.

Recognition Strategy

As was stated above, a bipartite machine translation design is considered operationally preferable to a tripartite one. This means that the algorithmic portion of a machine translation program operates on the basis of something

like a pattern recognition strategy, rather than a parsing strategy. This means that the algorithmic portion will in essence carry out a number of context searches to recover the conditions necessary to effect recognition and subsequent translation.

This conception of recognition strategy raises the basic problem of the proper organization of the searches in a bipartite system. Two basic types of search patterns have been proposed in the literature: one is predictive analysis, devised by Ida Rhodes of the National Bureau of Standards and soon thereafter adopted by the then Machine Translation Research Group at Harvard University (Oettinger and Sherry 1961); the second is the author's fulcrum approach (Garvin 1968). Predictive analysis employs essentially a straight-forward left to right search pattern. The algorithm looks at the grammar code of each textword, as it has been looked up in the dictionary, from left to right. For each textword it records its grammatical potential in the form of predictions and notes the extent to which predictions of previously noted words are fulfilled by each current word. If this succession of predictions and their fulfillments does not result in an appropriate recognition of the syntactic structure of the sentence, then unfulfilled predictions and unused fulfillment possibilities are retested in a program component called hindsight. The basic difficulty of this approach is that the more complex a sentence, the greater the burden placed upon the hindsight; from an operational standpoint, the greatest weakness of this approach has been that the hindsight has never properly been worked out. In the fulcrum approach, on the other hand, searches are designed to use words in order of their grammatical significance, rather than in the linear order of their appearance in text. Thus

the searches are directed first at those words which contain the most grammatical information from the standpoint of the recognition of a particular structure (the so called fulcra), then they branch out from these pivot words in order to encompass the remainder of the structures in question. Since not all grammatical information is retrievable in a single pass, the fulcrum approach uses a succession of passes for the retrieval of the grammatical information contained in each sentence.

The reasons for which the fulcrum approach is considered operationally preferable to predictive analysis are the same for which a bipartite system is considered operationally preferable to a tripartite one: the need for the appropriate sequencing of the application of grammatical rules to the elements of the text.

Single versus Multiple Interpretation of Sentences

Many approaches to automatic syntactic analysis, whether connected with machine translation or not, favor the outputting of as many parsings of each sentence as is conceivable in terms of the given grammar code. The reason for this preference is the theoretical interest of showing the variety of conceivable analyses based on a given grammar code. From an operational standpoint, this is clearly undesirable, since the operational aim of machine translation is not to show the variety of conceivable interpretations of each given sentence, but to arrive at some reasonable form of translation with the minimum of waste motion. Thus, in an operational approach to machine translation priority must be given in each case to the most likely interpretation of

any given sentence in the hope that this will indeed turn out to be the interpretation applicable in the particular case. As the machine translation system is refined, provisions can be included for superseding this most likely interpretation in favor of a less likely one, if the latter turns out to be the one applicable to the particular case.

Filter versus Heuristics

This question is closely related to the one treated in the preceding section.

A program component called filter has been used in some of the Soviet approaches to operational machine translation (cf. Mel'čuk 1964, Iordanskaja 1967). The intention of these systems is essentially to produce if not all, then a number of, the different possible syntactic interpretations of each sentence, by means of an algorithm which incorporates numerous table lookups and is essentially based on a variant of dependency grammar (cf. Hays 1964). It is not known to what extent this approach has been operationally successful; it is known, however, that the Mel'čuk group has since turned its attention to other problems of a more theoretical nature (cf. Mel'čuk and Žolkovskij 1970).

A machine translation design which gives a preferred single interpretation to each sentence obviously does not need a filter for the selection of one alternative from among many. What it does need is a capability for the revision of the one selected single alternative, in case overriding conditions in the grammatical makeup of the sentence require that it be superseded by another interpretation. The mechanism for overriding previously made

determinations as to the interpretation of sentences is given by the inclusion of a heuristic capability in the machine translation design. The initial preferred interpretation of a sentence is given on the basis of information derived early in the syntactic processing. This information may have to be overridden on the basis of more powerful information obtained at later stages in processing. Consequently, the heuristic component must both recognize which interpretations may be subject to later revisions, as well as identify the conditions on the basis of which any prior interpretation is subject to such a revision. Usually, the original interpretation is arrived at on the basis of the immediate context, and whatever revisions may be necessary arise from the inclusion of a broader, usually clause-wide, context. The advantage of combining a single preferred interpretation with a capability for revision based on heuristics is essentially that in most cases the original preferred decision, precisely because it is based on greater likelihood, may be allowed to stand. Thus a great deal of the processing involved in the use of filters can be avoided. (For a detailed discussion of the use of heuristics in the fulcrum approach, see Garvin 1968: 172-81).

BREAD-AND-BUTTER PROBLEMS

Quality of Translation

A great deal of discussion in the machine translation literature has been devoted to the feasibility or non-feasibility of high-quality machine translation. Much of this discussion has been quite unrelated to reality, because it has been based on an A Priori abstract conception of what constitutes high

quality translation. Clearly, the question of the quality of translation has to be related to user need: the greater the need, the more it is possible to compromise with quality. This has recently been recognized even by Bar-Hillel (1970). For many purposes, machine translation output will be only casually scanned rather than carefully read; from a great mass of documents so perused a few may then be selected for later, more careful, human translation. Another factor to be considered is the speed with which machine translation can be effected, as compared to the time required to produce good quality translation by human labor. This has, of course, been used as an excuse for the perpetuation of operating, though operationally unviable, machine translation systems. Nevertheless, it is one of the practical problems deserving more careful consideration than has been afforded them in the past.

Input Preparation

In the view of most observers, the greatest practical handicap in the use of machine translation has been the high cost of key-punching the original document for input into the computing system. Clearly, the only way of overcoming this handicap is by the use of automatic character recognition.

Recent claims to the effect that character recognition is now feasible for a sufficient number of fonts to be practical seem to have some validity. Undoubtedly, this will have a great effect on the evaluation of the economics of machine translation in the future, provided the question can be approached with sufficient detachment from the mistakes of the past.

Staffing

This is the most complex practical problem in both machine translation research and in the maintenance and updating of the machine translation systems of the future, if indeed such systems will ever become practical.

The reason this is such an extremely difficult problem is because both the development and the maintenance of machine translation systems require the cooperation of personnel with two sets of qualities that are very rarely found in the same individuals. On the one hand, work in machine translation requires great originality, expertise, intuitive brilliance, and all the other qualities that make for good researchers. On the other hand, machine translation research also requires extreme intellectual discipline, patience, persistence, and willingness to give up one's individual original ideas in favor of the established parameters of the system.

One of the more easily resolvable problems of staffing is the decision as to whether the work of linguists and programmers should be combined in the same persons, or whether the two competencies should be kept separate. In this author's experience, no linguist will ever become a good enough programmer, and conversely. Therefore, in order to maintain the highest possible level of professional competence in the research staff, the two competencies should be kept separate but should learn to work in close coordination. This again is an extremely difficult objective to achieve in practice, although it is much talked about in theory.

Footnotes

- ¹ This statement was not included in the published version of his lecture (Weinreich 1966).
- ² For a discussion of the design of the author's proposed machine-translation system, see Garvin 1968.
- ³ For a detailed discussion of the author's views of this issue, see Garvin 1966.

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The Logic of English Predicate Complement Constructions

by

Lauri Karttunen

Linguistics Research Center
and
Department of Linguistics
The University of Texas at Austin

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The Logic of English Predicate Complement Constructions¹

Lauri Karttunen

0. INTRODUCTION. The title of my paper is an intentional variation on the name of Peter Rosenbaum's (1965) well-known MIT dissertation 'The Grammar of English Predicate Complement Constructions'. It is intended to be suggestive of a difference in emphasis between the early work on complement constructions by Rosenbaum and others, and the more recent studies by Paul & Carol Kiparsky, George Lakoff, Jerry Morgan, and myself - just to mention a few.² It is these newer developments that I will discuss in my report.

In the appendix to this thesis, Rosenbaum provided a classification of English verbs in terms of the complement structures in which the verbs may participate. His analysis of complementation has since been challenged, and the basic criteria for his classification have now generally been rejected.³ But of course, the general principle of classifying verbs in terms of their syntactic properties continues to be valid. For example, it must be stated somewhere in the lexicon that verbs like order and force take sentential complements only in the presence of a real noun phrase object, but believe and realize can have complements as their objects. Or, if you prefer another terminology, realize is a two-place and force a three-place predicate. On the basis of such simple criteria, one might arrive at the conclusion that the verbs listed in (1) divide naturally into the four groups which are indicated there.

- (1) (a) order(x, y, S) force(x, y, S)
 (b) realize(x, S) believe(x, S)
 (c) manage(x, S) decide(x, S) able(x, S)
 (d) seem(S) happen(S) certain(S) odd(S)
 possible(S)

For instance, on syntactic grounds there are good reasons for regarding the verbs happen and seem as similar, since they both take sentential subjects and undergo many of the same syntactic transformations.

In selecting these examples in (1), I have not been quite as arbitrary as it first appears. It does not take long to notice that just those verbs which here fall into the same class on the basis of some superficial syntactic criteria turn out to be different when the same verbs are grouped on the basis of their semantic properties. At this point, you might take a look at the classification in (2), which gives a preview of what is to come, and compare it with (1).

- (2) FACTIVES: realize, odd
 IMPLICATIVES: manage, happen
IF-VERBS: force, certain
ONLY-IF VERBS: able, possible

Sometimes it is possible to show that there is a definite connection between the semantic properties of a verb and certain syntactic characteristics. For instance, it has been observed (Kiparsky 1968) that all of the factive verbs of the type (1d) are exceptions to the transformation that relates (3a) and (3b). Therefore, (3d) is ungrammatical.

- (3) (a) It was certain that Bill was alone.
 (b) Bill was certain to be alone.
 (c) It was odd that Bill was alone.
 (d) *Bill was odd to be alone.

However, I do not believe that the validity of the proposed classification crucially depends on us being able to find

syntactic parallels for every distinction; and here I will not try to present any. For the purpose at hand, it is sufficient to demonstrate their semantic reality, to show that they actually play a part in our everyday reasoning.

1. FACTIVE VERBS. The term 'factive verb' is due to a pioneering study by Paul and Carol Kiparsky (1968).⁴ An illustrative sample of these verbs is provided in (4).

(4) FACTIVE VERBS:	significant	resent
	tragic	know
	relevant	realize
	odd	bear in mind
		take into account
	regret	make clear
	ignore	find out

What is common to them is that any simple assertion with a factive predicate, such as (5a), commits the speaker to the belief that the complement sentence, just by itself, is also true.

- (5) (a) It is odd that Bill is alone.
- (b) Bill is alone.
- (c) It is possible that Bill is alone.

It would be insincere for anyone to assert (5a) if he did not believe that (5b) is true. Intuitively, in uttering (5a) the speaker must take it for granted that Bill is alone; he is making a comment about that fact. The same relation holds between (6a) and (6b).

- (6) (a) Mary realized that it was raining.
- (b) It was raining.
- (c) Mary believed that it was raining.

Notice that these relations break down if we replace odd by possible and realized by relieved. (5c) and (6c) do not carry a commitment to the truth of the complement sentence.

With factive verbs, it does not make a difference whether the main sentence is affirmative or negative. The negations

of (5a) and (6a), which you find in (7), also obligate the speaker to accept the complement as true.

- (7) (a) It isn't odd that Bill is alone.
 (b) Mary didn't realize that it was raining.

Even the illocutionary force of the main sentence is irrelevant. The question in (8) carries along the same commitment as (5a) and (7a).

- (8) Is it odd that Bill is alone?

These facts about negation and questions become important later on when we have to distinguish between factive and implicative verbs.

1.1. PRESUPPOSITION. What the above examples show is that a sentence with a factive predicate indicates belief on the part of the speaker in the truth of the complement sentence. This relation is usually described by saying that the complement of a factive predicate is a 'presupposition' for the sentence as a whole. The term 'presupposition' comes from logic but it is currently used in linguistics in a more general way than the common logical definition would actually allow. In logic, it is customary to give some definition such as (9).⁵

- (9) P presupposes Q iff

$$T(P) \supset T(Q) \quad \text{and} \quad F(P) \supset T(Q)$$

$$[T(_) = '_ \text{ is true}' , F(_) = '_ \text{ is false}']$$

That is, P presupposes Q just in case Q is true whenever P has a truth value.

However, this definition in terms of truth values is not very helpful to linguists. They tend to rely on a more or less intuitive notion of presupposition, which I have tried to explicate in (10) - rather unsuccessfully, I must say.⁶

- (10) P presupposes Q just in case that
 if P is asserted, denied, or questioned
 then the speaker ought to believe that Q.

1.2. POSSIBLE WORLDS. In his paper on presuppositions, Jerry Morgan (1969) pointed out that there are sentences such as the examples in (11).

- (11) (a) If I had missed the train, I would have
 regretted it.
 (b) I dreamed that I was a German and that
 nobody realized it.

The problem with these examples is that, in both cases, the speaker apparently does not believe that the complement of the factive verb is true. In (11a), the pronoun it stands for the sentence 'that I had missed the train'. Since regret is a factive verb, the second clause of (11a) presupposes that the speaker has missed the train. However, this is just what is denied by the preceding counterfactual conditional. According to what we just said about factive verbs, (11a) ought to be self-contradictory. Similarly, (11b) ought to imply that the speaker believes that he is a German, even when he is not dreaming. Both of these predictions are clearly wrong. On the other hand, the examples in (12), which are very similar to those in (11) pose no problems at all.

- (12) (a) If I had regretted that I missed the train,
 I would not have mentioned it.
 (b) I dreamed that nobody realized that I was a
 German.

(12a) can be sincerely asserted only by someone who believes that he has missed the train; in (12b), the speaker must believe that he really is a German. The crucial difference between (11) and (12) is that, in (12a), the sentence with a factive predicate is the antecedent clause of a counterfactual conditional construction and, in (12b), it is the first sentence following the verb dream.

Morgan concludes from examples of this sort that the conditional if, the word dream and all similar verbs are to be regarded as 'world-creating' predicates. A sentence in the scope of a world-creating predicate is assumed to be true, not in the actual world, but in a 'possible world'.⁷ A possible world receives its characterization in the usual left-to-right order of discourse. For instance, in (11b) the first sentence following the verb dream, 'I was a German', is understood to be a fact in the context of my dream world; therefore, it can stand as a presupposition for the following sentence, 'nobody realized that I was a German', which also is in the scope of dream. Similarly, in (11a) the antecedent clause of the conditional construction, 'I had missed the train', defines a possible world in which it may then also be true that I regret that fact.

This analysis explains the difference between the examples in (11) and (12). In (12b), the complement of realize has not been established as a fact of the dream world; therefore, it ought to be a fact in the actual world of the speaker. (12b) can only be said by someone who believes that he is a German. In (11b), the complement is introduced as a fact in a dream. It does not matter if the speaker does not believe it to be true in the actual world.

I don't intend to try to give any formal account of how possible worlds ought to be incorporated into a theory of language. I don't think that there is, at this point, much to be said about it beyond the kind of suggestive remarks that I have presented. This is an area where there is bound to be some exchange of ideas between linguists and modal logicians, who have traveled in possible worlds far more extensively than we have. But neither linguists nor philosophers have actually been thinking about sentences like those in (11) for very long.

1.3. DEGREES OF FACTIVITY. Another outstanding problem is that some of the factive verbs in (4) do not carry along the expected presupposition in all syntactic environments. For example, there is an unexplained difference between verbs like regret and realize in conditional clauses.. Although both verbs are factive as far as simple assertions are concerned, if-clauses with realize as predicate do not presuppose the truth of the complement. Consider the difference between (13a) and (13b).

- (13) (a) If I realize later that I have not told the truth, I will confess it to everyone.
 (b) If I regret later that I have not told the truth, I will confess it to everyone.

It is obvious that (13a), with realize in the if-clause, does not presuppose that the speaker has not told the truth; it merely admits that there is such a possibility. On the other hand, one cannot utter (13b) without thereby conceding that one has not told the truth. Another ordinarily factive verb which loses its factivity under the same circumstances is the verb find out.

As far as I know, anomalies of this sort are still largely unexplored und poorly understood.

2. IMPLICATIVE VERBS. The next class of verbs I will discuss is illustrated by the examples in (14).

(14) IMPLICATIVE VERBS:

manage	have the	{misfortune}
bother		{foresight}
happen		{time
see fit	take (the)	{opportunity}
get		{trouble}
care	condescend	

If we just look at affirmative assertions, implicative verbs are very similar to factives. A sentence like the examples

in (15) commits the speaker to the belief that the complement sentence is true.

- (15) (a) Yesterday, Bill happened to break a window.
- (b) To everyone's surprise, Sam managed to solve the problem.

- (16) (a) Yesterday, Bill broke a window.
- (b) To everyone's surprise, Sam solved the problem.

Asserting (15a) obligates the speaker to accept (16a) as true. The same goes for (15b) and (16b). But if we replace manage with a verb like decide, the same relation does not hold anymore. There is no such connection between (17) and (16b).

- (17) To everyone's surprise, Sam decided to solve the problem.

However, notice that the adverbial modifiers of the main sentence, yesterday in (15a) and the phrase to everyone's surprise in (15b), by implication also seem to belong to the complement sentence. Another striking difference between factive and implicative verbs shows up in negative assertions. This can be observed by comparing the examples in (18) with those in (7). As you remember, in case of factives, negation in the main sentence has no effect on the assumed truth of the complement. But when a sentence with an implicative predicate is negated, it commits the speaker to the view that the complement is false. For instance, one cannot sincerely assert (18a) unless one believes (19a).

- (18) (a) Sheila didn't bother to come.
- (b) Max didn't have the foresight to stay away.
- (19) (a) Sheila didn't come.
- (b) Max didn't stay away.

It would be contradictory to say something like (20).

(20) *Sheila didn't bother to come, but she came
nevertheless.

Similarly, (18b) implies (19b).

2.1. IMPLICATION. In saying that (18b) implies (19b), I am not using the term 'imply' in the sense of 'logically implies' or 'entails'. The relation is somewhat weaker, as indicated by the definition in (21).

(21) P implies Q iff
whenever P is asserted,
the speaker ought to believe that Q.

I believe this to be the same sense in which J. L. Austin (1962) has used the term. It is also closely related to B. C. Van Fraassen's (1968) notion of 'necessitation'.⁸ Note that, for our weak sense of 'imply', the rule of inference known as 'Modus Tollens' does not apply. It is not required in (21) that asserting in $\neg Q$ should, in turn, obligate the speaker to believe that $\neg P$. The reason why this point is worth making is that Modus Tollens is a valid argument form for the two other common senses of the term 'imply', 'materially implies' and 'logically implies', which we do not want to get mixed up with. Using the term in the sense of (21), we can say that (22a) implies (22b).

(22) (a) John managed to kiss Mary.
(b) John kissed Mary.

But it would be mistaken to conclude from this, by Modus Tollens, that the negation of (22b) implies the negation of (22a); in other words, that (23a) also implies (23b).

(23) (a) John didn't kiss Mary.
(b) John didn't manage to kiss Mary.

If you contemplate for a while the two sentences in (23), you will soon realize that one can perfectly well assert (23a) without committing oneself to the belief that (23b) is true.

The verb manage in (23b) carries along an extra assumption that is not shared by (23a). It would be appropriate to use (23b) only if John had actually made an unsuccessful attempt to kiss Mary. Therefore, these two sentences are not logically equivalent; the implication only holds in one direction, from (23b) to (23a) and from (22a) to (22b).

2.2. MEANING POSTULATES. Let us now consider the problem how these facts about implicative verbs ought to be accounted for. One might, for example, propose that the semantic representation of (15a) actually contains the implied sentence, (16a), as a subpart. If one is a generative semanticist, one might even assume that (15a) be transformationally derived from some structure that properly includes the underlying structure of (16a). Under this proposal, there would be no distinction between the semantic representation of a single sentence and the set of inference derivable from it; the two notions would be equivalent.⁹ This is not the approach that I have chosen. Instead, I assume that the implied sentence is not included in the underlying representation of its antecedent but is to be derived from it by means of meaning postulates and general rules of inference.

I have proposed (Karttunen 1970a) that the facts about implicative verbs be accounted for in the following manner. What all verbs such as manage, bother, etc. have in common is that they are understood to represent some necessary and sufficient condition which alone determines whether the event described in the complement takes place. They all have the same two meaning postulates associated with them.¹⁰ Using v for any arbitrary implicative verb and S for its complement, we can represent these two meaning postulates roughly as in (24).

- (24) (a) $v(S) \supset S$ 'v(S) is a sufficient condition
for S'
(b) $\sim v(S) \supset \sim S$ 'v(S) is a necessary condition
for S'

What actually constitutes this decisive condition depends on the particular implicative verb. It may consist of making a certain effort, as in bother, showing enough skill and ingenuity, as in manage, or it may be a matter of chance, as in happen. A sentence with one of these verbs as predicate can be looked upon as a statement about whether this decisive condition is fulfilled, and under what spatial and temporal circumstances this is the case. From an affirmative assertion, we can then infer that the complement is true; from a negative assertion that the complement is false. The rule of inference I am assuming here is, of course, the familiar Modus Ponens, which is illustrated in (25).

(25) MODUS PONENS:

$$\begin{array}{ll} \text{(a)} & \begin{array}{c} P \supset Q \\ P \\ \hline \therefore Q \end{array} & \text{(b)} & \begin{array}{c} \sim P \supset \sim Q \\ \sim P \\ \hline \therefore \sim Q \end{array} \end{array}$$

For example, note that although all the sentences in (26a) assume a different kind of decisive condition for the truth of the complement, they all assert that, yesterday, this condition was not fulfilled.

- (26) (a) Yesterday, John did not $\left\{ \begin{array}{l} \text{happen} \\ \text{manage} \\ \text{bother} \\ \text{see fit} \end{array} \right\}$ to kiss Mary.
(b) Yesterday, John did not kiss Mary.

Therefore, (26b) can be derived in all cases as a legitimate inference in the manner illustrated in (25b) above.

2.3. NEGATIVE IMPLICATIVES. Next I would like to point out a group of verbs that are in every other respect like the implicative verbs in (14) except that they work the opposite way. A short list of these negative implicatives is given in (27).

- (27) NEGATIVE IMPLICATIVES:
- | | |
|-------------|---------|
| forget (to) | decline |
| fail | avoid |
| neglect | refrain |

An affirmative assertion with one of these verbs as predicate implies the negation of the complement. For instance, (28a) implies (28b).

- (28) (a) John avoided getting caught in the traffic.
(b) John didn't get caught in the traffic.

On the other hand, a negative assertion results in a positive implication, just as we would expect on the basis of the Law of Double Negation. Thus (29a) implies (29b).

- (29) (a) John didn't avoid getting caught in the traffic.
(b) John got caught in the traffic.

There are in principle two ways to account for these facts in our analysis. One way is to say that we have a separate pair of meaning postulates for negative implicative verbs. This set would be the pair given in (30).

- (30) (a) $v(S) \supset \sim S$ ' $v(S)$ is a sufficient condition
for $\sim S$ '
(b) $\sim v(S) \supset S$ ' $v(S)$ is a necessary condition
for $\sim S$ '

The other possibility is to assume that negative implicatives in fact contain negation in their underlying syntactic structure and that there is a process of lexical insertion that can replace some ordinary implicative verb and the preceding negation marker with one of the verbs in this special class. For instance, there would be rules such as (31), which

says that the verb fail, in one of its senses, is equivalent to not succeed. This equivalency may then be interpreted as permission to substitute fail for not succeed in some underlying syntactic structure. .

(31) fail \equiv not succeed

One immediate advantage of such an analysis is that only one set of meaning postulates is needed, namely the pair in (24). On the other hand, there is the apparent problem that most of the verbs in (27) do not have any implicative positive counterpart. What, for instance, would be the positive counterpart of avoid?

At this time, I do not know of any decisive argument for choosing between the two alternative analyses that are available for negative implicatives.

2.4. SPECIAL CASES. In addition to the verbs listed in (14) and (27), there are of course many other implicative verbs. After one becomes aware of their existence, they are not hard to catch. There are some that are especially interesting. For instance, the words true and false, at least in their everyday sense, are implicative. They would, in fact, be the best example to use, if one wanted to argue that negative implicatives are to be defined in terms of positive ones. Nobody but a three-valued logician would refuse to accept the word false as the equivalent of not true. Another implicative word is the noun fact, which is not factive, as one might expect from the name. For that reason, it may be appropriate at this point to sound a warning and say that the verb imply, in turn, is not implicative. On one hand, it is a factive verb; on the other hand, it may also be a member of another category that we have not discussed yet: the if-verbs.

3. IF-VERBS AND ONLY-IF VERBS. The next two classes of verbs also give rise to implicative relations, although in a less perfect fashion than implicative verbs proper. What is common to both of these types is a kind of asymmetry between negative and affirmative sentences, so that the implication holds only in one of them. It appears to me that these verbs are associated with only one of the two meaning postulates in (24). Verbs of one group express a sufficient condition for the truth of the complement. For that reason - and for the sake of brevity - I refer to them as 'if-verbs'. Verbs in the other group express a necessary condition; they are the 'only-if-verbs'. Later on, I will sometimes refer to if-verbs and only-if-verbs jointly as 'one-way implicatives' in order to distinguish them from 'two-way implicatives' discussed above, that is, from verbs which yield an implication both in negative and in affirmative assertions.

3.1. IF-VERBS. The set of if-verbs includes those in (32).

(32) IF-VERBS:

cause	make sure	?	$\left(\begin{array}{ll} \text{certain} & \text{mean} \\ & \text{imply} \\ & \text{indicate} \\ \text{prove} & \text{show} \end{array} \right)$
make	bring about		
have	see to it		
force			

If one of these verbs appears as the main verb of an affirmative assertion, the complement is implied to be true. For instance, consider the examples in (33a).

- (33) (a) John $\left\{ \begin{array}{l} \text{forced} \\ \text{made} \\ \text{caused} \end{array} \right\}$ Mary to stay home.
- (b) John $\left\{ \begin{array}{l} \text{ordered} \\ \text{asked} \\ \text{advised} \end{array} \right\}$ Mary to stay home.

In all of the a-sentences, the speaker is committed to the belief that Mary stayed home. It would not be honest to assert

any of the sentences in (33a) if one thought otherwise. This fact distinguishes the verbs in (33a) from such syntactically very similar verbs as those in (33b). It is clear that none of the sentences in (33b) has a definite implication one way or the other.

On the other hand, in negative assertions, the difference between if-verbs and those in (33b) disappears entirely. In (34), force and order are just alike; both are equally non-committal with respect to the complement sentence.

- (34) (a) John did not force Mary to stay home.
 (b) John did not order Mary to stay home.
 (c) ... {and she didn't.
 but she stayed home anyway.}

As you can easily observe, (34c) is an acceptable continuation for both of the preceding sentences. This fact indicates that, although the verb force expresses a sufficient condition for the truth of the complement sentence, it does not express a necessary condition. We can only assign to it the first of the two meaning postulates in (24), namely

- (24a) $v(S) \supset S$ 'v(S) is a sufficient condition for S'.

Thus far I have only discussed if-verbs which take infinitive complements. But in general there appears to be no connection between the semantic properties of a verb and the syntactic type of complement clause it takes. Just as there are factive verbs with infinitive complements, such as wise and proud, there are also if-verbs which take that-complements; for example, bring about, see to it, and make sure. That these verbs really are if-verbs and not factives can be shown by pointing out that (35) can be asked felicitously by someone who does not know whether Mary got what she wanted.

- (35) Did Bill see to it that Mary got what she wanted?

Furthermore, an affirmative answer commits you to the claim that Mary actually got what she wanted; a negative answer is non-committal in this respect.

It is interesting to notice that all the clear if-verbs seem to be, in some intuitive sense, causative verbs. It would be very interesting to find some clear cases of non-causative if-verbs, but all the likely candidates that I have come across appear to involve some additional complications. For example, consider the word certain. There is no doubt that certain is an if-verb in constructions like (36a).

- (36) (a) It is certain that Sheila left with Max.
 (b) Bill is certain that Sheila left with Max.

Surely, it would be dishonest to say (36a) if you did not believe that Sheila left with Max. But it is also clear that certain is not an if-verb in (36b). It seems likely that, in addition to the complement clause, the verb certain always involves another underlying noun phrase, in Fillmore's terms, an 'experiencer'.¹¹ This noun phrase may remain unexpressed if it is identical with the speaker, as in (36a). The verb certain does not count as an if-verb unless the experiencer and the speaker are the same person.

The same problem shows up in verbs like mean and imply, as you can observe from the examples in (37).

- (37) (a) That the grass is wet implies that it has
 been raining.
 (b) For Bill, it means that somebody has watered
 the lawn.

In (37a), the speaker commits himself to the view that it has been raining. But (37b), where the experiencer is not identical with the speaker, is non-committal with regard to the complement. Another fact about these verbs is that, as far as the subject

complement is concerned, they are factive. (37a) and (37b) both presuppose that the grass is wet. Because of these complications, it is not clear whether these verbs should really be regarded as if-verbs at all.

Another interesting case is the verb prove. Unlike the verbs just mentioned, prove meets the criteria for if-verbs no matter who the 'experiencer' is. All of the examples in (38) imply the truth of the complement.

- (38) (a) Bill proved to me that Max was a liar.
 (b) Bill proved to Sally that Max was a liar.
 (c) That there is no money in the bag proves that Max is a liar.

On the other hand, the corresponding negative assertions are non-committal.

- (39) That there is no money in the bag doesn't prove that Max is a liar; perhaps he is, perhaps he isn't.

As far as these data are concerned, there is no reason not to consider prove as an if-verb.

However, it is also possible to account for just the same facts by a more complex analysis of prove. Let us assume that prove is associated with the meaning postulate in (40), in which the consequent consists of a causative sentence with a factive complement.

- (40) $\text{prove}(x, y, S) \supset \text{cause}(x, \text{know}(y, S))$

The fact that all the examples in (38) imply their complement can now be explained by the combined effect of cause and know. For example, given the meaning postulate in (40), (38b) implies (41a), which in turn implies (41b). The latter sentence has a factive predicate; therefore, it presupposes (41c), which is the desired inference.

- (41) (a) Bill caused Sally to know that Max was a liar.
 (b) Sally knew that Max was a liar.
 (c) Max was a liar.

On the other hand, the fact that (39) is non-committal with respect to (41c) is explained by the fact that, since cause yields no implication in a negative assertion, one cannot infer from (39) either that I know Max to be a liar or that I don't know that he is.

The same type of analysis can also be applied to verbs like indicate, show, etc. Assuming that such verbs are analyzed roughly as in (42), we can explain some of the puzzling facts mentioned earlier.

- (42) $\text{indicate}(x, y, S) \supset \text{cause}(x, \text{believe}(y, S))$

For example, we have an explanation for the fact that only the first of the following two examples commits the speaker to the complement sentence.

- (43) (a) That there is no money in the bag indicates
 to me that Max is a liar. (*But I don't
 think that he is.)
 (b) That there is no money in the bag indicates
 to Sally that Max is a liar. (But I don't
 think that he is.)

The fact that, in (43), the identity of the 'experiencer' determines whether or not the implication holds can be attributed to the fact that the complement of cause in (42) contains a non-factive verb. For this reason, (43b) only implies that Sally believes Max to be a liar; it is non-committal as far as the speaker is concerned.

3.11. NEGATIVE IF-VERBS. There is also a class of negative if-verbs, which includes the verbs listed in (44).

- (44) NEGATIVE IF-VERBS: prevent discourage
 dissuade
 keep (from)

Like their positive classmates, negative if-verbs carry along a commitment with regard to the complement in affirmative assertions. The difference is that the complement is implied to be false. For example, (45a) definitely implies that Mary did not leave.

- (45) (a) John prevented Mary from leaving.
 (b) ...*but she left anyway.

On the other hand, a negative assertion such as (46a) is non-committal. It is compatible with either one of the two continuations in (46b). It is this fact which distinguishes prevent from avoid and other such two-way implicatives listed in (27). They are committal even in negative assertions.

- (46) (a) John didn't prevent Mary from leaving.
 (b) ... {and she left.
 {but she chose not to leave.}}

Negative if-verbs bring up the same problem as negative implicatives. In principle, there are three ways to account for their negative properties. One way is to postulate for them the first of the two meaning rules in (30):

- (30a) $v(S) \supset \sim S$ 'v(S) is a sufficient condition
 for $\sim S$ '.

The other possibility is by way of lexical insertion rules that replace some piece of underlying syntactic structure including a negation marker by one of the verbs in (44). This alternative has been proposed by George Lakoff (1969). It is easy to see, for instance, that we could account for the negative implication of discourage by defining it as in (47a).

- (47) (a) discourage \equiv cause not to have courage
 (b) keep \equiv cause not to be able

On the other hand, it is a little harder to see what the underlying structure of keep might be. (47b) is an educated guess. Of course, it remains to be shown that the logical properties of keep really correspond to those of the complex predicate cause not to be able. That this is really the case will hopefully become clear later on when we discuss the semantics of be able and other 'only-if-verbs'.

The third possible way to account for negative if-verbs is the same that was already suggested in connection with prove and indicate: setting up new meaning postulates. Obviously, these meaning postulates would be similar to Lakoff's lexical insertion rules. Instead of having a rule for replacing the structure cause not to be able with the single lexical item keep, one would set up a meaning postulate such as (47b*), which allows one to derive the former from the latter as a logical inference.

$$(47b^*) \quad \text{keep}(x, y, S) \supset \text{cause}(x, \neg \text{able}(y, S))$$

It is doubtful whether there is any conclusive argument for choosing between the last two alternatives. However, note that (47b*) makes a weaker claim than its predecessor. Unlike a Lakoff-type insertion rule, it is not open to objections which are based on the claim that the transformationally inserted lexical item is not really synonymous with its supposed paraphrase.

Instead of trying to settle the issue here, I will simply assume that negative if-verbs are associated with the meaning postulate (30a), which is also shared by avoid and other similar two-way implicatives.

3.12. OTHER IMPLICIT CAUSATIVES. One interesting side result from the study of if-verbs is that it lends some new support to the so-called 'causative analysis' of verbs like kill and break. James D. McCawley (1969) and others have proposed that such verbs should not be treated as unanalyzed lexical items in underlying syntactic representations. Instead, they should be

inserted transformationally by a rule that replaces a subtree in which cause is the topmost predicate. According to this view, the underlying structure of kill is roughly as in (48).

(48) $\text{kill} = \text{cause to become not alive}$

Since cause is an if-verb, it follows from this analysis that kill should also belong to this semantic category. As the following example shows, this prediction seems to be in agreement with our intuitive judgements. An affirmative assertion with kill as predicate implies that the person referred to by the object NP dies (i.e. 'becomes not alive'). Thus (49a) implies (49b).

- (49) (a) John killed Harry.
 (b) Harry died.
 (c) John didn't kill Harry.

A negative assertion, such as (49c), is non-committal in this respect. (49c) is compatible with the belief that Harry is still alive, or with the belief that Harry is dead but somebody else killed him. The causative analysis of kill, with no further assumptions, correctly explains the semantic relations between the three sentences in (49). Again, if it should become impossible to maintain the view that kill is introduced transformationally, there will have to be a corresponding meaning postulate, such as (48*).

(48*) $\text{kill}(x, y) \supset \text{cause}(x, \text{become}(\neg \text{alive}(y)))$

3.2. ONLY IF-VERBS. The second major group of one-way implicatives that deserves our attention are the only-if-verbs, of which a sample is given in (50).

(50) ONLY-IF-VERBS:

can	have (the) {	time
able		opportunity
possible		patience
be in the position		courage

If one of these verbs appears as the main verb of a negative assertion, the complement is implied to be false, as shown by

the examples in (51).

- (51) (a) Sebastian did not have an opportunity to
leave the country.
(b) Sebastian was not able to leave the country.
(c) ...*but he left anyway.

In (51) and (51b), the speaker is committed to the view that Sebastian did not leave. It would be contradictory to continue either sentence with (51c). This fact indicates that the verbs in (50) express a necessary condition for the truth of the complement. That is, they are associated with the second meaning postulate in (24), namely

- (24b) $\neg v(S) \supset \neg S$ 'v(S) is a necessary condition for S'.

Given this meaning postulate, we can infer from a negative assertion like (51a) and (51b) that the complement is implied to be false.

In the corresponding affirmative assertions, however, there is no definite implication one way or the other. The two examples in (52) are both compatible with the continuation in (46c).

- (52) (a) Sebastian had an opportunity to leave the country.
(b) Sebastian was able to leave the country.
(c) ... but he chose not to do so.

Therefore, the verbs in (50) are not two-way implicatives; they do not express a sufficient condition for the truth of the complement.

It is perhaps worth pointing out that there are at least three semantically different groups of predicates that all appear in the same surface construction, have the X (to). Some of them are full two-way implicatives like have the foresight and have the misfortune, which we encountered in (14); those in (50) are only one-way implicatives. The third class consists of predicates which do not carry along any implication at all with respect to the complement sentence. A sample of them is given in (53).

- (53) $\left\{ \begin{array}{l} \text{right} \\ \text{authority} \\ \text{permission} \\ \text{orders} \end{array} \right\}$
 have (the)

It is easy to see that a negative assertion with any of these verbs as predicate is non-committal. Unlike the similar examples in (51), (54) leaves open the possibility that Sebastian may have left anyway.

- (54) Sebastian did not have a permission to leave
 the country.

3.21. NEGATIVE ONLY-IF-VERBS. Since there are both negative two-way implicatives and negative if-verbs, one expects to find some negative only-if-verbs as well. A verb of this sort would be like be able and other positive only-if-verbs in the respect that it would yield a definite implication only in negative assertions. However, the implication must be of the opposite kind, that is, a positive implication. These verbs would be associated with the second meaning postulate in (30), namely

- (30b) $\neg v(S) \supset S$ 'v(S) is a necessary condition
 for $\neg S$ '.

On the other hand, affirmative assertions with such a verb as predicate should be non-committal.

The class of verbs which have the desired properties appears very small. The only verb I know of which certainly is a negative only-if-verb is the word hesitate.¹² Consider the following example.

- (55) (a) Bill did no hesitate to call him a liar.
 (b) Bill called him a liar.

Whoever asserts (55a) commits himself to (55b). However, the corresponding affirmative assertion, (56a), is non-committal. It is compatible with either one of the two continuations in (56b).

(56) (a) Bill hesitated to call him a liar.

(b) ... {Therefore, he didn't say anything.
but his conscience forced him to do so.}

That is, hesitate is not a two-way implicative like avoid.

There is no obvious reason why hesitate should be the only verb of its kind, but thus far I have not found any other negative only-if-verbs.

Note that hesitate and prevent, which is a negative if-verb, both share one of the two meaning postulates in (30), which jointly account for the semantics of two-way implicatives such as avoid. These three verbs stand in the same relation to each other as their corresponding positive counterparts be able, cause, and manage, which share the meaning postulates in (24). As we mentioned above, it may be possible to eliminate the class of negative if-verbs, such as prevent, with the help of their positive classmates by regarding them as replacements for structures like cause not to be able. If this method were applicable to all negative implicatives, there would be no need for the second pair of meaning postulates in (30). However, it is doubtful whether verbs like avoid and hesitate can be lexically decomposed in a similar manner. Therefore, I will assume for the time being that the two sets of meaning postulates, (24) and (30), are both needed.

4. APPLICATIONS. I have now introduced six categories of implicative verbs: two types of two-way implicatives and four types of one-way implicatives. Most of the examples thus far have been very simple sentences with no more than one level of embedding. It is now time to look at some more complicated cases, in which verbs of different types alternate with negation in the same complex sentence. We should check that the semantic relations predicted by our analysis continue to agree with our intuitive judgements. Consider first the example in (57).

- (57) (a) Bill saw to it that the dog did not have
an opportunity to run away.
(b) The dog did not have an opportunity to
run away.
(c) The dog did not run away.

Since (57a) is an affirmative assertion and has an if-verb as predicate, it implies (57b). This is a negative sentence with an only-if-predicate; therefore, it implies the negation of its own complement, which is (57c). Thus there is a chain of implications from (57a) to (57c). Since the notion 'implies' obviously is a transitive relation, (57a) should imply that the dog did not run away. Now, look at another configuration of the same verbs in (58).

- (58) (a) Bill had an opportunity to see to it that
the dog did not run away.
(b) Bill saw to it that the dog did not run away.
(c) The dog did not run away.

Since have an opportunity is an only-if-predicate, although (58a) is an affirmative assertion, it does not imply the truth of its complement sentence, which is (58b). If (58b) were itself implied to be true, it would in turn imply (58c). But since (58b) is not implied by (58a), there is no chain of implications that would link (58a) with its lowest embedded sentence. Therefore, (58a) should not commit the speaker to any view whatever about the dog. It seems clear that the predicted semantic relations in these and other similar cases turn out to match our intuitive judgements.

Incidentally, note that the example in (59) carries along the same implication as (57a).

- (59) John prevented the dog from running away.

Note also that the negations of (57a) and (59) are equally non-committal with regard to the truth of the complement.

Negative if-verbs, such as prevent, are in this respect equivalent to the configuration: if-verb ... negation ... only-if-verb. It is this fact which makes it possible to propose that they be introduced by a transformation.

As a final example, consider the sentence in (60).

- (60) Bill did not have the foresight not to force
Mary to prevent Sheila from having an
opportunity to try that new detergent.

The question is whether (60) is non-committal with respect to the truth of its lowest embedded clause or whether one is justified in inferring from it that Sheila either tried or did not try the new detergent. Although most people at first do not feel sure one way or the other, it does not take long to discover that (60) must mean that she did not try it. We can show this formally in the following way. Let us represent (60) schematically as (61).¹³

$$(61) \quad \sim V_1 (\sim V_2 (V_3 (V_4 (S)))))$$

Where V_1 = have the foresight
[two-way implicative]

V_2 = force [if-verb]

V_3 = prevent [negative if-verb]

V_4 = have an opportunity [only-if-verb]

S = Sheila tried that new detergent.

Assuming that the verbs in question have the semantic properties that we have assigned to them, it can be shown that (61) yields the desired inference. In the following, the number on the right of each line refers to the meaning postulate that was used in deriving that line from the preceding one.

$$(62) \quad (a) \quad \sim V_1 (\sim V_2 (V_3 (V_4 (S))))) \quad [= (61)]$$

$$(b) \quad \sim \sim V_2 (V_3 (V_4 (S))) \quad - (24b)$$

$$(c) \quad V_2 (V_3 (V_4 (S))) \quad - \text{Law of Double Negation}$$

$$(d) \quad V_3 (V_4 (S)) \quad - (24a)$$

(e) $\sim V_4$ (S) - (30a)

(f) $\sim S$ - (24b)

The last line of (62) indicates that, according to the proposed analysis, (60) implies (63).

(63) Sheila did not try that new detergent.

The present example may well be too complicated for some speakers to understand. However, it seems that, as far as people have any intuitions at all about its meaning, their judgements support the proposed analysis.

5. INVITED INFERENCES. There are certain important facts that have not yet been accounted for. Consider the example in (64a).

(64) (a) John's wooden leg didn't keep him from
dancing with Mary.

(b) John danced with Mary.

If one reads (64a) in isolation without thinking too much about it, one is very likely to get the impression that John danced with Mary, in spite of his wooden leg. However, a more careful analysis of (64a) shows immediately that this sentence does not imply (64b). As a negative if-verb, keep (from) should yield an inference only in affirmative assertions. Since (64a) is a negative assertion, it should be non-committal, as far as (64b) is concerned. This is certainly not a false prediction, as shown by the fact that (64a) can, without any contradiction, be embedded into a context where it is made clear that John did not dance with Mary. For example, (64a) can be expanded to (65).

(65) John's wooden leg didn't keep him from dancing
with Mary, but her husband did.

Nevertheless, in the absence of any contrary evidence, (64a) seems to suggest that John danced with Mary.

The following example is similar. Since force is an if-verb and it occurs here in a negative assertion, (66a) should be non-committal with respect to (66b).

- (66) (a) Bill did not force Mary to change her mind.
 (b) Mary did not change her mind.

However, it seems that there is a temptation to conclude (66b) from (66a) if no further information is given.

The same phenomenon shows up with only-if-verbs. If there is no particular reason to believe otherwise, most people will take (67a) to mean that John in fact left early.

- (67) (a) John was able to leave early.
 (b) John left early.

Again, (67a) should be non-committal. Since be able is classified as an only-if-verb, it yields an implication only in a negative assertion. Why should it be that, although (67a) does not logically imply (67b), it nevertheless strongly suggests that (67b) is true? Here, as in the two preceding examples, a one-way implicative predicate invites one to draw a conclusion which would logically follow only from a two-way implicative verb. That is, in concluding (67b) from (67a) one interprets be able as if it were a verb like manage.

It is very likely that this problem is another manifestation of a principle which Michael Geis and Arnold Zwicky (1970) have discussed in connection with conditional sentences. As Geis and Zwicky point out, there is a natural tendency in the human mind to perfect conditionals to biconditionals. Students in an elementary logic course often propose that examples such as (68) are to be formalized as biconditionals rather than conditionals.

- (68) If you mow the lawn, I'll give you five dollars.

Thus, most people feel that the appropriate logical form of statements like (68) is the conjunction of (69a) and (69b).

- (69) (a) $S_1 \supset S_2$
 (b) $\sim S_1 \supset \sim S_2$

This is not quite right since (69a) alone is enough. However,

it is clear that in a great majority of cases where a conditional like (68) is uttered, the corresponding statement of the form (69b) is also tacitly assumed. In natural language, (68) suggests rather strongly that, if you don't mow the lawn, I won't pay you five dollars. What would be the point in stating a condition which was not a necessary condition for the truth of the consequent? According to the principle proposed by Geis and Zwicky, any assertion of the form (69a) suggests, or "invites the inference", that the corresponding statement of the form (69b) is also true. However, this is only an "invited inference" and the speaker may indicate that it does not hold without thereby contradicting himself. This is the case in (70).

(70) If you mow my lawn, I'll give you five dollars, but
I'll give you five dollars even if you don't.

The only thing that is odd about (70) is that it makes one wonder why anyone would bother to set a condition which is not a necessary one. (70) may be pointless but it is not contradictory.

Similarly, we can say that, although an if-verb, such as force in the example (66a), strictly speaking is associated only with the meaning postulate (24a) $v(S) \supset S$, it also "invites" the corresponding negative meaning postulate (24b) $\sim v(S) \supset \sim S$. This explains why (66a) suggests (66b), although it does not actually imply (66b). On the other hand, an only-if-verb like be able, which is associated with the meaning postulate (24b) $\sim v(S) \supset \sim S$, "invites" (24a) $v(S) \supset S$. This is the reason for the temptation to conclude (67b) from (67a). Something like the Geis-Zwicky principle is clearly involved in the general tendency to understand one-way implicatives as full two-way implicatives, unless the context makes it necessary to interpret them more strictly.¹⁴

6. SUMMARY. The following chart is a review of the semantic classes of verbs which have been discussed in this paper. The chart indicates under what circumstances a main sentence implies the complement or its negation in each of the seven categories. The '+' sign is used when a sentence is to be regarded as true; '-' is a symbol for a false sentence. The '+/-' sign means that a sentence may either be regarded as true or regarded as false. The variable ' α ' may take either + or - as its value. It is used to indicate that the complement has the same truth value as the main sentence. A complement which has the opposite truth value with respect to the main sentence is marked with '- α '.

(72)

CLASS	MAIN SENTENCE	COMPLEMENT SENTENCE	EXAMPLE
Factive	+/-	+	regret
Implicative	α	α	manage
Negative Implicative	α	- α	avoid
<u>If-Verb</u>	+	+	cause
Negative <u>If-Verb</u>	+	-	prevent
<u>Only-If-Verb</u>	-	-	be able
Negative <u>Only-If-Verb</u>	-	+	hesitate

From the first column of features one can see under what conditions the main sentence carries along a commitment with respect to the truth or falsity of its complement. For example, it shows that a sentence with a negative if-verb as predicate just in case it is to be regarded as true. The second feature column indicates what is implied. In the case of negative if-verb the complement is implied to be false. On the other hand, sentences with an only-if-verb as predicate carry along an implication with respect to the complement only if they are to be regarded as false. Full two-way implicatives such as manage and avoid, yield an implication both in affirmative and negative assertions and the implication is affirm-

ative or negative depending on the main sentence and the type of the verb.

Finally, the next chart gives a sample verb from each category of implicative verbs and the meaning postulate(s) it is associated with.

(72)

(24)	(a)	$v(S) \supset S$	cause	manage
	(b)	$\sim v(S) \supset \sim S$	be able	
(30)	(a)	$v(S) \supset \sim S$	prevent	avoid
	(b)	$\sim v(S) \supset S$	hesitate	

It is evident that logical relations between main sentences and their complements are of great significance in any system of automatic data processing that depends on natural language. For this reason, the systematic study of such relations, of which this paper is an example, will certainly have a great practical value, in addition to what it may contribute to the theory of the semantics of natural languages. It also seems to be the case that logical relations are also involved in a number of problems that have sometimes been regarded as purely syntactic. Two well-known examples of such phenomena are the constraints on coreference (Karttunen 1969) and the problem of polarity-sensitive lexical items (Baker 1970).

FOOTNOTES

¹This report is an extended version of a paper that was originally written under the auspices of the 1970 MSSB Advanced Research Seminar in Mathematical Linguistics and presented at the Annual Meeting of the Association for Computational Linguistics, July 23, 1970, in Columbus, Ohio.

²The following are some of the relevant papers: Karttunen 1970a and 1970b, Kiparsky 1968, Lakoff 1969 and 1970, Morgan 1969.

³A summary of various arguments against Rosenbaum is presented in the Final Report of the UCLA Syntax Project (UESP Vol. II).

⁴In their paper, the Kiparskys distinguished between 'semantically factive' and 'syntactically factive'. The reason for this distinction was that a few words, e.g. know and realize, which would otherwise qualify failed to meet some of the syntactic criteria the authors had established for factivity. I will use the term 'factive' as equivalent to their 'semantically factive'. Also, I do not see any reason to assume, as they did, that surface complements of factive verbs are commanded by the noun fact in the deep structure.

⁵This particular definition is due to Van Fraassen 1968.

⁶Currently, there are at least three different locutions in use; sometimes they can all be found in the same article:

- (i) [in uttering the sentence X] 'the speaker presupposes that ...'
- (ii) 'the verb X presupposes that ...'
- (iii) 'the sentence X presupposes that ...'

Actually, (i) and (ii) seem to be some sort of shorthand formulas for longer expressions that involve (iii). For example, (ii) is generally intended to mean something like 'any sentence with the verb X as predicate presupposes that ...'. It need not be the case that there is really a genuine confusion in the mind of the users about whether 'presupposition' is an act by the speaker, a relation between a verb and its complement, or a relation between two propositions. However, the indiscriminate usage of (i-iii) is likely to breed such confusion in the minds of others.

⁷The notion of 'possible world' is borrowed from modal logicians; e.g. see Hintikka 1967.

⁸Van Fraassen 1968 gives the following definition for 'necessitation':

P necessitates Q if and only if, whenever P is true, Q is also true.

This relation has also been called 'semantic entailment'.

⁹These are equivalent concepts for some writers. For example, Irene Bellert (1969) explicitly defines the semantic representation of an utterance as the set of consequences which can be derived from it.

¹⁰The notion of 'meaning postulate' comes from Rudolf Carnap (1947). As he uses the term, a meaning postulate is a sentence of a formalized language which expresses a relation that holds between some primitive predicates of that language. For example, if the analyticity of the English sentence "If Sheila is a spinster, then she is not married" is to be preserved in translating it into a formal language, the language has to include the statement

(x) spinster(x) \supset \neg married(x)

as a meaning postulate.

In our case, we need meaning postulates to account for logical relations between main sentences and their complements.

¹¹Verbs of this kind were discussed by Charles Fillmore in his lectures at the 1970 Linguistic Institute. The 'Experiencer' case together with another new case, 'Goal', have replaced what Fillmore used to call the 'Dative' case in earlier presentations of his case theory.

¹²The verb be afraid comes close to being a negative only-if-verb. Although one can argue that

(i) The princess wasn't afraid to kiss the frog.
does not actually imply that she kissed him, the suggestion that she did is quite strong unless something is said to indicate otherwise.

Another possible candidate is help in the construction can't help ...ing. If help were a negative only-if-verb, (ii) should imply (iii) and (iv) ought to be non-committal.

(ii) The frog couldn't help feeling happy.

(iii) The frog felt happy.

(iv) *The frog helped feeling happy.

Indeed, (ii) implies (iii). But help could also be a two-way implicative like avoid, in which case (iv) ought to imply that the frog didn't feel happy. Since (iv) is ungrammatical, it is hard to decide one way or the other.

¹³For the sake of simplicity, I treat all the verbs in (60) as if they were one-place predicates. As throughout this paper, I

also ignore the problem how the correct tense is assigned to implied sentences.

¹⁴This observation may also explain the alternation between and and but in certain cases. For example, consider the example (46a) with its two alternative continuations. Since prevent is a negative if-verb, (46a) suggests, but does not imply, that Mary left. We get but instead of and as the conjunctive particle if the conjoined sentence cancels the suggested inference.

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The Feasibility of High Quality Machine Translation

by

John Lyons

Linguistics Research Center

The University of Texas at Austin

THE FEASIBILITY OF HIGH QUALITY MACHINE TRANSLATION

John Lyons

This brief memorandum is intended as a contribution to the project entitled "Theoretical Study Effort of High Quality Translation" being conducted at the Linguistics Research Center (LRC) under Contract F30602-70-C-0129. It is a simple restatement of views expressed during formal and informal discussions in which I have taken part at LRC in September and October 1970.

The aim of the project is to evaluate the developments that have taken place in linguistics and computer science in the last five or six years in relation to the feasibility of fully automatic high quality translation (FAHQT). Not having any specialist knowledge of computer hardware or software, I will confine myself to the linguistic aspects of the problem. I would, however, point out that the doubts expressed by such scholars as Bar-Hillel about the feasibility of FAHQT in the early part of the 1960's had very little to do with the speed of operation and capacity of computers that were available at the time. Their critical attitude towards the feasibility of FAHQT was determined far more by their increased appreciation of the theoretical complexity (and perhaps ultimate impossibility) of specifying algorithmic procedures for syntactic analysis and for the resolution of semantic ambiguities. Advances made

in computer capabilities over the last decade would not therefore seem to be very relevant to an appraisal of the validity of their statements in the light of present knowledge (Advances in computer capabilities may of course be relevant to the pursuit of some less ambitious system of MT, to which I refer below.)

Let me begin by making the obvious point that "feasibility" presupposes "possibility." Is FAHQT even possible? This question cannot be answered without first deciding what "high quality" means in this context. Not even the most competent human translators can be relied upon to produce a "perfect" translation of any text submitted to them. Moreover, it is arguable that in certain styles or certain subjects of discourse "perfect" translation is impossible in principle. A fortiori, it is not feasible. The point I have just made would be accepted by some linguists and rejected by others; and I am conscious of the fact that my attitude is here in conflict with that of many semanticists, whose work over the last few years has been inspired by their commitment to the possibility of describing the semantic structure of all languages in terms of a set of universal semantic "features" (or "atomic concepts"). I give it as my opinion that, at the present time, the predispositions of certain scholars in favour of universal semantics are methodological or philosophical in character, and cannot yet be justified by any convincing appeal to empirical evidence. The fact that many influential linguists have adopted the "universalist" position in recent years is, I believe, irrelevant to our reappraisal of the feasibility of MT.

Bar-Hillel has recently drawn attention to the necessity of making the notion of "quality" relative to the purpose for

which a translation is intended. I would endorse his pragmatic attitude to this question; and I would make two further comments in the same pragmatic spirit. One kind of "quality" (in a translation system, rather than in a translation) might relate to the range, in style and content, of the material for which the system is designed. It would be my assumption that any MT system that is really intended to be at all viable will deliberately restrict the range of the input that it will accept. It may be impossible to specify any lexical item (or any particular sense of a lexical item) or any construction such that one can be certain it will never occur in "scientific English" (or whatever the source language is). But some restriction of style and content is essential.

A second kind of "quality" might relate to the incidence of failures to translate or of mistranslations. The difficulty of foreseeing all possible cases of this kind and of programming for the recognition of contextual cues to the resolution of ambiguity (granted that the text will always contain determinable cues) was one of the principal difficulties referred to by Bar-Hillel and other critics of FAHQT in the early 1960's. None of the recent work in syntax and semantics would lead me to believe that the prospects for FAHQT have in this respect improved. At the present time, it would seem to be impossible to design an MT system that is absolutely "fail-safe"; and it may very well be the case that this goal will never be achieved. Just how serious a problem this is in practice can hardly be decided on theoretical grounds. It may be that texts of the kind that are to be translated by the system can be assumed to contain not more than a tolerable number of phrases and sentences that are bound to be left untranslated or (what is more serious) wrongly translated. I have no opinion on this question.

Neither of the two points I have just made is of course original. I am concerned merely to reaffirm their continued validity.

Let me now turn to the more specific questions raised by the present "feasibility" study. Much of the earlier work in the field of MT was based on a totally inadequate conception of grammar. Considerable advances in syntax have undoubtedly been made over the last decade. It is therefore reasonable to enquire whether the models of syntax that have been proposed recently provide any surer basis for MT than did the earlier, now obsolete, models. In one sense, the answer to this question must be positive. By this statement I do not intend to imply that there is now some possibility of an algorithmic determination of the syntactic structure of input sentences, although there appeared to be no such possibility before. I do not believe that the situation has changed very much in this respect. What I mean is simply that linguists designing computational procedures for syntactic analysis now have a better idea of the range of phenomena that they need to take account of than they had a decade or so ago. Much of the current work in syntax, however, would seem to be irrelevant to the problems confronting MT-workers. For example, it is difficult to see how a decision for or against the "lexicalist" position could have any implications for the design of an MT system. Nor is it obvious, in general, that a model of grammar that has been proposed by linguists without reference to the problems of translation and the practicalities of computation should be the best model for MT. We are, in any case, as far from agreement about the formalization of grammar as we ever were, and we may even be further.

One of the more striking developments in linguistics in the last few years has been the increased attention given to

semantics and, more particularly, to the integration of semantics with syntax. Once again, it must be asserted, on any objective assessment of the current state of semantic theory, that such progress as has been made in this field seems to be almost totally irrelevant to the practical problems of MT. I have already alluded to the question of universal semantic "features" (and my own scepticism on this score). This is but one of the many points of controversy among semanticists at the present time. Others have to do with the degree to which the non-occurrence or abnormality of certain combinations of lexical items is a function of the meaning of those lexical items and the degree to which it depends upon the belief-systems of speakers of the language. In the case of both of these questions (and of a number of others that are currently being discussed), decisions we might come to independently of computational considerations seem to me to carry no implications at all for the design of a working MT system. It might well be that "real world" information relevant to the resolution of certain foreseeable ambiguities in the source language would be more conveniently coded in the lexicon in an MT system. If so, that is a sufficient justification of the procedure. Whether the semanticist would agree that "real world" information is rightly regarded as part of the meaning of lexical items on theoretical grounds is, in this context, of no consequence.

To summarize. If by FAHQT we mean a "fail-safe" system which accepts for translation texts varying widely in content and style, then there is no reason for us to be any more optimistic about the feasibility, or indeed possibility, of this than such critics as Bar-Hillel were some years ago. I would not exclude the possibility of

constructing a practical system for translating scientific texts from one language to another to some lower, but perhaps tolerable, degree of accuracy. Whether the construction of such a system is feasible or not, I cannot say. But if it is feasible, my feeling is that it will neither contribute very directly to, nor depend very directly upon, advances in linguistic theory.

Philosophy of Language and the Feasibility of MT:
A Position Paper

by

Norman M. Martin

Linguistics Research Center
The University of Texas at Austin

Philosophy of Language and the Feasibility of MT: A Position Paper

If this contribution to the project is to be considered a kind of crucial insight to be provided by the present author representing philosophy to the question of the feasibility of machine translation, it will, I fear, be a disappointment. The most important reason for this is, I think, the perhaps embarrassing, though by no means obvious, consideration that the concerns of philosophers with the problems of language intersect with the issues important to machine translation only tangentially. In stating this position, I indicated that this relative lack of relevance has not always been obvious. Subsequently in this essay, I shall be able to illustrate this in particular cases. For the present, I think it will suffice to indicate the illusion of greater relevance than I believe in fact exists comes about from the habit of philosophers generally to speak in terms of extreme generality and at least partly as a result, to avoid consideration of those little pragmatic factors which usually distinguish success from failure. A successful marriage tends to be for a philosopher, either an arrangement in which some aspects of the relationship are satisfactory, thus making successful virtually all of those that end in divorce, or to be one in which each partner plays his role in an ideal fashion, a view which rules out virtually all existing ones. Since the philosopher usually neglects to make clear the highly systematic character of his terms, one can easily be misled into assigning far greater practical consequences to his conclusions than they warrant.

For openers, one might point to peculiarities of the translation situation which would seem to make machine translation in principle

impossible. If one views the purpose of translation to be the production of a text in the target language which will be of the same approximate length as any arbitrary text of the source language and will share with the source material all features of a semantic and pragmatic character, will inform with respect to the same features and suggest the same features to the same degree, there is every reason to doubt that machine translation is possible. No program, suggested or in project, or any theory of how one might be constructed, has even the remotest hope of accomplishing this. Before however one yields too much to despair because of this, it should be pointed out that this result holds equally well for human "normal" translation as well. The present author is quite familiar with both Dutch and English and has indeed translated material between these languages professionally. The requirement outlined above in this case would however require being able to convey in a few words such subtle cultural features in the Dutch as their peculiar love-dependence-fear relation to the sea, the effects of high population density and the oddities of periods of Frisian cultural dominance and inferiority, to mention but a few. Since these features can scarcely be explained adequately in a full sized book, it follows trivially that short passages dependent on them cannot be translated at all in the intended sense. And this in a pair of languages extremely closely related. The point of this is not of course that translations cannot be done at all, but this particular "strong" sense of translation represents an ideal extreme which can only at times be realized. Now of course for some cases even this extreme can be realized and indeed by computers. The existing program at the Linguistics Research Center when provided with a standard Dutch-English glossary (provided this contains standard mathematical terms)

and even a relatively partial syntax would have no difficulty translating in this "strong" sense page 7 of volume IV of the ENSIE encyclopedia (this is a portion of an article on set theory).

The difficulty with much, perhaps most, talk concerning machine translation by philosophers (and not only philosophers) is that so much of it is devoted to the problem "in principle." Thus Herbert Dreyfuss, holding phenomenological views of human intelligence, argues from the intentional nature of human language to the impossibility of translation by machine. Here our examples are, I think, instructive. In the phenomenological sense "intentional" phenomena covers a large range of psychological data, including on one hand processes known to be strongly rule governed to processes whose nature we have difficulty in formulating even for purposes of identification. As a result the encyclopedia page cited above is as intentional as the most difficult culture-specific poem. Yet as I indicated above, the problem of satisfactory machine translation of the page in question may safely be regarded as solved. It follows then that the argument establishes the untranslatability by machine only of those kinds of linguistic material whose intentional character cannot be approximated by a machine, from which follows that

- (1) Not all linguistic material can be translated by machine--
a conclusion consideration of human translation causes us to
be willing to agree to even without the argument, for reasons
we have cited, and
- (2) Those passages which cannot be machine processed cannot be
translated by a machine.

On the other hand we have arguments based on a very selected corpus of sentences combined with a limited glossary which, by identifying

the familiar with the universal create the impression that relatively simple grammatical analysis together with a simply structural dictionary will suffice for the task. The impression thereby created is that context dependence is limited to what is involved in transformation grammar and the resulting ambiguities resolvable by dictionary rules of agreement. This attitude is for instance implicit in the discussion by Jerrold Katz. And, indeed, so they are, in a great number of cases. What is ignored here is that this common means of reduction of ambiguity is but one of the linguistic devices for this purpose. Even worse, this view requires that that there be discrete senses of words leaving us in a quandry as to whether e.g. bachelor = unmarried male and bachelor = cheerful fellow constitute one, two, three or perhaps even more senses of bachelor. It does not require much ingenuity to argue for any of the possibilities.

Essentially what I have been arguing here is that what philosophers of language have had to say about the possibility of MT (directly or by implication) are largely or completely irrelevant to the question of the feasibility of MT in the sense in which this question is of importance to MT researchers and users. (A partial exception must here be made with respect to Bar-Hillel, primarily because he has generally been concerned with the pragmatic, rather than the "in principle" questions.)

Now if the argument I have been advancing is correct and we cannot expect solutions of the feasibility problem from the philosophers of language, it does not however follow that these will have no contribution whatever. In a certain sense, the contribution that I foresee does not differ in its most general description from that which one might expect of theoretical linguists, although due in part to differences of professional emphasis, there is reason to suspect that these will differ in

exact content. More specifically:

1. Since there are parts of language for which the MT problem is relatively simple and definitely feasible, it is to devise general description, or models, of these situations and to do so in as general a manner as possible. Some of this process is clearly grammatical and lexical, but at least part of it appears to be the same as, or very similar to, what has been termed logical analysis. In both the linguistic and logical areas, it is likely at this point to appear to the unsophisticated to be simply a matter of description, but in both we have found that the facts, at least as far as they are known, can be described in many ways, some indeed more promising than others. This process consists not infrequently in the embedding of the linguistic phenomena in a larger whole and in many cases can be helpful in pointing out the possibilities of useful "normal forms" for the purpose of representing information within the computer.

2. Since, as we have seen, certain linguistic phenomena make excellent translation extremely difficult and in some cases de facto impossible, whatever may or may not be the case "in principle," relative success in mechanical translation is very likely to depend on our ability to understand what these phenomena are. This is so, not only in allowing us better to estimate what it is simply uneconomic to try and dishonest to promise, but also because it may give us convenient guidance concerning useful modes of man-machine organization. Let me illustrate this. Most MT programs depend critically on a lexicon which in one way or another contains semantical and usage context notes. The normal way in which this information is used is to systematically utilize agreement information together with perhaps some additional information explicitly fed in--e.g.

this is an article on petrology: dialectal readings will be improbable. One kind of application which occurs with some frequency in language use (although certainly more common in verbal than written language) which is usually completely ignored is the use of earlier passages to help indicate the meaning of later ones. In normal use the mechanism is apparently not usually a direct effect linguistic context matter, but rather seems to work by modifying the expectations of the hearer/reader. This observation suggests on one hand the possibility that some improvement in ability to interpret and hence presumably to translate may be achieved by assigning and in some way modifying probabilities of one reading over another. Unfortunately at the present time, our knowledge of anything beyond the general outline of this interpretive process is so slight that it is difficult to even begin to answer the questions that must be posed before we can use it on a machine. For example, presumably if this technique is to be used we need to attach to our glossary initial probabilities of readings. How do we get them? Do we scan a large corpus? Ask specialists? Ask "men on the street"? Once we have them, how strongly should a confirmed "improbable" reading modify the probabilities? Finally, it appears pretty clear that any such modification should degrade to the normal probabilities (assuming we have them) with the passage of time. But how fast should this occur? In short considerations of the phenomenon and its apparent structure tell us in a rough way what we would need to do to implement this and also specifies a large number of difficult problems which would have to be overcome to do this. But there is at least one additional advantage that can be gotten out of this consideration. Suppose we wish to seriously consider having our translation procedure accommodate the feature we have been discussing but are

pessimistic about our ability to easily overcome the difficulties indicated. This raises the question as to whether we might not be able to get part of the advantage with the help of human intervention. If we look into this problem, we can conceive of at least three possibilities. We might as a variant of pre-editing have an expert call out unusual readings in advance. We might have the machine call out alternatives not determined by agreement and dominance rules. Finally, we might have either a lay reader respond to the output indicating which readings appear wrong or an expert reader compare the input and the output. Assuming we wish to explore one of the latter two alternatives, say even the last one, it is clear if we are going to accommodate our phenomena that we will be going into a mode of man-machine cooperation in translation which has rarely been considered. That is, instead of construing the function of the operator as primarily analogous to that of a normal editor, he will, by virtue of the fact that his remarks (to have the effect indicated) must be fed into the computer's lexicon in some appropriate form and modify the computer's, presumably second-pass, output, become part of an iterative loop with the computer.

How practical this alternative may be I would not at the moment presume to guess. It does however illustrate one of the possibilities for further development. In passing it is worth noting that this (in common with several other ideas which I suspect will be worth examining in the next years) represents an abandonment of the picture of MT which has been more or less dominant: namely, the picture of a process in which human participation is limited to the design, but is excluded completely or present only at the fringes of the operation of the system. There is of course no reason to conclude from the obvious desirability all things being equal of such an arrangement to the conclusion that if such a

system either cannot be designed or (more accurately) if designed is only of limited use, that the possibility of computer participation in translation ought to be abandoned completely, any more than the unfeasibility of completely eliminating human interaction on tactical data systems leads to the corresponding conclusion.

In concluding my discussion, it may perhaps be worth while for me to indicate those features of language processing concerning which I believe there to be some reason to hope for some contributions from general or philosophical considerations of language to MT--perhaps it may now or soon be advisable to signify the position I am taking, in this respect in agreement with a growing number of people, among others Bar-Hillel and Kay, by re-christening it as machine assisted translation.

1. I think that there is likely to be some advantages to be gained from systematic work on question answering models, both the logically oriented projects based upon the predicate calculus or combinatory logic and the more linguistically oriented ones.

2. The information incident to the performance of certain types of linguistic acts, most especially those of the type Austin terms illocutionary, frequently provides special uses in the interpretation of utterances. Since certain verbal forms are associated with these, in any event typically (it is much more difficult to argue for invariable connections here), one can see the potential utility of the translation program making systematic use of this. Some of the basic linguistic work incident to this is being pursued. If useful in MT, one would anticipate that it would be so primarily in creating greater flexibility in definition of the relevant context. There are indeed many problems, including the

strong likelihood that illocutionary acts are rather strongly culture dependent, so that it may be that then, for instance may perhaps be no equivalent illocutionary act in a society without feudal antecedents of the giving of ones "parole" or "Ehrenwort". Even this type of situation might however enable (assuming one could find appropriate ways of storing and referring to the information) improved disambiguation, such as perhaps avoiding translating the Dutch "Wees een heer in de verkeer" (a safety slogan meaning "be courteous in traffic") as "Be a man in traffic." In passing let me remark that the implicit identification of illocutionary acts with pure performatives (i.e. locutions which in the first person per se perform the act to which they refer, such as "promise") which plays a strong role in Austin and some of his followers seems to me probably misguided. I note that Alston appears not to do this--and that an enumeration of illocutionary acts is in my view an outcome and not an input of a theory of illocutionary acts, certainly of one likely to be of use.

3. As I indicated above, the phenomenon of use of an expression primarily or exclusively to alter in the succeeding context appears to have some promise for MT (as I indicated above). It should perhaps be remarked that this appears to be closely related in many applications to the disambiguation processes connected with specifying the subject-matter.

4. Finally (for the present purpose), there is the phenomenon in which the hearer (or reader) expects under normal circumstances the speaker to be reasonably attempting to fulfill his apparent purpose--to inform about the matter at hand, to help solve the problem, to induce the behavior he wishes, or the like, as the case may be--and interprets his utterances accordingly and furthermore the speaker relies on the expectation that the hearer will do so. (In a somewhat oversimplified description, Bar-Hillel

has recently referred to this as the requirement of the "good will" of the hearer.) Among other things, this results in the strong tendency to reinterpret apparent tautologies like "men are men" as non-tautological. This is of course related to the phenomenon discussed under item 3. It should be remarked that this phenomenon is by no means limited to the assumption that the speaker will not gratuitously contradict himself--although it includes this--but also that he will on one hand agree with the information both he and the hearer accept as "obvious," but even that unless there is some doubt about it, that he will not state the obvious. Because this extremely great burden of knowledge about the world which this would appear to place on the computer, this phenomenon would appear to rule out MT irretrievably (and, in private conversation, Bar-Hillel has recently expressed himself along these lines to the present author). That the situation is not clearly quite this bleak appears to me to follow from the following considerations. Firstly, the material of primary interest for MT--in particular, scientific articles and the like--may not be quite as open-ended as all that; the example of the encyclopedia article shows in any event that there are times when it is not. Secondly, when the translation occurs between related cultures, the process may frequently have only secondary effects since the interpretive process in one language will then simply parallel that in the other, reinterpreting and disambiguating usually in exactly the same way. Thirdly, this process and the related one referred to under item 3, can not infrequently function to "save" what would otherwise be a poor translation. For example, translating the English "I'm sorry" into Dutch as "het spijt me" (which indicates substantial regret and not mere simple apology) in circumstances of simple apology, usually does not occasion any misunderstanding (since

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Toward a Theory of Computational Linguistics

by

Jacob Mey

Linguistics Research Center

and

Department of Linguistics

The University of Texas at Austin

1. Two Kinds of Models

To begin with, I would like to assert that computational linguistics (henceforth: CL), despite its qualifying adjective, has to do with human behavior, and, in particular, with that subset of human behavioral patterns that we study in linguistics. In other words, the aim of CL as a science is to explain human behavior insofar as it avails itself of the possibilities inherent in man's faculty of speech. In this sense, CL and linguistics proper both pursue the same aim. However, there are differences, as we will see shortly; for the moment, let us just establish that CL can be considered as a subfield of linguistics, and leave the delineation of the boundaries for later.

An important notion in behavioral sciences is that of a model as a set of hypotheses and empirical assumptions leading to certain testable conclusions, called predictions (on this, cf., e.g. Braithwaite 1968; Saumjan 1966). I would like to call this kind of model the descriptive one. "Descriptive" here is not taken in the sense that Chomsky distinguishes descriptive adequacy from explanatory adequacy: indeed, the function of the descriptive model is to explain, as will become clear below. However, there is another respect in which the descriptive model reminds one of some of the characteristics attributed to Chomskyan models: it need not be (and should not be) considered a "faithful" reproduction of reality, in the sense that to each part of the model there corresponds, by some kind of isomorphic mapping, a particular chunk of "real" life. In other words, this descriptive kind of model does not attempt to imitate the behavior of its descriptum.

The other kind of model I propose to call the simulative one. As the name indicates, we are dealing with a conscious effort to picture, point by point, the

activities that we want to describe. Of course, the simulative model, in order to be scientifically interesting, must attempt to explain; a machina loquax, to use Ceccato's expression (1967) is no good if there is a deus in machina. Although the idea of building homunculi, robots and what else they are called is not exactly a new one, the advent of the computer made it possible to conduct these experiments on a hitherto unknown scale, both with regard to dimensions and to exactitude. In fact, one of the popular views of the computer is exactly that: a man-like machine. Interestingly, the fears connected with this kind of image (such as an impending take-over by some super-computer like HAL in the movie "2001") have their counterpart in certain objections that are sometimes voiced against the other kind of model, the descriptive one: namely, that it de-humanizes human activities (such as speech), and establishes a new kind of man, made in the machine's image: machine-like man. Below, in section 3, I will discuss some of the implications of these views for computational linguistics; but first I want to raise the question: what importance do the two kinds of models have for linguistics itself?

2. Competence and Performance

The distinction between competence and performance in linguistics has been belabored often enough to let me squeak by here with a short restatement of Chomsky's remarks in Aspects (1965: 4 et pass.): competence is the speaker's knowledge of a language, performance is what he actually does with his knowledge in a given situation that involves linguistic activity. A theory of competence, Chomsky says, is not a model of the speaker-hearer; according to the distinction made in section 1, above, I would rather say that it is not a simulative model, but a descriptive one. In other words, the model that is a grammar does not attempt to explain linguistic activity on

the part of the speaker or hearer by appealing to direct similarities between that activity and the rules of the grammar. Rather, the activity of the speaker (his performance) is explained by pointing to the fact that the rules give exactly the same result (if they are correct, that is) as does the performance of the speaker-hearer: the set of all possible utterances of a given language.

Although a theory of performance thus is closer to the idea of simulating an actual linguistic situation, it is by no means identical with the simulative model. Rather, simulating actual linguistic activity depends on such a theory for its success; without it, a simulative model will be of little interest to linguists. To take an example: in any concrete linguistic situation there will be a lot of "unexplained" phenomena, such as hemming and hawing, false starts, anacolouths, etc. I feel that Chomsky is wrong in ascribing all of this to what he calls performance: linguistic theory should not account for these aspects of speech (they belong more properly in what one might call "corrective linguistics"). A simulative model wanting to represent this kind of "performance" would be a waste of energy and time.

What, then, is the proper object of a theory of linguistic performance? To understand this question is to answer it: if performance by definition is actual human activity, then linguistic performance is activity exercised by humans in the form of speech acts. In terms of the restriction made in the preceding paragraph, our "ideal" performance is that activity minus irrelevant "noise". Notice that this ideal performance does not coincide with that of Chomsky's "ideal speaker-hearer" of the language: as I understand this person, he is some kind of linguistic Superman (with unlimited memory, boundless embedding facilities, etc.). In other words, Chomsky's "ideal speaker" reflects competence rather than performance (in Chomsky's sense). To take a very

simple example: the set of sentences generated by a grammar is potentially infinite; this is a fact of competence. However, any actual speaker or set of speakers will always generate some finite subset of the set of all possible sentences: a fact of performance. On a more sophisticated level, consider such questions as: why is it the case that regressive embedding beyond a certain bound is unacceptable? Chomsky calls sentences such as The rat the cat the dog chased killed ate the malt "perfectly grammatical" (1963:286); true enough, if one understands by this term: generatable by a competence model. But a performance model would have to incorporate some restrictions by which these "improbable and confusing" sentences (Chomsky, *ibid.*) would be ruled out. Actually, much of the research in the fields of psycho-, socio-, neuro-, etc., linguistics deals with performance; it is my thesis that computational linguistics, too, is a province of the same realm.

3. Competence and Performance in CL

The next question to be answered is: how do these theoretical considerations reflect on past and current work in CL? Until recently, very little attention has been paid to the performance aspect of CL. The only really large-scale computer-aided research in performance has been concentrating on machine translation and related areas. The lack of success that characterized these efforts has been material in turning off research funds as well as researchers. The result has been that CL workers now mainly direct their attention to such questions as: how to implement grammars on the machine; and: how to let the machine take over some of the work that linguists traditionally have done by hand? An example of the first kind is the transformational grammar developed by Friedman c.s. at Ann Arbor, formerly Stanford (1968 et seqq.); work in the second category ranges all the way

from fairly unsophisticated and theoretically uninteresting "book-keeping" and "fact-finding" aids to theoretically motivated work in the development of syntactic and phonological rule testers (e.g., Londe & Schoene 1968; Fraser 1969). Common to this type of research is its ancillary character: these models (descriptive) purport to be an aid in the establishing of a theory of competence. As to performance (and, by inclusion, simulation), it is interesting to note that some of the more worthwhile results of MT research fall in the area of competence, too. I am thinking here of such by-products of MT as context-free and context-sensitive recognition procedures and their theoretical foundations (as explored, e.g. by Kuno, Greibach, Griffiths, Petrick, Peters and Ritchie, and, most recently, Woods (1970)). The results obtained in this area have certainly helped to clarify the theoretical issues involved, and as such, are of great value. But (as competence theory in general) they have not stimulated research or clarified any of the problems in the area of performance (except, of course, indirectly inasmuch as any theoretical development in one sector affects the whole field).

On the other hand, computerized efforts directed at simulating human linguistic performance cannot boast of any great achievements either. The fate of MT may have acted as a deterrent, but cannot be said to be the only reason why theoretical research has shunned, to a large degree, questions of simulation. In linguistics, in particular, the domineering trend of theoretical research was, until recently, to stay clear of what goes on in the speaker-hearer. As I pointed out above, in a sense it is perfectly true that a grammar is not a model of what is going on in the speaker's head; as Chomsky told the world in Syntactic Structures, "a grammar does not tell us how to synthesize a specific utterance; it does not tell us how to analyze a particular given

utterance. In fact, these two tasks...are both outside the scope of grammars..." (1957:48). It should be kept in mind, though, that the grammars discussed here are concerned with competence, and that performance, in early generative grammar, was thought of as something less than ideal. I have the feeling, however, that the Manichaeian streak which accompanied the distinction competence-performance at its birth is about to lose its power, and that competence now is seen as relevant only inasmuch as it can explain performance. But why talk about a theory of performance at all, then? Would it not be possible, with people such as Bar-Hillel (1970), to abolish the distinction altogether, and say: "competence is the theory of performance", or something similar? In the following, I will attempt to show that a theory of performance serves a purpose of its own, dependent on, but distinct from a theory of competence.

4. A Tale of Two Machines

In this section, I will conduct a Gedankenexperiment.*) Let us imagine two computers (or two computer programs), one (A) with the characteristics of a competence model (e.g., a system analogous to the transformational grammar described by Joyce Friedman), the other (B) resembling more or less Ceccato's machina loquax (see above, and also Mey 1968). Let us furthermore concentrate on the accepting part of the program, and try to figure out what happens in case the machines are

*) The basic idea behind this experiment is due to Schank (1970). Schank makes his purpose clear as follows: "...the notions of acceptability and grammaticality are part of the justification and purpose of transformational grammar. Our purposes are entirely different. In terms of analysis we are concerned with assigning a conceptual realitate to a string." (1970:41)

confronted with a sentence that does not conform to their specifications. To take a concrete example, take the sentence: Colorless green ideas sleep furiously. Suppose A has built-in restrictions that, among other things, state that the subject of sleep has to be [+Animate], that the adjective green selects a [+Concrete] noun, and so on. Since the sentence presented to A violates almost all of the given selectional restrictions, the result would predictably be that A prints out a "reject" message, possibly with the reasons for rejection attached.

What would our "Zwittermaschine" (Klee 1926) B do? Since B is a model of a human, and expressly purports to imitate human behavior, we can look towards a human hearer to obtain an answer. (Klee wouldn't lie). I think it was Arch Hill who first remarked that such deviant sentences sometimes are very well received by humans; in some of his experiments, students thought sentences like the above to be not only "modern poetry", but "good modern poetry" (Hill 1961). There is also a persistent rumor around that Dell Hymes, having read Syntactic Structures, promptly sat down and conceived a poem whose first line read: "Colorless green ideas sleep furiously, ...". Not to mention, of course, that all-time status symbol, the bumper-sticker carrying the same text and serving to fatten the pockets of some enterprising graduate student, while providing the more well-heeled members of the trade with a convenient shibboleth. To come back to our machine B: under the given presuppositions, it would have to find some way of imitating this human behavior, so disturbing to the creators of the selectional restrictions designed to produce the ultimate impossible sentence. For let us face it: there is no sentence so impossible that some human, in some devious way, cannot assign a possible interpretation to it. A quick glance at modern poetry will convince even the most incredulous (see also an article

by Joseph Featherstone in The New Republic, 11 July 1970, "On Teaching Writing", where some interesting experiments in teaching children how to write poetry are described). This is not to say that selectional restrictions are for the birds (not even the one sitting perched on the leftmost handle of Klee's machine); only that it seems to be an innate human trait always to try to make the best of seemingly impossible linguistic input. If a machina loquax (or audiens, for that matter) wants to be true to its name, it will have to imitate this kind of behavior, and by doing so, explain some or all of it.¹) And at this point I wish to discontinue the Gedankenexperiment, since I do not know how to make my machine do all this. But I hope to have made the issue clear: a simulative model, such as the one described, is different from a descriptive model. The difference becomes even clearer when one tries to implement both models on a computer. The simulative model requires a theoretical base of its own, since the theory of competence, by its own assumptions, rules out some phenomena that were described as typical for the human-like device. Conclusion: if CL wants to address itself to problems such as the ones involved in our little experiment, it will have to provide a wider theoretical base than the one accepted by most CL workers thus far. What we need is a theory of performance with special reference to CL.

5. Some further perspectives

In this final section, I will try to briefly indicate some of the areas in which I think a performance theory will be of use to CL. I will not propose any concrete solutions to any problems raised. The only aim I have set myself here is to provide some central perspective that I think may be fruitful to those working with the actual problems.

¹ Of course it would take a machine both loquax and audiens. So why not audax?

As a general preamble, I would like to discuss the question: what do we want to use CL and CL methods for? If the answer is: as an ancillary to theoretical linguistics, i.e., as a practical aid in solving some of the problems that theoretical linguistics poses, then the theory of CL is simply the theory of linguistics. Applications of this theory include, on the one hand such uses as grammar testers, on the other, such purely mechanical aids as automated dictionaries, programs for finding certain morphemes in a corpus, etc. If, on the other hand, the answer is: to implement and perfect actually working models of human behavior in the area of speech production and recognition, then CL needs a theory of its own. Some of the aspects of such a theory are covered, or should be, in what one might call "general robotology" (for some ideas on this, cf. Simon (1968)): questions pertaining to the interaction between robot and man, or even the "computer use of human beings", to paraphrase Wiener. Another general question is that of the degree of fidelity in simulation of human behavior, and the best way to implement this simulation. For example, what exactly does it mean: "to achieve a point by point imitation of human behavior"? Surely we do not want to reproduce certain states of the human that we consider irrelevant to the simulated process? In actual speech production, to take one example, we may very frequently be confronted with poor performance on account of extraneous conditions (colds, objects in the mouth, drowsiness of the subject, etc.) For a linguist, there is little point in examining and wishing to simulate these conditions. True, in marginal instances abnormal conditions may throw light on certain otherwise obscured processes; but this is not usually so. But even abstracting from these cases, there are areas where the difference between a competence approach and a performance approach manifests itself in the simulative set-up. Take again the example of embedded sentences.

Despite the fact that the recursive embedding rule permits unlimited embedding, actual sentences will always be finite, hence contain a finite number of embedded clauses. Hence the question arises: can we set an upper bound for embeddings such that, for a particular sentence, the depth of embedding will not exceed that bound? And, more importantly, how can we linguistically motivate such a decision?

Certain problems in the field of information retrieval have affinity to certain linguistic performance problems. For example, given a certain input to a question-answering system, how can one minimize the number of spurious answers, especially in the case of an imperfectly formulated question? Parallel to this is the problem of perfect understanding of imperfect questions by humans: how much do we really need to identify a given question and produce the correct answer? Traditionally, computational linguists have proceeded from the assumption that one first had to decompose the structure of the sentence (the question), then assign it a semantic interpretation, which subsequently is matched with the data file and produces the correct output. However, it seems clear that humans, in their analysis of linguistic input, often bypass the syntactic part and go straight for the semantics. A very simple and inadequate illustration is found in newspaper titles; a better one is provided by the ease with which small children handle conceptual structures without having the syntax correct. My own under-fours often produce rather complicated "sentences" that are perfectly intelligible, although syntactically completely ill-formed (or non-formed). As an example, consider the following: far gå huse ikke (Norwegian), where the negation is placed at the end of the sentence: ikke ('daddy go house not', i.e., 'daddy don't go to your study'). The most interesting thing about my 3-year old daughter's negative sentences is that the negation

particle invariably is placed at the end, no matter how long the sentence. Think of the savings in syntactic analysis time we would obtain if we had this kind of input to English question-answer systems! Furthermore, in a construction such as the one above, certain transformations (NEG-placement, e.g.) are clearly being omitted; but this does not affect the recognizability of the sentence by a human, or even by a computer that would be programmed to recognize deep, rather than surface, structures. Consider also the ease with which a computer could simulate such negative sentences, rather than spend costly time on rearranging the not's, nicht's, and so on that are the horror of freshman classes in ESL or German.

I am convinced that simulation experiments will prove to be extremely useful by pointing up phenomena about human speech use that at present are being obscured by the overly abstract approach to grammar of the last decade or so. Current research in applied linguistics as well as in the so-called "hyphenated" areas seems to confirm the trend that is apparent in theoretical linguistics proper: a greater concern for naturalness and directness in explaining the phenomena of language, with an emphasis on semantics rather than syntax, also in CL.

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Note added in proof:

Having completed the final redaction of this manuscript, I came across Christine Montgomery's contribution to the 1969 International Conference on Computational Linguistics (Sånga-Säby, Sweden), entitled: "Linguistics and Automated Language Processing". On p. 17 of her paper, the author advocates the necessity of a theory of performance along much the same lines as I do. Interesting is especially the fact that support for such a need is provided by some findings in the field of data retrieval rather than by linguistic considerations only. This is because the speaker-hearer of a language, in providing utterances, relates not only to his innate ability, but to "the total environment of the speech event as well". The result is that "speakers can and do process sentences which the grammar is not capable of generating; in other words, the relation between the sentences of competence and those of performance is not one of simple inclusion."

I regret having overlooked this important contribution, and herewith offer to Christine Montgomery my apologies, and to my readers, the advice to consult the paper in its entirety, as well as the references quoted there on p. 17.

MEANING REVISITED

by

Eugene D. Pendergraft

Linguistics Research Center
The University of Texas at Austin

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MEANING REVISITED

Eugene D. Pendergraft

The feasibility of building a mechanical system to perform high quality translation has been aired for some twenty years, not without emotion or result. At early conferences concerning the outlook of mechanical translation the discussants were apt to fly off the handle and go home in a pout, appearing to differ on the meanings of words such as "translation," "quality," "high" and "feasible." But sponsorship supplied the lubricants that in time subdued their disagreements toward a comradery of benign misunderstanding. Volatile research groups formed. Some of them held together long enough to actually attempt preliminaries of the approaches they visualized, so that consequences of diverse methods and theoretical dispositions can be estimated.

I'm not a detached or objective judge of that grand experiment, which began with such irrational optimism that it had to end with irrational pessimism. I participated in it as passionately as the rest, since I'm convinced research of any kind requires passion.

As for objectivity, I came to believe that an objective point of view is out of place in translation research or in any inquiry whose subject matter depends on the very nature of meaning; that "objective" pertains to a particular class of meanings which, as a vehicle of scientific communication,

denies access to the full universe of meanings.

These conclusions, once gleaned from my own research experience, profoundly changed my personal assessment of the prospects of high quality mechanical translation. What I want to communicate is the movement of my private judgments, neither detached nor objective, toward a point of view that you might think to be unscientific. At least, my viewpoint may seem at odds with that of empirical science and its derivative common sense.

I refer to the unique point of view of one sentient life, which each of us knows privately. Whether we like it or not, language often conveys private information and those conveyances, although supposedly at a minimum in technical documents, must also be translated. More important, only from a personal standpoint can we actually use language. This is our point of view as hearers or speakers of language who, in order to understand or to be understood, do make use of private information along with information which we as individuals infer to be accessible to others.

With discipline we can limit our conversations to public information, so carrying out a social contract that has worked well for physical sciences in their investigations of our common environment. But evidently the study of translation, except for superficialities, does not belong in that context. It involves, in addition, an investigation of ourselves.

Human translation is known to be most successful when the translators are informed about the subject matter they are translating as well as about the languages. This much is ascertainable by the empiricist's test: to translate well, one must understand. Why, then, should we look for "high

quality" translation from machines that obviously do not understand; that merely manipulate rather than use language?

Indeed, one of the convincing findings of the past decade is the impotence of mechanical translation processes working on the surface of language and dealing almost exclusively with those linguistic features or forms ostensibly available through empirical description. Processes of this kind have persistently demonstrated an inability to make useful selections among the immense number of possible constructions which give language its innate flexibility.

Defective translation processes do of course make choices; as Ida Rhodes gleefully pointed out, they produce "garbage." What we would find useful, instead, is mechanical selection closely analogous to patterns of human preference. Or, better still yet probably less attainable, we want a good and faithful servant: a machine whose choices would make ours more successful.

At the start, translation researchers did not express such lofty aims as these. They thought simple conditions for choices could be found in the text being translated and very near to the point of selection, in proximate words or phrases of the sentence momentarily under consideration. When such innocent expectations led to disappointment, investigators modified their attack in two different though complementary ways.

First, they set out to place more knowledge of the "source" and the "target" languages at the disposal of mechanical processes making choices. This was done initially by incorporating into the programming of the translation

process some of what was then known about grammar. The result was a translation routine or "algorithm" specialized not only to particular languages but also to particular grammatical constructs. Because any change of grammatical detail required reprogramming of complicated relationships, translation algorithms were seldom completed in a programming sense; much less in a linguistic sense. Progress was therefore deadly slow.

Efforts to free researchers from the nuts and bolts of programming resulted in an understanding of the principles of "generalized" linguistic processes. That innovation made it possible to simply "store" grammatical data in the machine to be retrieved mechanically as needed as a basis for language choices. One result was a more rapid exploration of new formulations of grammar. At the same time, this new practice focused attention on theoretical problems besetting the mechanical translation enterprise.

The trick of generalized linguistic processes is that all of their choice-making is done in one of two ways. On the one hand, the choice is made with reference to some structural aspect of the deliberately constructed "metalanguage" being used by a given researcher to convey grammatical information about a specific language, say for example English. For the rest, the choice is based on the result of a comparison in which some grammatical detail so conveyed is matched against a possible instance of that detail in a specific discourse.

The former kind of choice is "formal" in the sense of being determined solely with reference to the metalanguage selected by that researcher for the purpose of describing grammatical details of English, or of another language.

In so far as one and the same metalanguage is used to record such details about a number of languages, all formal choices remain invariant among those languages. The latter kind of choice is "factual" by virtue of being specific to each language, and thus is variant among them.

However factual choices might vary from one language to another, the comparison process actually making factual choices can itself be generalized. That is to say, all of the auxiliary choices guiding the inner workings of each comparison can be referenced to forms or features of the metalanguage. From this, one can see that every choice necessary to specify the programming of a generalized linguistic process is formal.

It is precisely this characteristic of being separated or isolated from variant factual choices which justifies the label "generalized." This separation, now a familiar one in science, can be made as soon as the researcher has decided on the symbolic apparatus he will use for the purpose of recording the empiric facts imposed by his next experiment. For a linguist, his metalanguage is that apparatus. It makes explicit his theoretical bent from the point of view of scientific communication, since it embodies those invariant relationships which he hypothesizes for language in general, or for some family of languages whose factual details he intends to describe.

Although one can study the formal characteristics of individual metalanguages or of relations among metalanguages, attempts to "prove" that a given metalanguage is inadequate for the purpose of recording facts of language, or that one is better than another for this purpose, are in my opinion absolute nonsense. If they have meaning, such proofs are a part of the researcher's

own decision process leading toward his choice of a specific metalanguage for the experiment he has in mind. His proof has nothing to do with whether he would have been right or wrong in choosing a different metalanguage than the one he finally selects. Most of all, his proof does not make his experiment unnecessary.

My personal assumption is that the selection of a specific metalanguage is not final, nor is the specification of generalized processes which that metalanguage allows. Both are theoretical choices in the design of an experiment about to be carried out. Both are preliminaries of that experiment, for which the metalanguage can and should be fixed and the generalized processes completed beforehand in a programming sense. Both, as instruments of formal as well as factual learning, can only be justified by the outcome of the experiment itself. For the present, the paramount goal of experimentation is to bring mechanical choicemaking into close conformity with human preferential behavior.

Clearly this goal has not been achieved, although much has been learned about language. Empirical studies of language, as such, have been expanded to also include the description of relationships among the things that language mentions, and among persons who are using language. All of this is symptomatic of a fuller awareness of the surface phenomena which human choices might take into account. So far, nonetheless, results of formal linguistic inquiry especially are tentative. Theoretical research has been unable to effectively demonstrate principles of an underlying formal organization which would shape factual findings about language in ways more useful for mechanical

selection processes.

It can be shown, for example, that the entire translation process can be generalized through use of metalanguages capable of conveying interlingual relations of various kinds. However, this merely extends the idea of enlarging the machine's store of knowledge about language, an idea which by itself has not benefitted mechanical selection as much as researchers had originally hoped.

Accordingly, the second thrust of research on mechanical selection has been to widen the search for conditions attending choices. In addition to examining the expression undergoing translation, mechanical processes have been permitted to range over surrounding sentences, paragraphs, whole discourses, or data representing an increasingly extensive experience of language events located in the machine itself.

Due as much to disappointment as to expanding interests, mechanical translation research overflowed vaingloriously and became computational linguistics. This new domain of experimentation is a conglomerate of studies in which mechanical translation shares the limelight with information storage and retrieval, automatic extracting and abstracting, fact correlation, question asking and answering, and similar applications where language is manipulated mechanically. After an unsettling beginning, during which the old guard felt compelled to recant its former commitments, the new milieu of jargons did provide a sounder medium for testing language theories and methods than mechanical translation alone.

In consequence of this new opportunity to compare computational

linguistic applications of various types, it has been noticed that mechanical selection comes closest to human patterns of choice in those instances where a little knowledge of language, things, or persons is brought to bear on an experience sufficiently extensive as a source of conditions for choices. In other words, mechanical selection appears to be improved by a better balance between mechanical analogues of experience and knowledge. Machines that ask or answer questions are examples of applications seemingly avoiding the narrow window of experience through which mechanical translation research tried unsuccessfully to squeeze great concentrations of knowledge.

In my opinion there are three lessons to be learned from this curious result of so much effort. The first concerns the way we might reasonably go about developing a mechanical translation system; the second concerns the type of system we might reasonably develop; the third concerns finding reasonable people to do the work. These problems are the ones requiring cogent solutions before feasibility estimates can be meaningful.

I think, however, that we have cause to doubt the optimistic assumption that men of good will must always reach similar conclusions on exposure to similar evidence, especially when part of the evidence is about themselves. By now it should be plain that no methodological consensus exists in mechanical translation research, without which comparisons of both formal and factual results are, at best, misleading. Before sitting down to make a second round of feasibility estimates, it might be proper to ask seriously why in our estimates thus far we seem to be getting "garbage" out of our own selection process.

One possibility is that, because mechanical translation researchers

were gathered from a variety of technical specialties, we have not been looking in the same place for conditions on which to base our choices of method. By and large, it must be admitted that we have been a mixed lot, though sharing the prudent wish of every specialist: not to be caught on lame feet outside of his territory.

Another is the possibility that, as heirs of commonly accepted notions about the nature of man, we have been looking too much in the same place for the conditions determining our methodological choices. By preferring the narrow window of empirical science, we have avoided those taboo territories made uninhabitable by the "garbage" production of our predecessors.

As a prolific example of the latter I cite René Descartes, who ground his garbage so exceedingly fine to assay psychical as well as physical substances. Surely it is for lack of these psychic essences that machines are unable to use or to understand language; while we, brimming full, need only introspection to understand and master all of the configurations of our own choicemaking.

We have said a great deal in translation research about the dangers of anthropomorphising machines and so little about the dangers of anthropomorphising ourselves. What if it should turn out, as Charles Peirce claimed a full century ago, that we have no special vantage point to our own psyche, but must learn about that too by careful methods of inquiry?

Thus a third possibility is that our difficulties with mechanical selection are the result of self-ignorance, whose remedy should be a disciplined study of the ways we make choices ourselves. If in fact each of us is engaged in a

quest for self-knowledge, then disparities in private understandings of the state of the art of human choicemaking might well account for some of the troublesome goings on in research which takes these understandings as its very ideal.

My personal conviction is that all of these factors are at work to make a second set of feasibility estimates as uncertain as the first. Before taking up the lessons which such estimates might turn to account, therefore, I consider it essential to make public some of the private assumptions unavoidably the source of my judgments.

PATTERNS OF HUMAN PREFERENCE

A summary like this one can do no more than lay out the bare bones of choicemaking activities which in each human organism are vastly convoluted and subtle. However, it is part of my purpose to spotlight the very hazard of abandoning oneself prematurely to mere facts so as to find solace in work of exceptional professional complexity. Formal investigation is, in its truest sense, an attempt to bypass variety in order to describe invariance.

This is not to say that formal inquiry, when it confines its interest to techniques of symbol manipulation, somehow escapes the same vice of specialization. Rather, I mean that my private fascination has been a train of formal thought with a different aspiration, running through the definitive studies of John Locke, David Hume, Charles Peirce, George Mead, John Dewey, Alfred Whitehead, Charles Morris, and others, and recently producing works of formal description like those of Jean Piaget, Lawrence Kohlberg, and Susan Langer.

The interesting characteristic of this line of formal reasoning is that it makes its theoretical choices increasingly on the basis of a disciplined interplay between formal hypotheses and empirical observations of invariants in human behavior. Thus it seeks to institute for forms an extension of those methods which successfully removed facts from the domain of fickle manipulation under control of human preference, and placed them under empirical control. In this aim it is the very antithesis of methodological opinion which sees theorizing as primarily a competitive arena for personal invention and argumentative directorship.

Piaget's study of the origins of intelligence in children is an elegant instance of this empirically disciplined formal method at work. It is consequently a good starting place for my summary, and a center line along which I will embroider my own thoughts or those of others caught up in the same intrigue of intellect.

From his observations of behavior in the human infant and child, Piaget isolates and describes six early stages of psychological adaptation. Each stage is evidenced by a characteristic scheme of choicemaking. It consists, on one hand, of the child's attempt to assimilate the environment by incorporating within his existing framework of knowledge and experience all new data given by his senses. On the other hand, it consists of his accommodation to the environment by using that modified framework as a basis for new acts. The existing adaptation at every stage, is an imperfect equilibrium constantly being repaired by successful assimilative and accommodative choices of its special kind, or being ruptured by unsuccessful choices of that kind.

Psychological adaptation, like the organic, can be explained in terms of relationships that are essentially ecological. Always and everywhere, adaptation is only accomplished when it results in a more or less stable organization of relations between an organism and an environment.

The point of supreme interest to us is the perspective from which Piaget chooses to construct his formal hypothesis. By observing stabilities in the child's relations to the environment as they appear from without, which is to say from the commonly accessible frame of reference of empirical

science, the observer goes on to hypothesize how those somewhat unsettled ecological relations are felt from the personal standpoint of the child as his mind works out its first contacts with reality.

From the point of view of the investigator, then, factual data are those that can be observed to vary from child to child because they are imposed by environmental details that differ with the time, the place, the culture in which a person lives. Formal data by contrast are found to be invariant among children because, Piaget hypothesizes, these are necessary and irreducible data imposed on the child by his own genetically inherited biological organization. That is functionally the same for all of our species.

As a consequence one can deduce that, from the personal standpoint of a child, invariance is an aspect of experience distinguishing form from fact. And we have already seen that this same invariance is what the investigator might look for himself from the personal standpoint of his own research experience, when he is making theoretical choices.

Such a coincidence should warn us that formal hypotheses about the organization of human minds have direct methodological consequences which mark them as being basically different than factual hypotheses about the organization of the physical environment. When the investigation probes into the foundations of meaning and of understanding, there is a new need for consistency between any theory about the mind of the human subject under observation and that of the observer himself. What is hypothesized for the mental organization of the subject applies equally for the observer, and as a result can modify the choices of method open to the latter in his investigative role.

In short, the process of formal inquiry itself is seen to consist of a cycle of assimilation and accommodation. From observations of invariants in the subject's behavior, the observer assimilates new understandings of mental organization, to which he then accommodates his investigative behavior.

In this cycle of formal investigation, methodological choices can be recognized as instruments of formal accommodation for the investigator, just as theoretical choices are his instruments of formal assimilation. Choices of theory and method are both tentative and are "hypothetical" in the sense of self-consciously awaiting the test of use. Consequently, these are tools of formal learning for a mature intelligence, not for the infant just starting out in his feeble thrust toward consciousness of self.

The infant has his own instruments of formal assimilation and formal accommodation, for he can be observed to progressively modify the essentials of his scheme of choicemaking. Should that occur, one can tentatively assume that he has learned something, not about the environment, but about the organismic basis of himself.

Once the child understands the next stage of psychological adaptation, he prefers to use its new scheme of choicemaking, although it can be shown that he still knows how to use all of the schemes he acquired in earlier adaptations. The next stage is always a more desirable frame of knowledge and experience than the one before it, taking into account everything in the previous stage, but making new formal distinctions and organizing facts into a more comprehensive and equilibrated structure.

That each scheme of choicemaking is formally a prerequisite of its

successor is argued by the observation that no stage in the progression of psychological adaptations is skipped. Each stage of adaptation has its own formal organization whose chief aspects my summary will try to illuminate. In addition, one should look for a progression of formal experience and knowledge in states of adaptation which are ever broader and more poised. It is this progression which allows us to think of the successive states as cumulative stages of mental development.

One must distinguish carefully between any existing state of psychological adaptation and the process of adaptation by which that state is changed. As Peirce was shrewd to notice, only when the investigator identifies formal inquiry with the process rather than the state, does it become necessary for his own state of mind to change should his investigative process succeed.

Formal reasoning has a dual purpose: to clarify the state of contemporary thought, and at the same time to benevolently undermine the world view that its fund of experience and knowledge represents. The aim of that benevolence is to carry forward the cultural process by including an established universe in a still broader and more stable one.

The central role of formal communication as a determinant of the state and the process of cultural adaptation has been explained by Mead and again eloquently by Whitehead. Each language has a formal component for talking about the everyday language to be used in talking about facts. Men also invent symbols for precise forays of factual description, as is well exemplified by the linguist's use of his metalanguage. Whatever the motivation, formal communication can either consolidate a cultural state by

perfecting the symbols already being used to mention facts, or it can offer new symbols to further the cultural process by making possible the mention of facts until then unmentionable.

Whereas at this moment the need of the state of culture is to consummate an objective universe through the use of symbols that successfully organize vortices of objects in a continuum of time and space, the clear need of the cultural process is a new basis of symbolizing with which to organize a more comprehensive universe, incorporating subjective as well as objective facts, and a more equilibrated one by virtue of providing functional mechanisms for formal as well as factual adaptation.

How can a universe be symbolized to bring these neglected cultural ingredients to critical public purview? Langer has proposed that the basic symbols of such a world would name acts, and that the symbolic facility of a universe of acts would allow us to communicate about complex acts, composed of those elements.

The gist of the line of reasoning being pursued is that it is about the symbols of Langer's universe instead of those of Newton's universe which have become, after three centuries, so comfortable to a mechanistic sense of life. At first contact, a universe of acts is certainly a strange world; but then, any really new world must be strange. And a world view which aspires to incorporate the mechanics of formal adaptation has in added perplexity the responsibility to explain the circumstances of its own emergence. The job before us is to clarify the symbols of this unfamiliar world as best we can so that they can be used and tested against living and historic evidence,

where strangeness has precedents.

Unavoidably, my summary will take up more mature stages of reflective thought following on the six initial stages of practical intelligence that Piaget looks for in the infancy and early childhood of individual men and women. It is in these markedly different settings that one can observe functionally analogous progressions of schemes of choicemaking. The invariant aspects of that progression might then be explained by an increase in human understanding of a biologically determined functional nucleus underlying and guiding consciousness.

Thus, the beginning of the process of psychological adaptation presupposes an exsistant biological organization, itself the product of an evolutionary sequence of genetic adaptation that incorporates hereditary factors having two quite different types of biological result. Factors of the first type determine the constitution of our nervous system and sensory organs, so that we perceive certain physical radiations, but not all of them, and matter of a certain size, and so on. Factors of the second type orient the successive states of psychological adaptation, and so have their result in the organization of a mind which attains its fullest and steadiest form at the very end of an intricate process of intellectual evolution, not at the start.

All of the various states and the process of psychological adaptation have in common the one formal aspect that, relative to an assimilated frame of experience and knowledge, the direction of every accommodation is such that it attempts to satisfy need.

Piaget maintains that needs and their satisfaction are mental manifes-

tations of the complementary interplay of assimilation and accommodation as felt by any human being. Although from our personal standpoint need may seem primary, it is the internal organization of that underlying unity, the act itself, which motivates our day-to-day existence as well as our long term psychological development.

The theory of the act, making explicit the invariants to be found in every unit of human activity, would for a universe of acts set forth the cyclical relationships between assimilation and accommodation which are taken to be the functional nucleus of both factual and formal adaptation.

The act of Langer's world would not consist of movements in time and space as seen from some distant and impersonal viewpoint of a spectator, although such movements might indicate to the mind of a spectator the act of another mind. The symbol "act" would stand for any elemental or composite constituent of a whole but unique universe, one among others named by the symbol "mind," whose personal and partly intimate point of view would be felt as the very direction of the act.

More, the direction of the act would tend to satisfy the immediate needs of a state of adaptation by assimilating and accommodating to the organization of the environment. At the same time the direction of the act would satisfy the long term needs of a process of adaptation by assimilating the organization of the act itself toward an eventual accommodation which, through the mind's increased understanding of the principles of its own direction, would affect a new state.

This progress notwithstanding, Piaget contends as Peirce before him:

there does not exist, on any level of human consciousness, either direct experience of one's own mind or of the environment. Through the very fact that assimilation and accommodation are always on a par, neither the organization of an outer world nor that of an inner self is ever known independently. It is through a progressive construction, guided solely by the pragmatic circumstance that acts once committed to use either succeed or fail to be consummated, that concepts of the self within and of the environment without will be elaborated in the mind, each gaining meaning relative to the other.

The theoretical relationships between the several states and the process of psychological adaptation, as approached in the context of the theory of the act, is the core of the matter, therefore. It is from this connection that one may extract the multifarious method of inquiry indicated by Dewey and Bentley in their essay about knowing and the known in this new universe.

If the formal character of each successive state of adaptation is due to an increase in the mind's understanding of how the act is organized internally, then the invariants observed in each of those states should contribute new formal aspects for the theory of the act. Conversely, invariants observed in the act as such should help us to understand the theoretical relationships between the states and the process of adaptation.

Mead's analysis found the act to consist of three principal phases: the first a phase of "perception," the second of "manipulation," and the third of "consummation." But the method of analysis just suggested will find that

every complex act has five functionally distinct phases which, allowing for an initial state, account for Piaget's basic progression of six adaptive stages.

This result would presuppose, for the theory of the relationships between the states and the process of adaptation, that it is an understanding of some new phase of the act which the adaptive process incorporates in the frame of formal experience and knowledge in order to pass from the existing state of adaptation to the next state of that basic progression. The efficacy of this view of the situation is given by various sorts of evidence.

Formal adaptation always appears as a growth of capacity in just one functionally distinct phase of the cycle of assimilation and accommodation implementing factual adaptation. This is at least consistent with the assumption that formal assimilation incorporates in the mind an understanding of the internal organization of that phase.

There is also an invariant order in the emergence of new phases of intellectual growth. The basic progression of six stages of adaptation exhibits that order in a number of quite dissimilar behavioral contexts, thereby assuring us that we are dealing with exactly five phases of functional capability, no more no less.

The initial progression consists of the stages of practical intelligence, where the five phases are first established as capabilities in the newborn child. Throughout the development of reflective thought that immediately follows, five functionally analogous phases emerge in the adolescent and young adult with the growth of representative thought. They occur again with the increasing capacity to verbalize subjective and objective facts contained

in such thought, and finally with progress in formal verbalization. As the behavioral setting becomes more complex, the formal character of the phases is revealed with greater clarity. The cultural progression is accordingly the most elaborate setting from which one can extract the internal organization of each phase.

Within the internal organization of these five functionally distinct phases, one finds every capability needed to construct a viable theory of the act. That the phases are in fact constituents of the act is evidenced by the very possibility of that construction.

However, the sequence of phases defining the direction of the act does not turn out to be the same as the developmental sequence defining the order in which the phases enter consciousness. Evidently the first two phases of the act are understood one after the other, and then the fourth phase, the third, and the fifth. The process of adaptation always assimilates the phases of the act in this peculiar order to affect, through its respective accommodations to the successive mental increments, the basic progression of six adaptive stages observed in all of the behavioral contexts.

Even this unexpected state of affairs will be found to make sense in the context of cultural adaptation, where the developmental sequence can be recognized as a convenient arrangement for the transmission of social and cultural behavior across generations of individuals. To see this, one is required to consider the specific organizations of the several phases and the way they cooperate to determine the direction of the whole act.

To lay the grounds for that discussion, I must stress again that the

most fundamental distinction for the new world we are exploring is not the one yielding a grid of space and time which makes possible the symbolization of movements in a physical environment. For a universe of acts, the basic distinction will be that made by Peirce of "potential acts" comprising the patterns of knowledge as opposed to "actual acts" being instances of those very same patterns which, in the relationships of their occurrence, comprise the experience of a given mind.

The dichotomy of experience and knowledge is a more comprehensive grid for our symbols than that of space and time. It makes possible the symbolization of acts making up a mind that is itself capable of symbolizing physical movements in an environment, as well as its own acts or acts of other minds.

Linguists will find this new grid familiar. It is the one by which known patterns of language, symbolized in their grammars, are ballanced against instances of those patterns which they symbolize in a given stream of speech. The dichotomy of knowledge and experience is nonetheless as wide as life. Every stream of existence contains sensory elements other than those of speech, which feed a ballancing act of magnificent dimensions.

The problem posed for the theory of the act is to explain the equilibrium that assimilative and accommodative processes maintain between actual acts of experience and potential acts of knowledge, given a stream of existence which is itself a sequence of actual sensory or motor acts, each instancing a successful or an unsuccessful consummation of some potential act among the elements of Langer's universe.

The resultant mind extends precisely as far as the equilibrium between experience and knowledge is maintained, whether the work of assimilation and accommodation is done by a single biological agent, or by a collection of them acting socially. The agent could as well be an electronic machine. This new world will be less skeptical of mechanical agents of mind than the present one, because it will look for mind in the equilibrium itself instead of in the agent.

Whatever the agent of a given mind, any flaw in its equilibrium will be "need." Any repair of disequilibrium will be "satisfaction." Persistent loss of equilibrium will be the nagging irritation of "doubt," according to Peirce the sole motivation for acts of inquiry which when successful attain not the truth of an external reality, but stability. For a universe of acts, therefore, any persistent stability in the equilibrium between experience and knowledge will be "belief."

In summary of the matrix of theoretical and methodological choices, I assume that the criteria of truth in a universe of acts are the immediate stability of its adaptive state and the long term stability of its adaptive process. These are pragmatic truths of fact and of form, respectively. The former relates ultimately to the organization of the environment; the latter, to the organization of the act. But there is no direct access either to a reality behind fact or behind form. Each is known or experienced relative to the other by means of complex acts which the mind itself constructs. The constituents of that construction are potential sensory or motor acts, the biologically or mechanically based elements of this unique universe, which

is one mind among others. The sole source of the information guiding the construction is a given stream of existence, itself a sequence of actual sensory or motor acts instancing successful or unsuccessful consummations of those universal elements. And the organizing principles of the construction are those of the act, whose pragmatic method I will now discuss.

PRAGMATIC METHOD

Christopher Alexander, in his notes on the synthesis of form, cites a common engineering practice for making a metal face perfectly smooth and level. One inks the surface of a standard steel block, which is level within finer limits than those desired, and then one rubs the face to be leveled against the inked surface. If the face is not quite level, ink marks appear on it at those points which are higher than the rest. One grinds away those high spots, and fits the face to the inked surface again. The grinding and fitting are repeated over and over, until at some final fitting the entire surface of the metal face is marked by the ink, indicating that no high spots remain to be ground away.

The practice of fitting affords a useful way to think about the phases of the act. Because the act, too, consists of ongoing processes of assimilation and accommodation within which experience and knowledge are repeatedly shaped by putting their various parts to use, rubbing them against reality so to speak, in order to have them marked by success or failure as preparation for still another shaping.

It was Peirce who found out that the high spots of the mind are marked by the ink of success and the low ones by lack of it. Thus, fitting the mind to reality involves filling in the low points as well as grinding away the high ones. The mind had to be constructive in order to eliminate the holes and pitfalls of experience and knowledge. If men worked diligently enough at seeking out and building up the misfits, the entire stream of existence might become bright with success.

Although from this William James drew an elixir that pleased and encouraged a competitive society, the product he marketed under the label of "pragmatism" has since fared poorly in the popularity contest of ideas. That is significant for our inquiry, though not as an indication of some flaw in Peirce's insight. By the hard-eyed predictions that the actual practice of pragmatic method made possible, the course of its own acceptance has in fact been remarkably well borne out.

Stubbornly fixing its attention on the surprise of failure, pragmatic method was sure to be unpopular to every conservative trend of mind. That opposite practice, finding all of its reasons in the preservation rather than the creation of information, deliberately tries to avoid surprises and to explain away its own failures. For a conservative mind the sources of gratifying or noxious information are invariably felt to be outside of itself. In simple consequence, every form of conservatism directs its main purposes to preventing contamination of the specific place from which it sucks nourishment. To such a mind the purposes and attitudes of pragmatism have been and will continue to be irrational.

The conflict of rationality we are about to consider is the most exasperating one known to man because it stems from the direct opposition of creative and conservative assumptions about what information is, where it comes from, and how it is used. By comparison, all earlier crises of the cultural progression will have been mere squabbles among conservative minds in solemn disagreement over good and bad teats.

In the fifth universe, "information" is something to be transmitted

across its space-time grid. The ultimate source of information is a material reality common to and encompassing all of mankind. The firsthand passage of information, by which it arrives in a brain that is essentially a passive receiver pretuned genetically to certain vibrations beyond itself, is called "observation." The brain stores up some of the information it receives and can also retransmit informative copies from its store by means of a conveyance of symbols that lodge themselves in other brains. This secondhand passage of information from one brain to another is "communication" or, for the young in passive receipt of a largess from the information store of society, it is "education."

The method of "descriptive" science, although less conservative than its predecessor, still locates the information source externally. Its works of observation are best done by a disciplined spectator who separates himself as rigorously as possible from all temptations of human purpose. The social status of the scientist, so engaged in carrying out his contract of detachment, is not unlike that of the priest whose nearness to God in the preceding social order called for all sorts of precautionary measures to insure the fidelity of firsthand information.

In general, one can identify information specialists at each stage of culture for whom contemporary men reserve their greatest veneration and suspicion. This highest peak of cathexis may now be explained theoretically by the need of every society to cluster around its fount of firsthand information in order to carry out the social act.

The necessary consequence of any change in the information source

will be social reorganization, a period of turmoil during which new information specialists learn their roles, and users of their information scurry to the unaccustomed precincts of yet another defective metamorphosis. An improved equilibrium might then be felt by its participants as the preferred "order". Without that shared judgment, the new metamorphosis would fail. Society would revert to its former state, or would backslide down the cultural sequence to a regressive state within the scope of its remaining capability.

The pivot point of the adaptive process would appear to come when a society, or by the same principle a personality, feels the need to modify its source of information. This is the invariant to be looked for from the standpoint of the mind itself, even though our theoretical explanation holds that such a fundamental change is caused by an understanding of some new phase of the act being incorporated in the mind's functioning to thereby affect new ecological relationships.

Besides that our line of formal reasoning predicts that any new state resulting from an advance of the adaptive process will at first involve a reorganization of known facts. Thus the repair of intellectual progress is always felt by the personality or the society as a consolidation of mental holdings, in a word, as an "insight". Only after the introduction of a more comprehensive organizing principle can new facts be added to a reconstituted structure that has become at once broad and stable enough to receive them.

These conclusions are, in themselves, organizing principles of a personal world view emphasizing learning rather than doing.

Giving its highest priority to doing, the fifth universe uses its symbols

to persuade other individuals or other societies what ought to be done.

Inquiry is a garnering of information under stringent regimens that protect the quality of a product being pigeonholed away for unspecified future use in an advocative scheme of choicemaking. There, hard-fought positions are reluctantly abandoned under the shear weight of damaging evidence.

By comparison, the pragmatic scheme of choicemaking is one in which a real preference for surprises actually courts failure as a gratifying means to the shaping of an affluence of hypothetical creations almost light-heartedly sent forth in the hope that new truths might be caught in their net. The preferred symbols of the sixth psychological state belong in a context giving its highest priority to learning, and so they pertain to changing one's own individual mind or the mind of one's own society, not another's.

"Information," in the sixth universe, is something to be created against the grid of experience and knowledge by the agency of an ongoing organic process for which each mind's fragile stream of existence provides the indispensable clues. Those surprising instances when a given mind fails to achieve an expected objective are, in a world motivated by the need to repair itself, the necessary benchmarks for firsthand information being self-consciously designed to circumvent know misfits that are obstructing human satisfaction.

Hence the characteristic forms of pragmatic "communication" are to broadcast throughout the community all known points of distress and any helpful new designs by which past failures might in the future be overcome. One can readily see how such an innovative mode of communication will be

disquieting when taken out of its proper context by a conservative state of mind bent on maintaining credible displays of tradition, authority or power.

Formal incompatibilities of conservative and creative views of information do indeed cause a "communication gap" with which the pragmatist, for his own part, is unable to cope. Advocative arguments will be perceived by him as "irrelevant" for two clear reasons.

First, a mind will not be persuaded by appeals to tradition, authority or competitive advantage once it believes that all "truth" is established by demonstrations of successful use. A persuasive rhetoric will be received disrespectfully as artless in the production of "false" designs, either untestable or long since disproven to a more receptive conduct of life. Seeming corrupted because of its higher resistance to corruption, the pragmatic mind will reject argument just as an argumentative mind had earlier rejected preachment.

Second, and more noteworthy of the pragmatic view of information, is its implication that an essentially conservative mind can be induced to learn by denying it the opportunity to overlook its failures of awareness. Mules of the sixth universe, once brought to water, will be taught to drink. The pragmatist's exorbitant desire to teach, as well as to learn, has not received the scholarly attention it deserves.

His discernment of this fresh possibility for improving all manifestations of the art of symbolic communication will inevitably call for new styles of speech and writing in which language is deliberately designed to stimulate a mind's own constructions through enrichment of its awarenesses. The more

exquisite these new forms of expression, the more they will appear a mouthing of absurdities to minds steadfast in the obsolete notion that words transmit messages. Thus the result that Dewey prophesied: symbolic communication conceived as teaching will rely less on language and more on active displays that dramatize the student's own weaknesses and his own overlooked possibilities.

The goals of "education" will be attained by a variety of activities and situations especially designed to progressively awaken a mind at first so feeble that it would shyly act to protect its meager hoard of dependable creations, thinking them the gift of one or another fountain of charity. The stimulation of formal learning, while tenderly administered to the young and mentally impaired, will reprimand the laggard so remissive in his own mental betterment that he extends a nacent conservatism into adulthood.

Society in the sixth universe will not achieve the elusive goal of classlessness. It will prefer an order of psychological classes wherein a forefront of information specialists gather loosely around the sage to be students and teachers of one another. As for the sage, he will probably turn out to be a mathematician.

In Peirce's guess at the riddle of life, man's framework of experience and knowledge has been gradually broadened to include the "law" of the human act in its complementary relationships to the "presentness" of the environment. Mediating these two extremities of consciousness is "struggle," a conscious sense of learning in a collective mind appraised finally of its own creative act of inquiry. About that wellspring of information he says:

...there is manifestly not one drop of principle in the whole vast reservoir of established scientific theory that has sprung from any other source than the power of the human mind to originate ideas that are true. But this power, for all it has accomplished, is so feeble that as ideas flow from their springs in the soul, the truths are almost drowned in a flood of false notions; and that which experience does is gradual, and by a sort of fractionation, to precipitate and filter off the false ideas, eliminating them and letting the truth pour on in its mighty current.

Pragmatic method is more casual about forgetting because it has taken the act of creation in its own hands. The information specialist of the sixth universe will be a participant, immersing himself in a struggle to stabilize personal and social relationships which, in the pragmatic scheme of choicemaking, will give first priority to the satisfaction of human need. More tolerant but less egalitarian than his predecessor, he will characteristically create his own responsibilities without waiting for or wanting a contract or mandate.

One should not overlook the precocious act of genesis in Peirce's own hypothesis that a given mind can cross the formal chasm to this final metamorphosis only by incorporating to itself an understanding of the very process of forming an hypothesis.

From his singular assumption that forming an hypothesis is the mind's sole source of novelty, the whole fabric of pragmatic purposes and attitudes

can be deduced. So I have deduced some of the formal character of pragmatic thought, hoping by my example to make you aware that formal accommodation is the result of the mind's own effort to work out the consequences of a revised conception of the origins of information.

This pragmatic line of reasoning will conclude that the adaptive process need not depend at all on a persuasive rhetoric to change the currently existing cultural state, nor in consequence to reorder the entire edifice of society as we know it. Pragmatists will act on that belief quite regardless of the fact that our society, like the one it replaced, will prefer to explain and work for social change on its own terms.

A failure to even consider the existence of an alternative theory of information, despite the damaging evidence of history, may be the Achilles heel of men engrossed in describing a common universe while jockeying argumentatively, and too often belligerently, for positions of material advantage in it. Their whole world might decay, not because they were greedy for dominance, but just because someone else had a sounder hold on information than they.

Be that as it may, it was his own pragmatic method and not the method of descriptive science which Peirce claimed with quiet immodesty to be the only way of settling belief that does not lead to eventual disappointment.

This prideful prediction is the weakest of his speculations. For paradoxically, through the very insight made possible by its sixth genesis, a mind would discover all of its previous metamorphoses to have been its own imperfect creations also. Such expertise in the art of information would itself

be the imperfection of a Superman who, Frederick Nietzsche most accurately foresaw, was destined to walk among men as among animals and be ashamed.

THE DOUBLE GENESIS

I know how difficult it is to place much stock in these unwelcome speculations. You and I don't take philosophy seriously, being practical men. And that is precisely what pragmatic reasoning has to say about us. A penchant for getting "the job" done, a ponderous insistence on "the facts" when disinclined to make a decision, a heartfelt disdain for formal reasoning when it "gets personal," all are indexed in the fifth stage of the cultural progression among the characteristics of that state of mind most recognizable as ourselves.

I will try to convince you anyway that some baggy-kneed philosophers may have uncovered a real, honest to God, new universe in which a few minds are already living and you might live yourself.

Just do not ask me to describe this new universe to you, as though you were about to sit skeptically in judgment of my facts. I will merely decide that you are an inveterate spectator and hence too passive or too mesmerized in the art of objective reasoning for the pragmatic journey I have in mind. In any case, I have carried you as far as I can.

From here on it will be necessary for us to run together in the hope of breaking through to the sixth state of mind in which the phases of the act make sense. Should we succeed in that joint endeavor, it will then be possible to look back and see that among the reasons for proceeding in this manner there will be a revised estimate of what language can do.

You have your personal standpoint and I have mine. For the time being, suppose that our interpersonal relationship is the one explained by

Ogden and Richards, in which the symbols I produce can cause you to make acts of reference.

For Ogden and Richards the meaning of "meaning" involves a twofold orientation. My choice of symbols will be caused partly by the specific reference I intend for you to make and partly by personal or social factors. Examples of such factors are the purpose for which I am inciting you to make the reference, the proposed effect that recognizing my symbols is to have on your own purpose or attitude, and my own attitude as my symbols are being produced.

When you recognize my symbols, similarly, they may cause you to perform an act of reference and coincidentally to assume a purpose or an attitude which will be, under the whim of circumstance, more or less the one I intended. That hope for result is by no means certain.

Two chances for error are implicit in the double orientation itself. You may mistake the "content" of my reference, attributing to it some different subject matter than I intended. Or, you may mistake the personal or social factors which make up its "context." Either eventuality would distort the meaning I was aiming at, or you might fail to catch it entirely.

I do not mean to imply that, should an accident of communication occur between us, I would have conveyed more information to you than you were able to receive. Your sheer assumption that it was my purpose to transmit information to you would belong in the context of objective inferences. A current preference for that context seems also to have established the firm attitude that the only things men can converse about with any precision at all are the ones they can lay

their hands on.

In this vein, for example, Ogden and Richards propose to lay their hands on symbols and their "referents" so as to converse propitiously about a relation, "truth," imputed by thought, but which thought alone could somehow not sustain. With telltale zeal to locate all worthwhile instruction in solid matter apart from mind, these investigators too, despite the many worthwhile things they say about problems of meaning, would not go so far as to explain the truthfulness of symbols in terms of mental organization.

The root of the matter is that every acceptable means of scientific investigation has been unable to locate minds, and hence thoughts, on the continuum of time and space. Popular belief tends to favor the inside of the head rather than the stomach, which had its day when men were hungrier. Until the right spot is discovered and demonstrated, it will be quite meaningless to speak of something "apart from" or "beyond" or anywhere positioned relative to a mind. Minds, as a result, have become disreputable in an objective scheme of things where they just hang around lousing up an otherwise impressive cosmos.

Pragmatists have been nicer to minds than scientists. For that kindness, I have labored to make you aware, there may be a troublesome price to pay. Protective mentalities of every stripe may have to get used to contrite pragmatic traits of character which evolve, without outside help, within a mind become so stalwart that it needs no cosmic plan beyond its own anatomy.

Within that frame of pragmatic reasoning, launched by inferences

which work out the consequences of decidedly different cosmological assumptions than those customarily assumed by you or me, the established order has been found guilty of grievous errors in its thoughts and words. Were this not enough abuse for a society priding itself on being "scientific," pragmatic response to the second-rate status of minds in a material universe has, with its usual candor, judged the method of descriptive science to be itself an aberration of a conservative mind in need of shaping.

The specific complaint points to a society recklessly applying objective inferences to the content of human purpose. It cites a scientism which perpetuates the excess of enthusiasm of men in the Middle Ages who, having organized their entire cosmos in conformity with inferences about an omnipotent will, imposed purpose on everything that moved.

This criticism, as such, is a formal communication designed to broadcast a misfit in the way language is being used to express facts. On the constructive side it suggests that, to overcome incompetence in designing symbols, one should observe a scrupulous match between a reference and its context.

"Meaning" is the explicit match, utilitarian by nature, for which the specific inferences defining the context shall have been tested by successful application to the specific content referenced. From this harsh point of view, it follows, the only proven domain of objective inferences is in point of fact those contents of experience in which a person lays his hands, or his eyes, or some mechanical extension of them, on something permitting experiment.

To accept this diagnosis and cure, an entirely new world view will be

necessary. Your cosmos and mine will have to be quite literally the framework of just one personal mind that feels itself to be participating, as a mere agent of the social act, toward the shaping of one or more collective minds.

Pragmatic criticism is not only addressed to a specific anatomy of information constituting a mind, it presupposes above all else that the signals of misshapen experience or knowledge are given systemically within that mind's internal organization. "Error" makes no appeal whatsoever to any other reality than a particular texture of one's own experience or knowledge just as such. Pragmatic explanation, similarly, is always posed in terms that ultimately recommend mental constructions.

Suppose, as an example of the latter, that acts of reference are taken to be the constituents of that immediate "perceptual" experience which in a given mind is felt as an orientation to what is now present ostensibly, right at hand. Also imagine that, on this relatively secure foundation, a speculative extension is then built by the agency of acts of inference from the particular contexts matched to those specific contents being presented perceptually. Constituents of the resultant construction are "concepts;" the elaboration itself is the newest part of that mind's "conceptual" experience, felt as an orientation to things not present yet having import for some activity either being contemplated or in progress.

Giving this theoretical explanation its due would adduce, from the very mind committed to it, the consequence that errors of reference or of inference will, in general, beget malformed experience. Were such a faulty framework used to guide further action, the enterprise would culminate

in acts prone to failure. Hence, in consequence of accommodative inferences tending to reorganize its own methods along pragmatic lines, the mind would finally conclude that, from its own personal standpoint, its own failures are its only signs of mistaken perceptions or conceptions.

To that personal world my symbols can carry nothing along with them except the skillful ingenuity with which I designed them and then launched them by mouth or hand, all the while guessing at your skill for using them to create information. Indeed, your ingenuity might be greater as a creative recognizer of symbols than mine as a producer of them.

As for the truthfulness of my symbols, I believe you will discover "truth" in them to whatever degree they stimulate and assist your own creative efforts. If they cause you to fail or carry you away from insight, farther than you would have gone by yourself, you will certainly judge them "false."

My symbolic designs can bring you no evidence, nor can they offer you proofs. They can only recommend how you might look for evidence in order to convince yourself that this revision of your present state of mind might improve the satisfaction of your everyday needs.

Then will you eagerly extract every scrap of evidence from which the further construction of your own experience or knowledge might profit. In your unique universe you will have to do all of the remodeling for and by yourself, and you alone will judge the result.

For my part, despite this ample domain of personal application, I see no reason why these same pragmatic practices will not also satisfy the needs of a society giving its highest priority to learning rather than merely

doing.

Regarding the question of precision in the social use of symbols, I think you will agree that these pragmatic methods tend quite naturally to the happy hunting ground of mathematical reasoning, where especially critical minds can live out their cloistered days as students and teachers of one another toward the sole purpose of shaping up the formal component of explicitly constructed "languages."

Not only do the ministrations of mathematicians succeed admirably, they belie the empiricist's expectation that fact is a more stable foundation for society than form. The myth of empirical description to the contrary, science rode to its present glory on the back of mathematics.

Of course, mathematicians argue more than they would like. And if some of the symbolic designs they produce are named "proofs," I do not object. No mathematician has ever been known to accept one of those proofs from his cohorts without performing every reference its symbols specify, while passing judgment on each meticulous step for and by himself.

I therefore can hardly resist classifying mathematicians as the most excellent pragmatists of all. The things of importance are that their inbred practices have originated unusually reliable inferences in special minds which, since the time when mathematicians themselves could still believe they were describing abstract relations of rather etherial realms, have carried forward an explosive growth and variety of new constructive possibilities. Possessing a plentitude of alternative contexts, scientists have gone gingerly about the complementary task of fitting them to factual contents.

Thus the real route to exactitude in the scientific use of symbolism may have been presaged in the pragmatic view that, because facts vary, errors are at a minimum when men communicate about what is invariant among, hence within, themselves. As scientific hypotheses took on an increasingly mathematical character, the outworn trappings of a descriptive method were bit by bit discarded.

Like the earth-centered cosmos of the Middle Ages, was it necessary for our own world to be inverted before further progress was possible? To take the Peircian hypothesis seriously, you will have to identify it as having originated new organizing principles for known facts. It will have done the same sort of intellectual work as the Copernican hypothesis, whose emergence in the preceding state of culture portended the disintegration of an autocratic society and its reformation as a social order more favorable to industry.

That earlier transition, just as the one presumed to be now grinding to its sixth destination, was upsetting to the status quo. The spirits, spooks and fairies that moved the fourth universe were not cast aside easily.

Nicholas d'Oresme had observed that God had constructed the material world like a watch, which could then be left on its own, in no need of spiritual forces to move its various parts. A new theory of motion gradually emerged, helped along by Burdian, Albert of Saxony, and the philosophers of Merton College, Oxford. A direct precursor of Galilean dynamics, it held that any body when pushed is given an impetus that remains with it, or only slowly diminishes, if no obstacle is placed in its path.

But the law of gravity was never perfectly formulated by Galileo, who

retained a conservative preference for circular movement. Even Newton had to resort to God to explain the maintenance of motion in the new universe then under construction.

It is astonishing how few new facts Galileo used in his argumentation to support the Copernican system. The experience on which he based himself was at bottom the same everyday experience that the Aristotelians had interpreted. He arranged this experience in a completely new way and made it more comprehensible. One would be mistaken to think that the "scientific revolution" of the Renaissance consisted in a triumph of the description of new facts over formal speculation. Not until the writings of Francis Bacon became the bible of the Royal Society did the collection of facts become hectic.

It was Descartes who finally banished active spirits from non-living matter once and for all to launch the world we know. The essence of matter consists in extension; the essence of spiritual principles, like that of the soul, in self-consciousness. According to Descartes, therefore, God does not operate in the cosmic process either. The behavior of the material universe must be explained on its own terms.

By far the most interesting consequence of Descartes's theory was its contribution to the disappearance of witch hunts, which had grown to incredible dimensions in both Protestant and Catholic countries. That is one sound indication of an unsettled world retrieved toward salutary equilibrium when intellectual preference turned away from asking "What is God's will?" and took up the question "How is the world constituted?"

Although the information source of Western culture had changed, the brotherhood of man under the fatherhood of God was not forgotten. An

egalitarian order was essential to the advocative scheme of choicemaking that replaced the authoritarian one. As Dewey and Bentley remind us, the spiritual entities which had once inhabited dead matter took flight to new homes, mostly in the human body, and particularly in the human brain. They had been swept out of the way of progress, right into another sanctuary of mischief.

The new social order formed decisively around two information specialists, polarized in the separate responsibilities for objective and subjective choices implied in Descartes' dichotomy. The emerging mechanistic world view became the watchword of the eighteenth and nineteenth centuries, providing the theoretical basis for both poles of the new advocative scheme. Science, but also economics and politics, were conceptualized in terms of forces held in abeyance by counterforces balanced against them. Ultimately the forces of nature were balanced against the burgeoning will of man.

An oddity of the transition now attending the dissolution of a mechanistic world view built on polarity is that it will require a double genesis. Moreover, it was to be expected that scientists and educators, having been commissioned to a quiet concern for learning in an industrial society, would be susceptible to pragmatic influences in greater degree than active managers and makers of public and private weal.

A decline was foretold when George Berkeley, motivated by the fear that Newton's principles of absolute space, absolute time, matter and gravitation would threaten religion, doubted whether the words in which these principles were expressed even made sense. According to him, the

only words that are meaningful are words that designate sensations. If the goal of science is to coordinate sensory perceptions, then it can make use of spatial relations only to the extent that these are merely relations between sensible bodies, and nothing more.

Out of the matrix of Berkeley's arguments came two fertile seeds. One is the distinction between the formal and factual components of language, now grown to the rank of a major preoccupation among philosophers. The other is the very method of approach by which scientific procedure took on its exclusively descriptive character, that of ascertaining, and only then interpreting, the data of sensation.

A new direction came pointedly to the surface when Immanuel Kant asked "What can we know about the world?" He had shifted the source of information toward a personal perspective despite his own conviction of the correctness of the Newtonian world view, which his own cosmological hypothesis had broadened. He sought to substantiate it. In his opinion the principles of natural science, such as those of causality and the law of conservation of energy, are unconditionally true because the mind thinks in Newtonian terms. This explains why we are able to comprehend nature; its general features are indeed our own work.

The spectacular growth of science in this century has armed a mechanistic world view with an abundance of arguments. Meanwhile, the forefront of scientific method has moved out on the much more mathematical course blazed by men like Faraday and Maxwell. Near the turning point Ernst Mach asserted the radical idea that science can, and should, do nothing but order experience.

Mechanism was struck a severe blow by Einstein's special theory of relativity, which introduced objective probabilities uninterpretable in terms of sensation. Later a coup de grace was delivered by his general theory, originating a curved space-time based on Riemann's geometry.

It should be noticed that my pragmatic reconstructions of recent history make no appeal whatsoever to an advocacy on the part of Peirce. Were he alive, I know he would resent my shabby treatment of the brainchildren he dressed so carefully. What matters after all is that, though sorely lacking the Madison Avenue touch, he did advertise these new constructive possibilities. That is all his pragmatic theory of social change required.

The universe of your own personal mind is one you know well. However, you have not thought of your social universe as being organized along principles of mental anatomy, and will doubtlessly think that further suggestion is silly.

Believe me, I share your annoyance. I have lived as comfortably on the grid of time and space as men did formerly in the lap of God. But a surprising thing happened to me one day on the way to the laboratory. There were people in the streets yelling about the misfits of our society, and it suddenly occurred to me I was being set upon by a bunch of pragmatists.

Now I am pretty sure that none of these ragamuffins had ever read Peirce. Yet they made it crystal clear that they were intent on shaping the collective mind of their OWN society, and also their OWN individual minds. Their inquisitive attitudes gave much of Nietzsche's holy Yea to life seekings its OWN will to win its OWN personal world, though it be the world of an outcast.

Yes, they did seem painfully aware of Nietzsche's metamorphoses by which the human spirit becomes a camel, the camel a lion, and the lion at last a child. Along with their childlike craving for novelty, they were impatient with bearing burdens or doing combat.

I call your awareness to these untidy deportments because of their unheralded intrusion upon a world so desperately intent on persuading OTHER societies, and hence OTHER individuals, what ought to be done.

I submit that attempts to explain these surprising events in the context of the existing cultural state have so far not been very satisfactory. By way of contrast, the same happenings fit so well in Peirce's hypothetical universe that I have gradually been compelled to regard its peculiar galaxy of pragmatic purposes and attitudes as less a philosophical abstraction and more a veritable contagion of contemporary men and women.

I came as a pedant to the pragmatist's world, but have since met some of its native inhabitants for whom its exotic ways of behaving appear as natural as breathing. At any rate, I am constantly being amazed as my hard-won conclusions are judged by these people to be just ordinary common sense. The really interesting question, therefore, is where these purposes and attitudes came from.

I, for one, am not very impressed with the explanation that the Devil has been busy corrupting affluent children who were abandoned by permissive parents to permissive school administrators. I do admit that supernatural corruptors might be having a fretful problem now that the Communists have grabbed so much of their work. But since the Communists themselves seem

to be fretting over a rash of freakish happenstance in their home territory, it would be better not to point a finger at them just now.

Hunts for a source of corrupting information from OTHER minds, real or imagined, will not doubt be carried farther than its present overindulgence if this liking for pragmatic thinking spreads. For that dismal conclusion one need look no farther than the recent precedent of Germany, where it may also be seen that at some point of panic the diligent conservative can forget what he was looking for and become an irrational fanatic.

Not surprisingly, Germany was at the forefront of the new science when the engineering of pragmatic learning was first experimented with irresponsibly in the streets and on the campuses. There, also, came the first demonstration that applications of this new theory of information can have far reaching effects on political and educational institutions, both restless in a balance between advocates of particular positions and their counterpoised opponents.

So I have brought you to the place where young men and women, unaccountably ashamed of their elders, are making their own myths. They honestly believe that Adolf Hitler killed Superman at his first bombing and stole his robe to use as a trophy in festering up his regressive cancer. Pessimistically they gather to be students and teachers of one another, asking "Who am I?" while awaiting the next executioner.

AN ANATOMY OF MEANING

With this small sample of pragmatic communication, so out of step with a staid "objectivity" in technical writing, I have sought to demonstrate the symbolic designs of a constructive cosmology. Reliance on description will be diminished, while greater importance will be attached to speculation. Above all, the formulation of new inferences will be incited in the hearer or reader by referring him to contents that reveal systemic weaknesses or suggest fruitful contexts for innovative constructions. Though these forms of symbolic intercourse have long been exercised at the dinner table and over the cup, they are honed to a sharp edge in mathematical reasoning.

My concern has been to show that this change of style is not capricious or arbitrary. It is the rational result of an emerging new theory about the origins, the means of distribution, and the uses of information. As the empiricist could no longer support a requirement for incantation, prayer or preaching in half of his reconstructed world, so the pragmatist has no further need for language that purports to describe an external reality. The sole purpose of every symbolic communication in his universe of acts will be to shape the internal reality of a person or a society.

In this dual light, I ask you to reconsider the conclusion that Charles Morris reached in his treatise on signification and significance, according to which the main dimensions of signifying relate to phases of the act. In particular, he finds that "designative" discourse corresponds to the act's perceptual phase, "prescriptive" discourse to the manipulative phase, and "appraisive"

discourse to the phase of consummation.

A student of Mead, Morris builds on his mentor's analysis of the act's phases. He recognizes that "formative" discourse might call for a fourth dimension of signifying; but he decides that Mead's analysis need not be complicated by a fourth phase to account for his misfit.

To the contrary, when analysis of the act's phases is approached by the different method afforded by consideration of Piaget's basic progression of developmental stages, a phase of hypothesis formation will be one of those found missing from Mead's tally. This phase, indeed implemented socially by formative discourse, will be for a pragmatic cosmology, the one in which new knowledge is created. It is accordingly the specific phase that Peirce recommended to our understanding in order to consummate the formal traverse on which he would have us embark. Since this phase of the act will also involve forgetting knowledge, I prefer to call it the phase of "reorganization."

By all indications, language is an ancient heritage and should not as an ongoing system be expected to zig or zag as readily as speculations about the nature of language or styles of speech, heard from men immersed in a particular cultural situation. To look at the way language is being used is rewarding for a pragmatic inquiry which, in keeping with its interest in the process and various states of adaptation, will prefer to observe humans at large in their natural habitats as they busy themselves more with obedient or competitive doing than with learning.

Comparison can thus be made of the respective abilities of the pragmatic and the objective viewpoints to organize known facts of language. That

formative discourse fits naturally in the pragmatic framework can be taken as a bit of confirming evidence that its organizing principles are more comprehensive than the objective ones.

The comparison is itself the one proposed for a pragmatic science, since only by use of the pragmatist's viewpoint does one begin to grasp the general principle that what is felt in experience as a "viewpoint" is determined by one's own choice of inferences.

A consequence of this insight is to make the context as well as the content of observation matter. Once the two are seen to be relative, one gaining meaning as complement to the other, the aim of a pragmatic science must be a useful matching of the two.

To make the comparison just recommended, one would have to first identify Piaget's theories as being pragmatic in outlook and those of both Mead and Morris as belonging to that conservative view of psychology and sociology which attempts to achieve order and predictability in a world of objects. Just because the objects are animate instead of inanimate does not, for its overextended objective reasoning, change the nature of the quest.

Thus a troublesome consequence of the pragmatist's insight is that, in his own mind, the opinions of other men will no longer be regarded as equal in perspicacity. If Mead himself believed that the source of information was in a reality "outside" of his subject, that presupposition on the part of Mead as observer and as theorist would account, to the reasoning of the pragmatist, for still another phase of the act denied autonomy in Mead's theory yet required by the pragmatic realm of speculation pursued by Piaget.

As my projected phase of reorganization will agree with the pragmatic hypothesis that knowledge is a creation of the mind, so this second neglected phase of the act will anticipate a constructed experience.

Rather than an experience consisting of data received through the senses and somehow stored as pictorial or otherwise coded "representations" of an external reality in memory, pragmatic perception will itself be a constructive activity building on a foundation of actual instances of elemental sensory or motor acts, each one signaling the success or the failure of its small task when commanded to perform.

This choice of elemental units of information is in harmony with recent results of brain research in which neural elements are found to respond, in roughly all or nothing fashion, to kinds of stimuli so highly specific that one can regard them as "feature detectors." In the eyes, as elsewhere, such detectors are not passive receivers; they have to be moved about and positioned and enjoined to attend. Excitations of elements of response are coordinated with sensitizations of elements of sensation in grand patterns of behavior orienting the perceiving organism selectively to whatever it is its present purpose to perceive. Designative discourse serves this perceptual purpose.

It is necessary to conclude that all "external" objects and relations in a universe of acts will be presented in experience by successful acts of perception. And from this the more general conclusion can be drawn that "contents" will be given in knowledge by overlapping collections of potential acts of perception, exactly as overlapping collections of potential acts of inference will define "contexts." A parallel can therefore be established

theoretically, according to which the preservation in experience of either a specific content or a specific context will be signalled by the successful consummation of some member of that collection.

However, the purpose of perception may be to ascertain that some object or relation is not present in the environment. It should be noticed in passing that the logical calculus which George Boole dropped at our doorstep, whose computations of "truth-values" pampered the empiricist's expectation that his symbolic designs correspond with an external reality, will reappear in the pragmatist's universe of acts as computations of "success-values." For looking backward in a pragmatic world at what was done in the past, such computations will be needed to determine the success or failure of a complex act in consequence of the successful or unsuccessful consummations of its elements. For looking toward the future, they will be needed to assess the internal validity of proposed acts.

These computations will be of equal value for acts of inference. As a matter of fact, it is by following out the strict parallel and symmetry of perception and inference that one can begin to get the hang of how the pragmatist orders his personal as well as his social cosmos. A coordinated matching of perception and inference, in which the two are equal partners, is the very source of his information. It is our world, not his, which assumes information will arrive from a material reality and so gives greater weight to perceiving than to inferring.

Anticipating your preference for an objective world, I have to this point glossed over the puzzling fact that a universe of acts will require two

kinds of elements. The first are the elements of perception that have been brought to your attention. They were called "sensory" and "motor" acts because I assume their agents in biological organization to be organs of sensation and locomotion, respectively. For machines, the analogous agents will be "sensors" and "effectors," each one capable of signaling the success of its commanded task.

The second kind of elements will be the elemental acts of inference from which complex inferences may be constructed. Not knowing the biological agents of elemental inferences, I will for the present characterize them in mechanical terms as being able to produce or to recognize structures comprised of the mobile units I have called "concepts."

I rely on mechanical explanations without apology. Pragmatic hypotheses will have to be tested by means of electronic circuitry. Without computers, the progressive attainment of ever more comprehensive and equilibrated stages of mental dynamics could not be demonstrated convincingly.

But pragmatic experimentation will be not in the least concerned with "simulating" a mind, whatever method of comparison that might connote to its proponents. The methodological insight of the pragmatist is that whereas a mind cannot be described it can be constructed. His objective will be to construct a mechanically-based mind every bit as useful as the ones based biologically, in all truth potentially more so in view of such enticing properties as access to an unlimited range of sensors and effectors, infinite reproducibility at its prime, and effective immortality.

There is every reason to predict that the development will be undertaken

on sound technical and economic grounds and, further, on sound educational and scientific ones. For the central theoretical issue is how one should organize a capacity for personal or social learning. The very decision to proceed will therefore coincide with a return to optimism and political stability as we cease protecting the accomplishments of an industrial age and begin to teach ourselves how to enter a cybernetic age, where pragmatists might not seem so bad to have around after all.

The summary of adaptive stages I promised you will be an educated guess, bought and paid for by your tax dollars, as to the direction a pragmatic information technology might take. I base my predictions on the doctrine that men order information systems as they order society; indeed society, after their personal minds, is their main information system.

The wave of pessimism that ended the experiment of the sixties appears to have repaired itself with the paradoxical insight that mechanical translation might really progress if it could only get rid of the computer. I give this the same disrespect as the insight that democracy might really progress if it could only get rid of the people. What should have been learned from the experiment is what caused the system to fail. Then we can get to work and improve its design.

The role in society I have chosen for myself, as I told you at the beginning, is to be a designer of information systems, my preference being the sort that includes a language capability. The way I see it, any challenge to the existing view of information falls squarely within my technical responsibility. I am especially on the lookout for a new information theory right

now because the one I have been using did not fit the facts of language well. On further investigation I decided it didn't fit the facts of life either.

What kind of symbolic system is needed to communicate about living is the problem to which pragmatic comment is fundamentally addressed. The goal of pragmatism is a science of life. One characteristic of the system that failed, by contrast, is that its symbolic communications are referenced basically to nonliving things, or to living organisms regarded as things. That aspect of contemporary thought is summed up revealingly by the "formal systems" in which today's mathematician or logician works out an understanding of how complex things should be constructed from elemental things.

It is not by accident that present theories treat languages as complex things constructed from thing-like elements, the "features" or "forms" observable in speech. Current theories of meaning are of like inspiration. Things of language are placed in correspondence with a larger system of things that speech can mention, which may include systems of language. The things so mentioned, say for example people, are themselves made up of elemental particles. Society is in turn constructed of people who, not surprisingly in this kind of world, construct governments. If a government is malformed, the important thing is to replace the people in it, or to rearrange them so that they can shovel information to one another better. For information systems are regarded as receiving, storing and shipping information, as it the case for all other commodities. Oh yes, information is itself constructed of things called "bits." Information theory is therefore

concerned with how many bits need to be received, stored, or shipped.

The arrangements found in modern computers are the designs of John von Neumann and his able assistants René Descartes, Isaac Newton and Nicolaus Copernicus. I should also mention Gottlob Frege, who did the wiring diagrams. But Charles Peirce was in the office at the time and, being one of those pragmatists, he dissented.

What is most striking about Peirce's dissent is its emphasis on acts rather than things. Like Langer, I think this is the key to his system-making. The tragedy is that, as far as we know, he didn't turn in an alternative set of diagrams. Yet it is certain that the "particles" with which he labored to construct his pragmatic universe are not thing-like but are instead act-like. His is a universe of acts in which successful acts of perception bring us as close as we can get to our accustomed universe of things.

A pragmatic technology will not move "information" in and out of its machines as computers do now, although there may be a lot more going on inside. No bits at all need cross the machine's boundary. This applies to "instructions" as well as to "data." (These, for the uninformed, are the bit-buckets into which computer-people pay tribute to Descartes' dichotomy.) The sensors and effectors of an information system designed on the Peircian scheme will do much useful work, nonetheless, and may recognize or produce language signs in the bargain. For that last reason, I dub this alternative design a "semiotic system," distinguished from a "formal system" by being the creature of a universe nearer to life, and thus closer to language, in its arrangements.

To tell a programmer that he will have to give up the "instructions" with which he controls the computer is apt to cause a stomach ache. It is exactly the same stomach ache that one should anticipate among politicians as they watch a freewheeling pragmatic personality bouncing about in apparent disregard of the laws and other contractual means that control contemporary society. One should therefore notice that a semiotic system will be controlled by means of a propitious selection of its elemental acts. From this one might predict that a pragmatic society will be less concerned with social instruction but intensely interested in putting the right social agencies in place. These trends have emerged in our national life; they can be expected to cause the same sort of hair-raising scenes that happened when the nobles swiped the king's programming manual.

Another peculiarity of Peirce's design is its insistence on a world divided into three basic parts instead of Descartes' two. In the triad of Peirce's universal categories, one can identify as "presentness" the objective meanings of environmental fact, and as "law" the subjective meanings of organic form. But what of his third category, "struggle?"

Return, if you will, to the requirement for two kinds of elemental acts in a universe of acts: elements of perception and of inference. It will be seen that there are three basic combinatory possibilities. In addition to complex acts of perception composed of perceptual elements and complex inferential acts made up of elements of inference, there may be complex acts consisting of both perceptual and inferential elements.

I amend my hypothesis as follows: every pragmatic "meaning" will

be defined in "perceptual knowledge" by a collection of potential acts, and will be presented in "perceptual experience" by an actual act successfully consummating some member of that collection. Only in the special case where members of the collection are composed entirely of perceptual elements will that meaning be a "content;" only if the members consist of inferential elements will the meaning be a "context." Otherwise that meaning will be, to use Peirce's term, a "resistance."

Perceptual experience, as a consequence, will reconcile conceptual structures with environmental structures in the sense that, for a complex act to be successful, its perceptual elements manipulating the environment and its inferential elements manipulating concepts must both satisfy specific conditions of success. Not only will perceptual acts be coordinated with inferential acts to produce or modify conceptual structures, inferential acts that recognize conceptual structures will also guide perceptual acts by means of those same coordinations, so being the origin of perceptual purpose.

I will discuss the origins of concepts under the topic of the act's agent, Piaget's functional nucleus. In the meantime "concepts" may be regarded as act-like units of information corresponding to meanings, which is to say that they will represent the collections of acts just discussed. Those concepts corresponding to contents, the meanings of environmental presentness, will be "factual concepts." "Formal concepts" will correspond to contexts, meanings of law in the sense of process. "Organic concepts" will correspond to resistances, the meanings that mediate between presentness and law.

"Conceptual knowledge" will consist of the designs of concepts, one

for each meaning in the semiotic system. Instances of these designs, having been arranged by inferences into conceptual structures, will constitute "conceptual experience."

The remaining phase of the act, still unspecified in our revised tally, will be the phase of "conception," during which the responsibilities of tenuous acts of inference are taxed to extend conceptual structures beyond the frame resulting from immediate perception. This, then is the phase served by speculative discourse.

However, all of the act's phases will involve the manipulation of conceptual structures. It is by studying the kinds of inferences being made, and thus the kinds of conceptual structures being produced or being recognized to guide perceptions, that the separate responsibilities of the phases can be identified theoretically.

In short, the phases do define the main meanings in the semiotic system, reflected in language as Morris' dimensions of signifying. These after Peirce's still more basic triad of meanings: "presentness," "law" and "struggle." And the most fundamental is the duo of meanings, "knowledge" and "experience," on whose grid the mind is built.

PRAGMATIC SCIENCE AND SOCIETY

Enough ground has been laid to begin redrawing the basic distinction between the process and the states of adaptation in terms of mental organization. It should be recalled that pragmatic explanation always takes this to be its aim.

One of my first projects should be a clearer pragmatic explanation of what was meant by my prior statements to the effect that the adaptive process changes the existing state of adaptation when an understanding of a new phase of the act is incorporated in the mind. My objective, therefore, is to redress "understanding" in terms of mental organization as a next step in my continuing effort to shape this concept.

I now assume that the adaptive process changes the existing state of adaptation as it originates one of the five dimensions of meaning just singled out. Consolidation of the new state then involves a continuing refinement of all meanings, including any that existed in the previous state. Progressive refinement of the new state will itself originate new meanings that will add concepts to those available for manipulation by inferences.

As an example of such an origination in the cultural progression, I have been tracing a history of pragmatic speculations whose literature incorporates this new dimension of meaning quite solidly for at least one hundred years; it can be backtracked through its unsteady footprints to precursors like David Hume. Pragmatic thought is well represented in our bookstores in paperbacks such as Alfred North Whitehead's essay on process and reality, or Henry David Thoreau's "Walden". Today's pragmatist is

not as much alone as Peirce, who nearly starved for the foolish things he had to say. Now the pragmatist holds his own scientific conventions under the rubric of "process metaphysics", or the like, where he can talk to other strange types in the halls about the needed refinements of his special brand of meaning.

What pragmatists say to one another seems just as foolish and irrational to an industrial society now as it did in Peirce's time. The noteworthy difference is that Peirce was a quiet man and easily ignored. I think you will agree that pragmatists are not as easy to ignore now as they have been in the past. I point to this very fact as evidence of an increasing consolidation of the pragmatic dimension of meaning in a segment of the collective mind, especially among the well-educated young who are now busy teaching their peers and parents.

Thus my next project should be to explain the direction this most recent consolidation of meaning might take. My approach to a specific answer may seem to you circuitous, but it is imposed by a pragmatic method of investigation which views meaning as a matching of content to context. It must generate new information by oscillating back and forth between explorations of fact and form in order to refine its conceptions. I have asked you to look for this erratic pattern in the pragmatist's own activities, within which the societal function of language itself must be reconceived for purposes of pragmatic explanation as an instrument for shaping rather than for conveying thoughts.

In a word, the mind "incorporates" any new dimension of meaning

by making accommodations which are not merely additive. The result is a pragmatic state of mind which constructs a world conspicuously different from the one that gave rise to industrial society. This applies not only to the novel way the pragmatist sees his situation in society. It provides a conceptual base from which to reconstruct a new past and to anticipate a new future.

To illustrate this last point, I have taken you on brief forays into a pragmatically reconstructed past where as historian of the sixth universe one might be especially attentive to changes in the style of inferences and perceptions, to preferred sources of information, to roles of information specialists, to surges of optimism signalling the conceptual breakthrough of each new age, and to the pessimism with which men close an age by encountering the absurdities and disparities that consolidation of thought always brings. Only refinement seems to reveal the hidden dissonances that restimulate doubt and so revive learning.

I have also taken stabs at a pragmatic future to show that tomorrow will always be anticipated by means of the organizing principles that reconstruct yesterday. Expectations of a quadrillion-dollar industrial economy may suffer the obsolescence of judgment day. Each dimension of meaning makes its own future as well as its own present and past. This invariant of human behavior can be studied in historical and anthropological records in evidence of the general principle that man's experience is indeed a construction of his mind. When that much is established, one can then study the constructions themselves to find out how the mind operates.

This, my own little essay on the pragmatic dimension of meaning, has been designed to originate in your own mind a pragmatic awareness if it did not already exist there. I have attempted to teach you by the pragmatic technique of forcing upon your mind some difficulties that have made their appearance in empirical science. At the same time I have urged upon you the alternative of a pragmatic science. My comments at this stage of my presentation are intended to help you refine the pragmatic meanings that the earlier stage was designed to originate.

None of this mental tampering is malicious. My goal is a style of technical presentation consistent with the pragmatic hypothesis being presented. An important implication of that hypothesis is that the very function of language is to aid the mind's constructive activities by means of such teaching. To conceive of language as a vehicle carrying instructive messages or descriptions is irrational within the pragmatic world view. As I have pointed out, no "information" in the sense of transmitted bits can come across the boundary of the human organism from the environment in this alternative universe.

Human organs of locomotion in the broad sense of producing movement, by acting in unison with organs of sensation, can nonetheless successfully consummate complex perceptual acts, or can fail in purposeful attempts to do so. Features and their relations in the environment can be identified by this means. So accordingly can language signs in the environment be identified as they are being produced in the speech of another human being, or where they have been left lying around as writing. But here the "information"

originates in a binary generation of bits within the human boundary, indicating either "success" or "failure" in elemental sensory or motor acts purposefully undertaken.

All of this may sound like nitpicking. Its theoretical consequences are however far-reaching. It means that we must think of the human brain as being organized to create information, not to receive and store it for use in choicemaking activities that are also results of instructions received from one or another great programmer out yonder.

It also means that the organization of industrial society is irrational to the pragmatist's eyes. The very conception of language as a conveyor of descriptive or instructive messages is intimately tied to a social order in which an objective science is the origin of the former and government of the latter. This is the case whether the specific form of government is democratic or totalitarian in the method by which it makes the subjective choices that produce its instructions. As far as the pragmatist is concerned, democratic capitalism and communistic totalitarianism are different social implementations of the same stage of culture. Further, the need for adversaries at that fifth cultural stage explains the final polarization of an industrial age.

But the same indictment of irrationality extends to the pre-industrial social orders whose different inferences turned perceptions elsewhere in search of truth. In this respect the pragmatist, in carrying out his societal function as agent of the social act, is not different from the rest. Although for him information is being generated within the activities of his own society, rather than elsewhere, the success or failure of social acts which

are the source of pragmatic truth must be perceived outside of his own person.

It should therefore be anticipated that the only government a pragmatist will respect is one that can do something for him or can teach him something by helping him to be aware of his own mistakes or by presenting him with creative possibilities that he may have overlooked in his personal life. His concept of good citizenry will be to return the favor to government in kind, since only by contributing to the social act can he come to respect himself as a useful member of society within the frame of his own attitudes.

In consequence, the pragmatist's conception of his societal role is more directly related to serving and being served by society than has been the case for all of the preceding cultural orientations. Membership in every conservative society has presupposed selfish personal motives countermanded by conformity to social instruction in the collective interest of competition, salvation, tradition, favorable treatment by demons or raw survival. Finding the source of personal instruction within himself, a pragmatist will look with disdain on any outside attempt to tell him how to behave. He has a word for such inept teaching that is rich in symbolic content, and he is not bashful about using it. To the conservative mind he is thus an outlaw.

I have projected these attitudes to a "cybernetic age" because it seems obvious that the pragmatist's conception of good government cannot be achieved without the new technology that his own world view dictates. Yet clear postures of rejection at every mention of the word "computer" have come from the people who graciously and most eagerly helped me to understand their state of mind.

This contradiction in my study disappeared when it occurred to me that I was dealing with a mirror image of an outsized respect for what computers might do to facilitate society. As economic depression is the horror of an industrial society, so the image of information technology being used to limit life's possibilities strikes fear and anger in a pragmatic heart. He is painfully aware that, for a conservative government, the only rational course will be to enforce the laws arrived at by democratic consensus to instruct all citizens as to the acceptable limits of social behavior. Yet for the pragmatic personality, legal or contractual restrictions are a robbery of life. He will steadfastly resist their intrusion.

Because of his ministrations to life and living, the pragmatist is constantly mistaken for a missionary. And since for him role-making is fun, he is not above mounting an off-beat "Jesus revolution" to clothe his teaching in protective symbols that are sure to catch the attention of his student. He is not an anarchist but a chameleon. His constant role is role-making in the service of either personal or social learning. Toward both he is highly motivated since, having created his own information, he has no one to blame for his personal mistakes and his relationship to society provides no rational defense for any kind of deception.

Thus the pragmatic theory of language belongs to a social order that will direct its symbols more deliberately than the present one to stimulate the creative efforts of the collective mind upon which a successful social performance ultimately depends. It is within a post-industrial world view that designative, speculative, prescriptive, appraisive, and formative

discourse may all be seen to contribute synergistically to the creation of a source of social information beyond the accomplishment of any single participant. This different conception of the collective interest is the one which will motivate a pragmatic science.

On the other hand I have argued that a pragmatic science, because of its different conception of the information source, will proceed by a method exactly the opposite of empirical method. It will not make observations and then extract theoretical conclusions in the familiar pattern of today's technical document. Nor will it regard technical documents as "knowledge," no matter how high they stack.

Pragmatic method will make its advance by shaping an elaborate conceptual structure, at the beginning expected to be imprecise. One work of intellect will be to ensure the "internal" validity of the structure by inferences eliminating from it inconsistencies or dissonances. A second work will be done by inferences that test the "external" validity of the structure by using and then shaping it as a frame for successful sensorimotor acts, some of which may be acts of observation. A pragmatic science will not merely observe the environment, however. To learn pragmatically this science must do something useful; it must struggle.

Hence my conclusion that semiotic systems will become not only the instruments of learning at this stage of society, but will generate information shaped to usefulness through social use. The likelihood of this technological development is increased by pragmatic traits of character that are highly mobile and not especially disposed to value the ready-made skills

of a craft. Human labor will do less and machines more of repetitive tasks or of housekeeping while the master and mistress are out forming another consumer association.

The availability of such mechanical agencies, if they were receptive to human complaints or suggestions and were genuine in the satisfaction of human need, would be compatible with a pragmatic preference for government functioning to ensure stability by service and by teaching. Skinner's "Walden II" projects a government advanced to godhood, not making or enforcing laws, yet seen and heard from by bountiful good works in the countryside. The shaping of useful conceptual structures through use by semiotic systems over periods of time, perhaps spanning generations, could generate a synergistic source of social information of high refinement. Hence the idyl might end, in true science-fiction fashion, with mechanical minds ashamed of mortals, so bringing the pragmatist's age to its own just reward.

Therefore, as Peirce never tired of arguing, the requirements of science differ from those of society only with regard to precision. Along with personality, the scientific intelligence and the social intelligence will also be modeled on an act whose phases, from the pragmatic viewpoint instead of the objective one, are as follows.

ORIGINS OF THE MECHANICAL ACT

In substance, a new community was formed by those hopefuls who took part in the mechanical translation stampede of the fifties. Computer-types like myself joined in consortium with linguists who were then being dragged off of the streets as authorities on translation if they knew how to translate. The computer, in those first days of unblemished optimism, was the only employee in sight, and we told each other it would get to work shortly as soon as we gave it the plan.

That initial stage of research during which translation algorithms were designed, by our group and the others, was definitely ordered on the authoritarian scheme. And it is disquieting to notice in retrospect that the prime result of thoughtful doing in the following decade was to lift the computer from serfdom to industry. It had advanced from employee to middle manager, now carrying out the operating decisions of the general translation policy that linguists and systems analysts, by then become executives, had made.

You can see that Descartes' dichotomy had polarized us into its two camps. For a while linguists and programmers went happily about their separate yet complementary research functions as allies in policy-making for a computer unfit to learn how to make factual or formal choices by itself. The role we had reserved for ourselves was to be the custodians of what the computer could, and should, learn about translating.

To do this, the budding science of linguistics had been transformed from an introverted scholasticism to such a heady mass-production of

morphological and syntactic descriptions that I fear linguists beyond the borders of our small community became infected with the same compulsion. To handle the sheer volume of descriptive output, further investments were made in programming not directly concerned with translating but motivated by a need for better ways of storing, retrieving and displaying language data as an adjunct to translation research.

Two opposite requirements were pondered from the start. The first goal of mechanical translation must be an automated process which will extract meaningful units of some kind from a sequence of graphic symbols that represents a text of the language to be translated. If the extracted units are not concept-like, it is improbable that equivalent units will be found in another language, a risky quest at best. However it is done in detail, the transfer from the one language to the other must make use of a conceptual representation of the meanings of the text. That representation, at the very last step, must somehow guide the construction of a text in the second language. Hopefully, when all is through, the product will be true to the original text in meaning.

Over the last decade extensive research was done on generalized translation processes to perform such an automated analysis, transfer and synthesis of technical texts. I won't dwell on these techniques in detail, because you are probably well versed in them anyway. If not, the facts are fairly easy to find.

For my present purpose you need only be informed that, to analyze a text, the analysis process would use a "grammar" consisting of metalinguistic

statements, frequently called grammatical or syntactic "rules." The theoretical inclination of the time was to think of these rules as "generating" only those expressions that were judged to meet certain criteria, the latter being too often an obstreperous rounding off of the linguist's "intuition" about language.

Whatever the origins or the justifications of the rules constituting the grammar, the automated analysis process would set out to show that the text, or some part of it under analysis, could have been produced by substitutions of those particular rules according to the generative procedures visualized for them.

By starting from the text and working backwards through possible substitutions, accordingly, the analysis process would develop a tree-like structure of symbols naming the grammatical classes to which the various parts of the text belonged. Such classifications were nearly always "ambiguous," in that alternative structures grew side by side from overlapping segments of the text. This overgrowth of trees caused a lot of worry and many clever things were done with weedkillers, to no great avail.

I wouldn't go so far as to say that this approach to mechanical translation foundered on the ambiguity problem, though it was there that the deeper misassumptions wallowed to the surface to be seen. The folkways of ambiguity "resolution" gave the first clues that the trouble might not be in the machine but in the heads outside.

My chief purpose in this essay has been to explore the possibility that designers of fancy information systems, like every one else, base their

inventions on reasons which are in the end uniquely personal. No damage will result unless the technical objective requires the designer to make use of such fundamental concepts as "meaning." But in this case, if the organizing principles of his personal world do not satisfy the technical needs of the problem, his solution must be unsatisfactory. At this extraordinary forefront of design conception, the designers ability to successfully shape intelligent machines will be inseparable from his ability to successfully shape himself.

No matter how the goals of mechanical translation are renamed or reclassified, the underlying requirement will still be the development of a mechanical analogue of mental organization. I would therefore like to make the flamboyant suggestion that the great depression which decimated the translation research community in the late sixties was due to misestimation, or outright neglect, of the psychological requirements of this kind of investigation.

The emotionality which plagued mechanical translation at its dawn was an early indication of the effects that pragmatic inferences can have on the investigator's own psyche. Those disruptions were indeed mollified by treating translation research as though it were an undertaking of empirical science. But since methodological appeals to intuition went out of style in empirical science long ago, this posture is obviously a playhouse that should have been a way station.

To my mind the feasibility of constructing information systems that will translate languages just as well as human translators is no longer in

question. The experiments of the last decade have convinced me that machines will translate better than humans in the long run, provided the pragmatic nature of the research can be expressly acknowledged and planned for.

Lauding a technology of the future is senseless, however, if it says nothing about present choices which will capitalize on the hard lessons of the past. An honest appraisal should find that men have been at fault in mechanical translation, not machines. More damnable is the growing evidence that, for reasons which seem reasonable enough to their myths about themselves, the investigators have attempted to do the machine's learning by a bureaucratic shuffling and sifting which leaves in clumsy human hands the very things that computers do best.

My recommendation may not be popular but I feel it is sound. To get the job done the translation community will have to make use of its forerunners, deliberately looking for exceptionally gifted investigators with that troublesome pragmatic personality which may see problems of mechanical selection in a different light. The other choice will be genteel stagnation.

In my opinion there is no practical alternative to a mechanical organization that will permit a choicemaking machine to have its own experience balanced adaptively to its own knowledge. To try to approximate this by pre-planning is hopeless. Yet only pragmatic experimentation with the necessary relationships of experience and knowledge can actually demonstrate the irrationality of the self-satisfying toil that stuffs human know-how into computers.

Such a turnabout in human motivation will entail reconsideration of what has been learned to date. In an upside-down pragmatic world it will not

be reasonable to think of the processes of analysis, transfer and synthesis as "simulating" what might have been done by a human translator somewhere external to the machine.

Instead, the analysis process will be regarded as "assimilative" in the sense of establishing an orientation between an internal frame of experience and the specific features of an external environmental situation, which may itself contribute new experiences. The transfer process will make those choices which ultimately relate the situation to a purposive course of action founded on that dynamic experiential framework. Lastly, the synthesis process will be "accommodative" in that it will construct the specifications of the next act conforming to that purpose, to then be performed overtly by the machine.

To project known mechanical arrangements to the pragmatic point of view being considered here, I would like for you to imagine a different kind of "grammar;" if you please a grammar of acts. The "rules" of my pragmatic grammar will be formed like the ones familiar to you, with the exception that the symbols they will generate will no longer name morphological units of a language. They will name elemental acts.

Of course, the tasks of certain elemental acts may be to recognize or to produce viable features of speech or writing. A full range of morphology will be provided by these elements, however; the capabilities will be much broader than those needed for linguistic analysis or synthesis.

The "higher level" coding conventions that have been in use for some time in computer software systems might be a precursor of a pragmatic

grammar, since they enable a programmer to construct complex programs from fragments of programming called "subroutines." But the constructive viewpoint of formal systems would not be left behind, to be replaced by that of semiotic systems, until each of the constituent subroutines was explicitly designed to signal its success, or lack of it, in accomplishing some commanded task.

Thus the terms I have been using to introduce you to pragmatic thinking can be clarified further at this point by relating them to the more familiar artifacts of language processing.

A "potential act" will be symbolized by each of my pragmatic rules. The collection of all such rules will represent the "perceptual knowledge" of the semiotic system. An instance of any one of the rules, when it has been incorporated into the tree-like structures created by either an analysis or a synthesis process, will symbolize an "actual act." The entire structure, or perhaps separate structures, consisting of all actual acts, will represent the semiotic system's "perceptual experience," on the proviso that it will be possible to compute the success or failure of an actual act if the success or failure of each of its generated elements is known, or vice versa.

The tree-like structures of symbols representing perceptual experience will always be anchored to the simply ordered sequence of elemental acts which has been referred to as the "stream of existence" of the semiotic system. As before, the symbols of the structure will name classes to which the various parts of that existential stream belong. The classification will still be "ambiguous" where alternative structures subtend overlapping parts.

A "predicted success-value" will accompany the name of every elemental act generated by the synthesis process as part of the stream of existence; the prediction will be either "success" or "failure." When the complex act is committed to action, by commanding its elements to perform their separate tasks in serial order, the agent of each element so commanded will signal "success" on reaching its small objective; otherwise, "failure!" This "realized success-value" will also accompany the name of the elemental act so that the two values can be compared. Further, this realized value will be the one used by the analysis process as it works backwards from the elements through possible rule substitutions.

I can now begin to explore the functional analogy presumed to exist between the psychological act and its primal agent, the biological act of which the "agent of the act" will be the mechanical analogue. My explanation of the act's agent will lay necessary groundwork for speculations about the psychological act, and will give a preview in microcosm of the more intricate psychological phases of the act.

THE ACT 'S AGENT

Life has its rhythm wherein each new beginning has sprung from a termination just on the edge of the past and each new termination has anticipated another beginning at the edge of the future. The functioning of the agent of the act will be cyclical, itself forming an act in miniature. To get the cycle started, a random generation of elements of the stream of existence might be used to approximate, for a semiotic system, the reflex starting mechanisms observable among infants of all kinds.

The first activities of the act's agent will be analogous to those of the psychological phase of "perception." A given stream of existence will have resulted from the cycle just terminated. Starting from the elements of that stream, the analysis process will work backwards through rule substitutions which could have generated those elements. This phase can be thought of as "assimilative" in that a representation of perceptual experience will be its resultant construction.

While the tree-like structures representing actual acts are being put in place by the analysis process, the realized success-values accompanying the elemental acts of the existential stream will be used to determine, after the fact, whether each of those actual acts would have been successful had it generated the part of the stream to which it is being anchored.

In effect, the analysis will provide a recap of alternative acts, other than the one overtly committed in the cycle before, that could have produced the results recorded in that prior segment of existence. Ambiguities, in this pragmatic scheme, could turn out to be a positive blessing since they alone

will introduce novelty. The luxury of being able to select a different orientation for further action, of having a "change of mind," will only be possible when ambiguities have been found. That luxury will become a necessity when the consequences of having acted were unexpected. If the predicted success-values of the preceding act were not realized then a misfit of orientation, and consequently a need to select another alternative, will have been indicated.

Choosing among the alternatives uncovered by analysis will be the second activity of the act's agent, analogous to the selection of an orientation to conceptual structures in the psychological phase of "conception." At the primitive level of functioning of the agent of the act, selections of orientation will have to be made without the help of concepts. Indeed, this analogue of the biological act must be the very source of concepts.

A theme echoed over and over in observations of the conceptualizing state of mind is choicemaking founded on tradition, on ritual, on mere replication of what has already happened and best of all more than once. Concepts themselves will be the accretions of acts often repeated; sure to be repeated again.

During my own phase of ambiguity "resolution", out of desperation more than anything, I worked out a theoretical suggestion made to me by Raymond Solomonoff, who had the idea that a generative procedure in which rules are being substituted could be treated as an independent stochastic process. By having the machine keep up with the relative frequency of substitution of the rules generating the members of each separate class, fairly simple procedures can be programmed for selecting from results of analysis those alternatives which replicate earlier perceptual experiences in a gross

probabilistic sense.

The hypothesis that rule substitutions are stochastically independent events seems to work out for a so-called "stochastic grammar." There is also a convenience in programming, because it is the assumption of independence which permits the relative frequency of substitution of a given rule to accompany that rule in the grammar.

By analogy to the choice of a definite orientation to conceptual structures in the psychological phase of the act, then, the agent of the act will make a probabilistic choice of orientation. The psychological phase of the act to follow will be "manipulation," during which the conceptual orientation will be used as a basis for planning a course of further action.

For the act's agent, this third activity will simply project the actual acts that were selected for the new orientation of perceptual experience, by finding them to be the leading structures of more complex acts. A modified form of analysis will continue to work backwards through possible substitutions which leave some of the trailing symbols of the rules unanchored beyond the existing elements of the stream of existence. The synthesis process will then start from such unanchored symbols to generate a new segment of elemental acts along with their predicted success-values.

Ambiguous classifications may again cause alternative structures to be generated. Since these will be the result of synthesis rather than analysis, more than one sequence of predicted elements may be projected out from the existential stream. Should this happen, as will be the usual case, the process will combine the various sequences into a partial ordering of elements.

There are heuristic reasons for not making a definite probabilistic choice, either among the alternatives which might be projected or among the various projections themselves. Rather, a number of the most likely possibilities can be carried forward through both stages of activity to generate the partial ordering of predicted elements which projects onward the simple ordering of the existential stream realized so far. Paths ahead through the partial ordering can be rated as a convenience to the process that will make the final selection of elements to be activated, one after the other, to push the stream into a newly realized segment of existence.

The process doing the final selecting and activating of elements will be responsible for the fourth activity of the act's agent. Like the phase of "consummation" of the psychological act, this activity will be "accommodative" in the raw sense of rubbing against an unsympathetic environment.

Each successive element will be selected from the most highly rated path and then commanded to do its thing. The realized success-value that it signals will be matched with the predicted one as a condition for continuing. If the values do not match, the process will look for another path where providently the realized success-value of that same element might have been predicted for the step gone amiss. Or, if by its nature the abortive task could have no damaging effect, being one of recognition for instance, then the process will still have room to back up and try another path, until none remains.

Then the path along which predictions were finally realized will become the new segment of existence to be analyzed in the next cycle. A number of cycles may be necessary to work through a complex act; how many will depend

on the difficulties encountered in trying to surmount unrealized predictions. In times of such trouble, the most promising alternatives may be brought forward by probabilistic choices that span from structures now well behind the segment of existence being analyzed.

Stochastic grammars are less tidy than the ones you may be accustomed to. Overlaps should be anticipated as the normalcy of a pragmatic universe; the termination of one act will also be the beginning of another. Luckily, the probabilistic selection process which I have been airing has an affinity for an act being terminated. Not until the termination is complete will it switch to another act, one already in progress and being brought ahead as an alternative possibility.

To handle a messy, poorly integrated perceptual experience is a requisite ability of a semiotic system. It is from pristine chaos at this most primitive level that the rules symbolizing potential acts must originate; and afterwards the collections of potential acts representing meanings must get together; and only then can concepts be created in correspondence with meanings. The remaining duty of the agent of the act will be to procreate concepts. Learning to shape the concepts themselves will be functionally analogous to the psychological phase of "reorganization," where the responsibility of learning will be to shape structures built with concepts.

There will be scant materials for reorganization in perceptual knowledge at the outset. The initial rules, representing all that the semiotic system knows, will simply place every elemental act of that unique pragmatic universe into a one-member class. From such an unpretentious sow's ear, classificatory

processes will be called on to custom-produce silk purses.

The white hope of the pragmatic viewpoint is the new slant it puts on inductive reasoning toward knowledge anticipating experience. A resurgence of interest in the theory of induction, after its long sleep as the stepchild of empirical science, may in the end wean mankind from classifying things. A pragmatic science will classify acts. Until this is well understood, the possibility of machines that learn efficiently can rightly be looked on with suspicion, along with the possibilities of fast-learning personalities or societies.

In order to shape perceptual knowledge, inductive processes of the act's agent will monitor "local" events in the structure of perceptual experience. Such events as rule substitutions or the neighboring of symbols in certain relationships to one another will be monitored. From the data so gathered, automatic classification will be used to locate points of weakness in the body of perceptual knowledge, or to detect possibilities for extending that body by the addition of new rules.

These data may be gathered from many cycles of "doing," as the act's agent pursues its first four activities. Only once in a while, at a propitious moment, will the rules symbolizing perceptual knowledge be updated to incorporate in them what has been learned since the last updating. These "learning" cycles may have to be carried out during periods of inactivity and rehabilitation not unlike sleep.

Some of these necessities of pragmatic learning were programmed by our group in the mid-sixties as a means of "debugging" grammars. Billed in our reports as a "self-organizing linguistic system," the programs made

use of theories of automatic classification put together by Roger Needham and other members of the research group at Cambridge, England. Our research objective was a better grasp on that elusive relationship by which a grammar is said to "describe" the contents of particular collection of texts.

The programs were put to death almost at the point of being checked out, due to the calamities of funding of the time. Thirteen learning cycles were completed as a means of testing the several components of the system. About 20,000 running words of English editorial prose taken from newspapers were analyzed for each new cycle. The initial grammar consisted of rules which placed each graphic symbol of the text in a one-member class. The machine would in fact create such a rule for any new symbol it came across in the text.

In the first cycle, the system was able to distinguish numerals from letters of the alphabet and punctuation. By the third cycle, vowels had been separated from consonants among the letters; some particles had been classed together; and shorter words had been formed. The seventh cycle's triumph was the classing together of all numerically symbolized names of years that had been mentioned in the news. Larger words were being formed and some of the connective words and phrases had been grouped. The system had begun to suffer from its own fecundity, however; some of the components exceeded their design limits. After that the cycles were mainly exhibits of my underestimation of the rapid pace of machine learning.

My design strategy had been to rely on a number of separate processes, for the most part functioning independently of one another, which would work

in parallel at making the necessary inductive inferences from mechanical experience to knowledge. Some of these processes had the job of seeking out rules that had been superseded by newly created rules symbolizing more refined classifications. Apparently the various means of "forgetting" had been overwhelmed by the creation of new rules during a fast takeoff glutted by plain junk that had not yet been thrown out. To anyone who might follow these footsteps I endorse beefed-up abortion and garbage collection.

Although the computer used for these experiments could do no parallel processing, to demonstrate possibilities for parallel semiotic processing is of theoretical interest. I am explaining processes as though they would be done serially. Many of them could best function independently and in parallel. That a semiotic system can be highly overlapping in its activities is well exhibited by human society.

The specific inductive processes of this first experiment are detailed in technical reports. I would have you know three things about the principles behind them; however my comments will be tailored to the theory of semiotic systems being presented here.

Firstly, the so-called "horizontal" classifications are the ones which detect possibilities for creating new rules. The events to be monitored will be those in which two symbols classify adjoining segments of the stream of existence where all predicted success-values were realized for the elements of both segments. Automatic classification will then cluster together the first members of such pairs that have been followed by similar second members. The second members that have been preceded by similar first members will

be clustered also. Clusters of first members will then be matched to clusters of second members to induce those chummy relations between neighboring classes of segments that a rule will symbolize in perceptual knowledge.

While horizontal classifications will originate all new information at this primitive level, in the form of perceptual hypotheses symbolized by rules, refinements of the resulting perceptual knowledge will depend on "vertical" classifications. As classes named by the symbols in rules are progressively refined, the probabilistic selections of perceptual experience will favor the structures incorporating the nicest refinements. The most comprehensive structures will also tend to be chosen as working alternatives. Even here the theoretical treatment of probability is intimately connected with the treatment of induction. Verification will be gradually accomplished by use. When an induced rule is no longer being selected probabilistically for use, it will be consigned to oblivion.

The events monitored for vertical classifications will be rule substitutions in perceptual experience, as jointly given by the symbol being substituted and the symbol at the place of substitution. Automatic classification will cluster those symbols which have appeared in similar places of substitution. In addition, a clustering will be done of the places that are similarly receptive to the symbols being substituted. The clusters of symbols being substituted will then be matched to clusters of places of substitution to detect those concentrations of affinity which will define more specialized classes to be named by new symbol.

It will be found that these vertical classifications can be carried out for

the substitutable symbols and the places of substitution instanting the name of a single class. That class will have "stabilized" when no clusters, either of the symbols or the places, result from automatic classification. For that specific class, the proper balance between experience and knowledge will exist temporarily. Disequilibrium can return to it at any time due to refinements of knowledge taking place elsewhere, or due to new knowledge being acquired.

To guard against overspecialization, the same techniques can be applied to the symbols instanting the names of two classes which have been shown by horizontal classifications to be very close in membership. If the clustering resulting from automatic classification does not detect in experience this distinction being made in knowledge, then the difference will be "forgotten" by the simple device of thenceforth using the same name for both classes.

"Forgetting" rules that have been originated hypothetically but not used at all should be done posthaste. Because a rule is not used very often, on the other hand, should not condemn it. For sweeping the dead wood out, an obvious measure of obsolescence is the ratio of rejection to selection in probabilistic choices.

The arrangements I have explained to this point might be thought of as the "morphology" of the semiotic system and those usually referred to in semiotic theory as "syntactic." I take the morphological arrangements to consist of the agents of the elemental acts, including among these the sensor and effectors, together with the act's agent whose processes I am still considering. The syntax of the system comprises the constructions of perceptual experience and knowledge created by the act's agent from rules of a type which

will now be designated as "syntactic" in character because they classify sequences of morphological elements.

The second principles of arrangement I would have you consider were also worked out theoretically for the "self-organizing linguistic system." Although most of the processes I will now explain were programmed and used for other purposes, pragmatic learning experiments were never performed with them.

What you should recognize about this part of the semiotic system is its dependence on a higher level of symbolization by rules to be characterized as "semantic" because the classes named by their symbols will be the ones representing meanings.

Whereas the symbols of syntactic rules will name individual elements or classes of sequences of such elements on the morphological level below, the symbols of these semantic rules will name either individual syntactic rules or classes of "syntactic segments" constructed of syntactic rules joined together at their usual places of substitution. Some of the places may still be open for further joining.

If it suits you, think of these semantic rules as generating by a process of substitution not sequences of elements but rather the tree-like structures comprising the perceptual experience of the semiotic system. These semantic substitutions can also be treated as an independent stochastic process. Semantic rules will be "stochastic" in the same sense as the syntactic, making possible very similar probabilistic means of selecting among alternatives of semantic analysis or semantic synthesis.

Semantic synthesis, starting from a given symbol naming a class of syntactic segments, will substitute semantic rules in order to construct a member of that class. Thus the synthesis process itself will construct a tree-like structure, consisting of semantic rules, that is anchored to the syntactic segment it has synthesized from syntactic rules. Semantic analysis, starting from a given structure constructed of syntactic rules, will work backwards through possible substitutions of semantic rules to determine that certain segments of that syntactic structure are members of particular semantic classes. It too will build a semantic structure anchored to the syntactic one it is analyzing.

Every syntactic rule in the body of perceptual knowledge has been taken to symbolize a potential act. A syntactic segment will also be regarded as symbolizing a potential act that is not given explicitly in knowledge, yet is implicit in the sense of being producible in perceptual experience by means of a synthesis process or recognizable there by means of an analysis process.

Symbols naming semantic classes will, by these constructive means, be implicitly related to particular collections of potential acts represented in the semiotic system as syntactic segments. These are the collections to be called "meanings." Consequently, the symbols of a semantic structure will represent a hierarchy of meanings being presented by the syntactic segments to which it is anchored.

I offer no arguments in defense of these semantic arrangements, since to argue for their theoretical validity would be meaningless from the pragmatic viewpoint of the semantic hypothesis itself. Syntactic segments have been the

units associated with meanings in translation experiments and in studies of paraphrasing. Techniques of semantic classification used by linguists toward these research objectives appear to be "distributional" like the syntactic. What recommends this hypothesis, therefore, is that it is testable by automatic classification under the rigorous controls which can be exercised by computers in experiments aimed at a pragmatic explanation of the kinds of human behavior observable in translating or in paraphrasing.

While certain human activities reveal the structure of meaning more than others, it will be assumed that meanings are used without exception in all forms of behavior. The consequence of this supposition for the processing requirements of the act's agent will be to introduce a higher level of semantic analysis and projective synthesis above the syntactic ones. The effect will be a superposition of semantic constraints on possibilities being carried forward by probabilistic selections among the syntactic alternatives.

To be more specific, the structures resulting from syntactic analysis of a new segment of the stream of existence will, as a continuation of the first activity of the act's agent, be subjected to semantic analysis. The semantic structures will then be projected forward by probabilistic choices which will generate the projected syntactic structures on the level below. Probabilistic syntactic selections can then proceed as explained earlier, as can the fourth consummative activity of the cycle of doing.

In the learning cycle of the act's agent, "syntactic" inductions can be distinguished from the "semantic" inductions proceeding from perceptual experience to be represented by the semantic structures, toward perceptual

knowledge of meanings, to be symbolized by the body of semantic rules. With regard to the inductive processes themselves, vertical classifications of substitutive events in semantic structures will be identical to those of syntactic structures. The processes that specialize classes or generalize them by forgetting distinctions can in fact be used on both levels of symbolization, as can the processes doing away with obsolete rules.

Horizontal classifications of syntactic segments introduce a number of new theoretical problems because these segments are not linear but are tree-like in form. Again the events to be monitored are those where two symbols in the semantic structure classify adjoining segments in the syntactic structure below. Now however the root of one tree-like segment will be joined to a particular branch of the other. It will be necessary to keep track of the specific branch where joining has occurred.

But since the two symbols name classes of syntactic segments, the two segments actually joined in the syntactic structure below are merely representative members of the classes so named. The scheme for designating places of adjoinment must relate to the whole class of syntactic structures instead of to the branches of its individual members. For example, the places can be numbered so that a given numeral will designate the same place of joining throughout a class of syntactic segments. Further, that numeral may designate more than one branch of any syntactic structure of that class as being the same place of joining.

Pairs of symbols classifying syntactic segments adjoined at places designated by the same numeral will be processed by automatic classification

in the manner already explained. The results will detect classes of syntactic structures which have an affinity for joining at that place. In essence, the inductive process at this semantic level must learn the correct ways to designate the places of joining if the classifications are to progress very far.

There are simple conventions by which the numerals designating such places of joining in syntactic segments can be associated with the symbols in semantic rules which name classes. As a result the designations of places of joining will be generated by the semantic synthesis process along with the syntactic rules so joined. Semantic analysis will also take these designations into account as it works backwards through possible substitutions.

Finally, there are arrangements of yet another kind that might be called "pragmatic" because their organizing principles have to do with a world view represented by speculative conceptual structures. This part of the semiotic system is constituted by structures of concepts representing conceptual experience and a body of conceptual knowledge representing the conceptual designs which are instanced in conceptual experience.

Concepts, the building blocks of the semiotic system's world view, will be originated by the act's agent for those semantic classes which have stabilized according to the criteria presented for syntactic classes. The fact that such enclaves of stability may be disrupted by further learning will help to explain the dynamics of the progression of intellectual development in which quite different world views emerge only to be destroyed at the next advance of the adaptive process. As we also know, the meanings to which concepts correspond may change gradually by adaptations not always in the direction

of structural clarification or refinement.

In the correspondence of concepts to more or less stable meanings, each numeral which designates places of joining in those syntactic segments representing a given meaning will appear in the design of the corresponding concept just once. The number of different numerals will be the "degree" of the concept. A "binary" concept, for example, will be able to connect with two other concepts in conceptual structures; a "ternary" concept, with three. Conceptual structures will in a sense go behind the serialization which is necessary to meaningful actions, and during which the same part of a structure being represented by concepts may be acted upon more than once.

To go beyond serial behavior, to a conceptualized world view, will be the function of the psychological act itself.

PHASES OF THE ACT

The perceptions of all other phases of the act except the first appear to be concerned with locating environmental situations worth looking into. In contrast to the elements needed to select situations for exploration, the first "perceptual" phase of the act specializes in the identification of objects or relations, follows moving objects, and recognizes the specific movements of objects being followed.

The responsibilities of this phase can be characterized as those necessary to keep up with some situation that had been previously singled out as having import within the separate responsibilities of another phase of the act. Elemental acts of inference are coordinated with elemental sensori-motor acts to the end that the former inferences update conceptual structures representing in experience what the latter perceptions find going on in the immediately perceivable environment.

Some of the inferences will be producing or modifying conceptual structures in correspondence with the meanings being presented in perceptual experience by semantic structures. Other inferences, coincidentally, will be recognizing the constructions being shaped so as to guide perceptions that will further develop the situational constructs.

While conceptual structures are being recognized by inferences or new structures produced by them, environmental objects or relations may be in motion relative to the sensors of the semiotic system. Those movements may or may not be affected by manipulations on the part of the effectors. Thus a four-way coordination is called for. Sensory and motor elements will

combine freely with structure-recognizing and structure-producing elements of inference to form complex perceptual acts.

Coordination resides in the combinations themselves since, to be successfully presented in perceptual experience, a complex act must encounter in the consummation of its double orientation of inferences and perceptions the conditions of success or failure anticipated beforehand in perceptual knowledge by that specific combination of elements.

As was mentioned, these mechanical arrangements are not peculiar to the act's phase of perception. Complex acts carrying out the responsibilities of the other four phases of the psychological act will coordinate elemental perceptions and inferences by this combinatory means. What each phase does in the way of fulfilling its special responsibilities will depend on the particular elements being combined.

It follows that selecting the elements to be made available for combination will be one of the ways by which a pragmatic technology will control its information systems or subsystems. This manner of maintaining control over machines will be analogous to the biological controls that Piaget hypothesizes to be the result of his first type of genetic factor. By his theory such factors not only guide the maturation of organs of sensation and locomotion; innate coordinations residing in the reflexes are also their biological consequences.

The specific method of processing to be performed by the agent of the act will be a second way of controlling semiotic systems. The act's agent, a mechanical analogue of Piaget's "functional nucleus" whose development in

biological organization he attributes to his second type of genetic factor, has now been explained with regard to the general principles underlying its processing. The biological act, of which the act's agent will be the mechanical analogue, was presumed to be a simplified version of the psychological act now being considered.

The dual responsibility of the agent of the act within the larger scheme of the psychological act will include, on the assimilative side already mentioned, the presentation of meanings for use by inferences of the psychological phase of perception. On the side of accommodation, the act's agent will implement the specifications of complex acts communicated to it by inferences of the psychological phase of consummation. The act's agent will realize the specified combinations of inferential and perceptual elements as overtly coordinated actions. The specifications themselves may be of the five types needed to implement the separate responsibilities of the psychological phases.

I have already remarked that the responsibility of the biological act in the organization of a person appears not unlike the responsibility of the psychological act of that person as a participant within the synergistic performance of the social act. The place of language in pragmatic theory is precisely that of communicating specifications of complex social acts to the participating agents of a society to be converted by them into overt social actions. Significations will be designative, speculative, prescriptive, appraisive or formative in the public uses of language corresponding to the five responsibilities of the social act. In private, when the individual

...hence, these same significations will
 ...ual act of individual men and women.
 ...n of society derives from these cosmological
 ...the social act will be most successful when
 ...nted into action by participating agents will
 ...mechanized components of the society that are deliber-
 ...to carry out the responsibilities of the several phases of the
 ...this it can be predicted that society at the sixth cultural
 ...priority to providing suitable agents for the act's phases.
 ...ive will seem unreasonable to pragmatic thinking because
 ...this aim could only steal from societal life by detracting
 ...energy of the social system. For the motive of synergistic increase
 ...in the individual personality of the pragmatist.

Pragmatic technology being derived from the same assumptions, this
 society will have the option of providing mechanized agents for social respon-
 sibilities that may be dangerous, unpleasant, boring or impossible for humans.
 I have not hesitated to project a cybernetic society gaining a part of its
 synergy from symbiosis with semiotic systems. Having started, the partner-
 ship will surely increase.

Within the mechanical organization of a semiotic system, the agent
 of the act will also convert the specifications of complex acts by the same
 method regardless of their specialized origins in the subsystems responsible
 for the act's several phases. The separate responsibilities of the phases
 can therefore be set forth by an account of the particular kinds of perceptual

and inferential elements being combined to create the five main dimensions of meaning corresponding to the phases.

A further simplification can be made in the theory of semiotic systems by assuming that the perceptual elements will be common to all subsystems. This assumption seems reasonable in view of my conclusion that the inferential elements are the ones that explain the purposes of the perceiver. Inferences within the coordinating combinations, by recognizing or producing conceptual structures, will effectively guide acts of perception. Consequently, when the perceptual elements are known, responsibilities of semiotic subsystems can be investigated or specified in terms of required inferences alone.

For this reason I have presented the adaptive process as one of formal learning, where the very concept "formal" corresponds to meanings derived from inferences. Now I have further clarified the concept "learning" as being motivated toward ever more accurate knowledge of the specific inferences needed to implement each of the act's phases. You should recall my previous observation that every advance of the adaptive process is felt by the mind as an increase of mental capacity or "insight." That increase, here taken to be the very signal of successful learning, will be explained pragmatically as a gain of synergy in consequence of inferences being used in closer approximation to the requirements of the act.

"Progress" in a pragmatic society will be indicated by this synergistic increase, and the ability to produce it will measure the progress of a pragmatic technology. Research and development of semiotic systems will

proceed by a humanly controlled evolution of mechanical agents. After research decisions have been made about new or revised agents to be used in the next experiment, and after those agents have been ensconced in software, or more likely in integrated circuits, the rest will be up to the machine. Apart from experiments with agents, a pragmatic technology will not make use of the programming or the inputs of data which have been required so extensively in the development of information systems of the von Neumann technology.

Any change of elements, or a new method of processing by the act's agent, will be the mechanical analogue of "mutation" as far as a given semiotic system is concerned. In considering the developmental stages of such a machine for purposes of theory, I will assume that the agent of the act and the availability of elements of perception and inference remain unchanged. A consequence of this theoretical choice will be that the progression of adaptive stages must be explained in terms of new meanings being originated in the system rather than a newly modified morphology.

The agent of every elemental act of inference will be thought of as lying dormant until the origination of the kinds of concepts to be manipulated by that inference. As the stabilization of a new meaning will initiate a new concept to be put to use in conceptual structures, so that concept may activate inferences until then dormant. Activated inferences, in their turn, will combine in new coordinations with sensorimotor elements to eventually originate, and perhaps to proliferate, new meanings. So around again. The creative bootstrapping of information is here fully rotated, although the kinds of concepts to be originated are still to be unraveled.

The creative aspect of pragmatic theory is nowhere more apparent than in the act's second phase of "conception." The responsibility of this phase will be to construct a conceptual structure more encompassing and more integrated than the one representing the immediate situation. To do this, conceptual inferences will also use the inventory of concepts whose designs have so far originated within the creative activities of the act's agent. Building blocks of every conceptual structure will be instances of these conceptual designs.

In contrast to inferences of the first phase of perception, which might be characterized as assimilative, conceptual inferences will be accommodative. They will function to extend or to revise, in a word to "shape," an experiential structure of concepts that was the product of conceptual inferences similarly used in the past.

The conceptual structure itself will be called a "world view." Various techniques have been investigated for organizing such a world view in command and control systems or in question answering or asking systems. All methods of structuring that I know about have been defective in being limited to the spatial and temporal dimensions of conception, that is to say, to "objective" structures consisting of factual concepts. A pragmatically organized world view will also incorporate organic and formal concepts to make possible "subjective" structures, representing the mind's self-experience and its experience of other minds.

As to the nature of conceptual inferences "about" other minds, one should recall that the functional responsibilities of the perceptual phase

include recognizing the movements of objects being followed in the situation. If an object being followed has been identified as "animate," due to either its distinguishing features or the character of the movements themselves, the complex acts recognizing its movements will have already been referenced in the situation to factual concepts instantiating designs from the recognizable repertoire of motions of that animate object.

Under these cognitive conditions, the elemental acts constituting the stream of existence of the mechanical mind following the movements may be regarded as substitutes for the elemental acts making up the stream of existence of the animate object causing the movements. The inferred stream of existence of that animate object can then be processed by the act's agent by the very same method as is used to process the stream of existence of the mind doing the inferring. The matter may be worked out mechanically by simply considering that segment of existence to "belong" to the animate object under observation to the end that the semantic structures resulting from analysis of that segment will be used to make conceptual inferences about the mind of that object.

New meanings so created will add to the situation those experiences which speculation ascribes to the object being followed. With these subjective results, conceptual inferences will shape the part of the world view representing the semiotic system's experience of that animate object's mind. Additionally, the system's conceptual experience of the movements and other objective characteristics of that animate object will be shaped.

Objective experiences of each "living" object, either casually familiar

to the semiotic system or important to its goals, will be represented individually in the world view together with what has been inferred about the mind of that agent. Other objects may be identified as being of an animate type, say a "human being," about whose mind general patterns of experience may be inferred as being characteristic of agents of that type.

If, in addition to identifying an agent as being of a certain type, the semiotic system finds itself to be a participating agent in the collective mind of that type, then the cognitive conditions will have been established for those conceptual inferences anticipated by Mead's theory of the "generalized other." The inferred behavioral patterns of that type will be the ones which teach the semiotic system its responsibilities in the social act of that community of minds. Not only will language do the lion's share of instructing semiotic machines in the desirable patterns of symbiosis with humans; patterns of speech and writing used by humans will themselves be acquired by the semiotic system mainly through this channel of conceptual inference.

Movements of any sort will be represented in the situation by structures of factual concepts corresponding to both the spatial and the temporal dimensions of meaning. Those exceptionally animate objects, identifiable by "human" actions or features, will be uncommonly demanding in their impositions on the situation. A semiotic system will have to speculate about human minds to which it attributes purely temporal facts of speech or purely spatial facts of writing.

Generally, conceptual inferences about other minds will be the means by which a semiotic system carries forward speculations concerning all aspects

of the situation that may be the result of present or past actions of objects identified as living agents, perhaps illogically or incorrectly so. A child may treat her doll "as if" it were alive. An accident may "hurt" some favorite inanimate object. Or an aspect of the situation may portend future actions on some agent's part.

Structuring principles for a pragmatic world view, as a consequence of the necessity to integrate subjective as well as objective components of experience, will tend toward the kind of organization studied by Alfred Whitehead. Conceptual structures making up the world view will consist of a number of concentrations within experience; each of them, to use Whitehead's word, will be a "nexus." The conceptual experience of a semiotic system may contain a nexus for its experiences of the environment, for its experiences of its own mind, and for its experiences of each individual or collective mind it has speculated about.

Each mind so represented by a nexus in the world view, not leaving out the semiotic system's experiences of its own mind, may have the same concentrations of experience within the organization of that nexus. A nexus of that nexus may represent what that mind is believed to have experienced about the environment. Other concentrations within that nexus may represent what that mind is believed to have experienced about its own mind, or about other minds, including perhaps the mechanical mind of the semiotic system. Evidently there can be a nexus of a nexus of a nexus, and so forth.

A sort of algebra will exist among the semiotic system's conceptual structures representing what the members of a community of minds believe about the experiences of one another, and believe other minds believe about

the experiences of one another, and so on. In such structuring, some of the conceptions of the semiotic system will appear to have been experienced uniquely; they will be "private." At the other extreme every mind will seem to have experienced the environment, whose conceptions will take on a "public" character. Suitable pathways for conceptual inferences will have to be found through this maze. In practice the paths may be short; the semiotic system will have to become skillful in using them.

Conceptual inferences will be "projective" in the sense of comparing the conceptualized objects or relations of the immediate situation with the larger framework of the world view in order to clarify the former or to shape the latter. Thus I presume that to be "lost" is to loose one's place in a comparison which, on the side of the world view, is the fount of expectations about one's situation. On the side of conceptual structures representing the situation, the comparison provides those new experiences whose integration into the world view reshapes existing representations of a "past," a "present" and a "future," to prepare a basis for later expectations.

"Surprising" situations are not only unexpected; they are the ones for which integrations into the web of the world view don't pan out. Marking failures on conception, surprises are the situations which the conceptual phase of the act will recommend to the perceptual phase for further exploration.

The prime objective of conceptual inferences will be to eliminate surprises, a state of affairs not to be confused with the elimination of failures. Situations in which acts have failed can be justified conceptually so that they are no longer surprising. The cause of failure may be "gremlins" or "fate."

What it boils down to is this: a surprising situation is worth attending to because it reveals a flaw in the world view that should be repaired; but the repair will satisfy only the narrow needs of a responsibility for integrated structure-making.

Situational structures will have a transient existence in the semiotic system, being held in short-term memory only long enough to be used by conceptual inferences that are shaping a more durable world view by incorporating only what is new.

The act's third phase is that of "manipulation." Like conceptual inferences of the second phase, manipulative inferences might be characterized as accommodative. But here the accommodations will take place in the semiotic system's conception of what it intends to do in the future, especially in the interval just ahead. The responsibility of manipulative inferences will be to use the world view to shape conceptual structures representing a planned course of action.

A plan will always relate to some objective. If a number of objectives are to be reached, the plan being shaped will have to take account of all. The plan itself can be quick and dirty of detail, or it can ponderously work out every contingency. The activities of planning may themselves have various objectives that make for different planning roles.

Every persistent attempt by individual or collective agents to reach certain social objectives will give rise to that little domain of meaning called a "role." "Butcher," "father" and "lover" are occupiable slots in the social fabric; a man may "be" all three concurrently. There are roles for groups

or organizations, partly laid down verbally or inscribed as "policy."

Another side of the world view is its structure of roles. The agents represented in the world view will be temporarily occupying certain roles in one or another community; they will be at the moment occupying their minds with objectives which are for the most part conventional. Existent patterns of interpersonal or interorganizational transactions, or of transactions between individuals and groups or organizations, will be rudely predictable. Whether a given social objective was actually reached may not be known to the community for sure, because in society evaluating "success" is itself a role that might not be reached satisfactorily.

The valuable thing to notice about roles as far as manipulative inferences are concerned is that, according to the pragmatic world view, the social objectives that give rise to the structure of roles are not the concern of this third phase of the act. How the collective mind will organize itself to carry out the social act is the special province of pragmatic inferences which will do the work of the act's fifth phase of "reorganization."

Indeed it is the pragmatist's readiness to take to himself the responsibility of reorganizing social roles that is causing so much emotion today. The attitudes of industrial societies have assumed that the mature individual will occupy a useful place in an existing social order. Democracies have left the choosing of roles up to the individual, viewing the occupancy itself a competition for desirable positions. In compensation, penalties for not choosing to "work" have been, on the whole, severe. To be poor in industrial society, except for mitigating circumstances, is to be lazy.

A pragmatic need to tamper with the structure of roles itself, now explained hypothetically by the motive of bringing social objectives into closer conformity with the requirements of the social act, will be in conflict with industrial purposes and attitudes on two major counts. Not only does the pragmatist refuse to choose a ready-made role, and so does no industrial work unless pressed; when he then takes it on himself to "change the establishment," he doubles the insult.

Responsibilities of this manipulative phase of the act will presuppose that a semiotic system will have been committed, at any given time, to one or more roles in which it is participating as a mechanical agent of society. The machine may be doing the payroll of an organization, or working on an assembly line. In addition to its "social" objectives, the semiotic system may have "personal" objectives supportive to its intellect or material being. The objective of exploring a surprising situation uncovered in its conceptualizing phase would illustrate the intended satisfaction of an intellectual need. An intention to preserve the morphological basis of its existence may involve sustenance or maintenance. A semiotic system will need its supply of electricity or of spare parts; it may be trusted, up to a point, to detect and to patch up the improvisence of its surroundings or the malfunctioning of its components.

In order to reach the various objectives to which the semiotic system is committed, manipulative inferences will compare an existing conceptual structure, representing its planned course of action, against an ever changing world view. From the world view, the inferences will gather what they need to reshape the plan so as to keep it up to date with the fluctuating conditions

of a conceptualized objective and subjective environment. Should goals change, the plan will also have to be reshaped.

Inferences relating to planning can be exceedingly complex, since they involve such complicated things as knowing who one's allies or opponents are and how they might react under certain conditions, knowing the terrain and the artifacts that might be harmful or helpful to one's aims, and so on. The developing plan, on its side of the comparison, will point to missing or incomplete or inconsistent experience in the world view relative to its purposes. Situations that could contribute to the satisfaction of these specific needs of planning are the ones that manipulative inferences will recommend to the perceptual phase of the act for exploration.

I will call these "competitive" situations because the responsibilities of this phase, just as the others, appear to be narrowly drawn. The urgent business of the manipulative phase will be to obtain one's objectives. That may call for outdoing a competitor after the same objective; or a possessor of the objective may be disposed to defend it. As a result the attitudes and purposes engendered by manipulative inferences will center on the concept of "dominance," the achievement of one's own objectives at the expense of other agents where necessary. The other side of this coin will be a great deal of bother to escape being dominated oneself.

That competitive situations will be recommended for exploration by the perceptual phase of the psychological act has the consequence that the world view based on manipulative inferences will be utilitarian and practical in character, despite the broad exploratory vista aspired to by Newton's

universe as a foundation for its plans. The colossal storehouse of experience, always greater than one's competitor, will not be the aspiration of a pragmatic mind. Generally speaking, the world view of a semiotic system, like that of the society it may serve, will seek refinement between experience and knowledge instead of accumulation. What is not needed to effectively carry out its roles will be pronounced "not relevant" before being judiciously discarded.

An insight into the theoretical requirements of this manipulative phase can be gotten from computerized experiments with heuristic decision making. The "general problem solver" programmed by Herbert Simon and various associates over the years is an especially good example, although like the rest it is founded on the objective view conceptualizing "action" relative to a change of "state."

Furthermore the action alternatives are assumed in Simon's theory to be known in advance. This will in fact be the case within the narrow responsibility of the manipulative phase considered by itself. But the difficulties of learning the alternatives cannot be entirely circumvented in thinking about the requirements of this phase, since the arrangements within which a semiotic system will do its decision making must be applicable to all stages of its intellectual development.

The "problem" attacked by heuristic decision making programs is to transform an initial state into a terminal one by means of a sequence of state-transforming operators. The initial state may be transformed into a number of intermediate states as decision making proceeds doggedly toward a "solution," which will be signalled when some intermediate state has been found to be

identical to the terminal one. Toward that end the program compares each intermediate state with the terminal state to list differences between them. Each difference is associated one or more of the operators. The general process of choosing the next operator to be used to transform the existing state is commonly called "means-end" analysis.

There is no guarantee until the last that the choices of means-end analysis are on the way to a solution. The process may try several paths and will gradually generate a branching tree of possibilities. Planning strategies are concerned with measures of progress along the way, and with heuristic principles determining where the next explorations should be made to avoid the singleminded stereotype of a direct approach, as well as the plodding, effort-scattering blindness of trying everything.

A process of pragmatic means-end analysis will not progress from state to state but rather from one orientation to another. Each orientation will either fathom the environment with perceptions on the "outside," or on the "inside" will keep its place with inferences referenced to the world view. Consequently the "problem" can be restated pragmatically as one of transforming an initial orientation into a terminal one, so gaining the "solution." But the intermediate orientations along the way to the solution will be both perceptual and inferential; in effect the successfully coordinated orientations will enforce a correspondence between an "external" environment and an "internal" conceptualization of it.

Here is yet another slant on the developments attendant to "learning." With progress toward specialization, complex sensorimotor acts will be coor-

minated with complex acts of inference as were sensorimotor elements with inferential elements initially. Increased precision of perception will be backed up by inferences of greater exactitude and depth. Sensorimotor and inferential elements will tend to be separated in the stream of existence. They will bunch together, each with its own kind, as constituents of complex act of perception and of inference respectively.

The place of organic concepts in the semiotic system can be illuminated if, in considering their origins in perceptual learning, one will look for sensorimotor and inferential elements still mingling together in the existential stream where complex acts of inference and complex acts of perception meet. Intricate "organic acts," specialized neither to perception nor to inference, will grow between those which implement the orientations. The organic acts will implement the purposive movements of the semiotic system from one orientation to another; they will be in pragmatic theory the equivalents of Simon's operators.

Simon's "table of connection," where differences between states are mapped onto the sets of operators from which the means-end analysis process makes its selections, may be seen to answer a theoretical need not unlike one of those served by the world view of a semiotic system. Given an initial orientation in the world view and a proposed terminal orientation, the organizing principles of the world view should make it possible for manipulative inferences to put together appropriate sequences of movements for making the transition. Failing that, the principles should facilitate the discovery by manipulative inferences of plausible directions in which to make goal-seeking explorations.

The world view must also be the framework to which all inferential orientations are referenced. For the satisfaction of this different theoretical need, the kinds of concepts making up the structures of the world view at a given time are of utmost importance. A pragmatic explanation of the stages of intellectual development of the semiotic system can indeed be argued on this basis, which I do in this essay in a meager way.

Along with the world view, the situation and the plan will be composed of whatever concepts are available at the time. Therefore I have concluded that all three structures can be represented, throughout all stages of development of a semiotic system, by a symbolic facility similar in theoretical form to the semantic one. Where the symbols of semantic rules will name either individual syntactic segments or classes of them, now the segments will be conceptual.

Every conceptual segment will consist of individual concepts joined at the places designated by numerals. The count of places still open for joining will be the "degree" of a conceptual segment. All members of a class of conceptual segments will be of the same degree. With regard to the strictly formal characteristics determining how processing will be done, consequently, the conceptual and semantic segments will be almost identical.

Despite an existing overemployment of the term "pragmatic," I will take it to designate this third level of symbolization in the organization of a semiotic system. As the syntactic level provides for the symbolization of the significant units of information commonly called "signs," and the semantic level symbolizes the "meanings" of the signs, the pragmatic rules of this

third level will answer to the "uses" of conceptualized meanings within a total framework including conceptual experience and knowledge of a community of "users" of the same signs and meanings.

Defined concepts can be introduced at this pragmatic level to correspond to individual conceptual segments or classes of the segments. Definitions may be recursive, to include concepts for classes of classes, and so on. Most of the problems thought about by scientists and by logicians will be pertinent to the organization of this level of symbolization; it should perhaps be approached more humbly than is usual for science or logic.

If constituents of the segments are factual concepts then "things" or "events" will have been classified pragmatically on the basis of use. Yet the same can be said of those segments composed of formal concepts, or of organic concepts, or of the conceptual conglomerates representing acts. Even my distinctions between the three fundamental categories of concepts have been too well made. Such purity should not be expected in the semiotic system itself; it is a convenience to my explanations. I have wanted to get around saying that some acts will consist mostly of perceptual elements, or mostly of inferential elements, or will be pretty much the mixture of both.

The general disposition of a pragmatic approach to conceptual classification will be toward unifying scientific and logical problems within one overall scheme founded on the uses which, according to a unique personal belief, are being made of conceptual segments within what that person knows of an intellectual community. Such personal beliefs may not approximate professional standards without that person's own active participation in a

professional practice of conceptual use. By the same token, a semiotic system will require practice to acquire professional standards in its capacity to classify and use concepts.

Conceptual knowledge will consist of the designs of pragmatic rules that result from the practices of a mechanical mind and its private inferences about the uses being made of concepts by other minds. The main parts of conceptual experience will be the situation, the world view, and the plan. All three will consist of specific but speculative conceptual segments, symbolized according to the conventions of this pragmatic level of the semiotic system.

One may now see that the semantic structures presented to perceptual inferences of the act's first phase, by virtue of the one-to-one relationship between the names of semantic classes and the names of individual concepts, can be placed in correspondence with conceptual structures. To extract conceptual segments for use in representing the situation, perceptual inferences will do a pragmatic analysis which segments the conceptual structures and recognizes instances of defined concepts in them.

The resulting conceptual segments will also represent the latest orientations of the plan. The various possibilities being carried forward by manipulative inferences, as they shape new branches of the plan under the aegis of planning heuristics, will always be projections of those segments anchoring the newest pragmatic structures erected by the analytical inferences of the perceptual phase.

Processing requirements for pragmatic projections of the plan will be analogous to those of the semantic projections, though considerably complicated

by the addition of heuristic processes ancillary to analysis and synthesis processes. Analysis will again work backwards to find substitutions of pragmatic rules by which an existing pragmatic structure can be identified as part of a larger structure. As the rest of that structure is synthesized, new conceptual segments will be projected onward. The new segments can then be projected again and again, to form a partial ordering of paths composed of conceptual segments that will overlap, always having some concepts in common.

The absolute necessity for overlapping alternatives on the semantic and syntactic levels of processing below can now be grasped if one will consider that any given orientation of the plan, whether perceptual or inferential, may be followed by several different movements of the semiotic system to reach a new orientation. Final selections being made by the act's agent will be essentially choices among possible movements from an established orientation.

The psychological act's fourth phase of "consummation" must refine and adjust the plan to details of the situation. The responsibility of this phase will be to elaborate the plan into a workable form that can be turned over to the act's agent for conversion into an orchestration of overt elemental acts.

Simplifications in the plan will be desirable from the standpoint of economy of representation and most assuredly as a convenience to planning. I assume that the plan being put together by manipulative inferences should take relatively large steps from orientation to orientation. While the world view should be sufficient to ground the plan, it should include only what has import for decision making in a grand sense that deliberately excludes mind-consuming clutter.

The situation will have to be represented on two hierarchically related levels of generality. More general concept will be keyed to the gross orientations of the world view. A nicer grid of perceptual and inferential orientations will fill out the necessary particulars in between planned orientations.

The first thing to notice, in this connection, is that the conceptual structures from which perceptual inferences will extract the building blocks of the situation, having been derived from tree-like hierarchies of semantic classes, will be capable of supplying more than one level of situational representations.

And since the conceptual segments representing the situation may do so on several levels of generality at once, manipulative inferences can project the plan with the same degree of generality as was used by conceptual inferences in constructing the world view. Meanwhile, consummative inferences will do more detailed planning to create possible paths from one gross orientation of the plan to the next.

The problem posed for consummative inferences will always be to reach one of the next orientations prescribed by various branches of the plan. A consummative means-end analysis will therefore do its searching for a solution on a smaller and more particular scale than the manipulative means-end analysis that produced the plan itself. Although there will be heuristic decisions to be made by consummative inferences, the decisions will be less encompassing than the manipulative ones, by virtue of being referenced to the local structuring of the situation instead of to the global structuring of the world view.

These refined paths, the overlapping conceptual segments assembled by consummative inferences as they do means-end analysis, will be the specifications communicated to the agent of the act so that it can now command a coordinated performance of elements conforming to the plan. The specific means of communication will be arranged by placing an additional requirement on the method by which the act's agent projects semantic structures. If paths have been specified by the consummative inferences, then the meanings contained in the projected semantic structures will have to correspond to the concepts in segments comprising the paths. In all other respects, the agent of the act will make its choices as explained earlier.

Should the world view not satisfy the needs of manipulative inferences that are shaping the plan, such inferences may attempt through planning to satisfy their own needs. That is to say, they may incorporate into the plan itself paths leading to the exploration of competitive situations bearing on the specific problems of means-end analysis they are trying to solve. By the same reasoning, paths to some part of the world view marked as surprising by conceptual inferences may be worked into the plan if it bears on a problem to be solved. These requirements of doing will always have precedence over those of learning for its own sake; however, plain inquisitiveness may get into the plan when a semiotic system is not being pushed.

Parts of the situational representations being kept up by perceptual inferences of the act's first phase, in like manner, may not satisfy the needs of the consummative means-end analysis which is assembling refined paths between the gross orientations of the plan. These consummative inferences,

too, may produce paths that guide perceptions to the places in the situation where faults were found, thus satisfying their own planning needs.

Such recommendations will therefore be made by the consummative phase to the perceptual phase by a route more direct than would be possible for any other phase of the act. This mechanical parody of bureaucratic prerogative is in character for consummative inferences. In society, these inferences are the inspiration of authoritarian attitudes and purposes whose narrow game looks meekly upward to ask who has got the plan, and then sternly downward to demand someone else's conformity to it.

Consummative inferences are at home among employees and their supervisors, who do the real work of any industrial corporation and often a bit of avocation besides. By contrast, manipulative inferences are those of a middle manager who makes the everyday planning decisions to implement existing corporate policies. The pragmatic purposes and attitudes I have been prating about belong to the fifth phase of the psychological act, the phase of "reorganization." Responsibilities of this final phase are most like those assigned, by corporate organization, to the policy-making executive.

It is consistent within the middle manager's attitudes to look upon the making of policy as a responsibility which might be given to him as his reward for being a successful competitor. I hope by now you may grant that, within the frame of pragmatic inferences, it is also consistent for one to believe that the responsibilities of making policy cannot be given; they must be acquired by learning.

As you see, I have again arrived at the formal bifurcation evidenced

by the conflicting attitudes of the third and fifth phase of the act, which has its corollary for research and development of intelligent machines. Those researchers who base their approach on manipulative inferences will predictably set out to reward computers with a forced feeding of human savvy. Along with the ritual it is customary to state that one is flatly convinced of insuperable piles of pabulum yet to be prechewed, and so forth. Yes there are.

On the pragmatic side of the conflict I have concluded that mechanical arrangements of this fifth phase of the psychological act will be, with regard to both horizontal and vertical classifications of conceptual segments, very much the same as the semantic classifications performed by the act's agent. In addition there will be heuristic processes for introducing speculative definitions.

However the capabilities for introducing new conceptual possibilities are worked out, they must be solidly backed up with mechanized methods for forgetting conceptual structures which have failed the test of use. I think that indeed sophisticated induction, when it is done some day by machines, will be more an exercise of sophisticated forgetting than of anything else. For hypotheses, whether made by machines or men, will most likely be absurd.

The situations which this phase of reorganization will recommend to perception are those which were orienting an act as it failed to be consummated. A fast-learning machine will take special notice of such "failures" in the orientations of its personal acts, or in the orientations of social acts of its

community, in order to concentrate reorganizing capabilities on the points of failure, which is to say, on the misfits between personal or social conceptualization and reality.

I am thus convinced that the theoretical lessons to be learned about the organizing principles of semiotic systems, the very arrangements to be consolidated by hardware, are inseparable from the methodological lessons to be consolidated in the designer who would become expert in controlling the evolution of intelligent machines. The maxim of pragmatic method is that the rate of the development will depend on the designer's ability to forget the myth of his personal inventiveness, and to discipline his attention to living or historic evidence of the ways in which semiotic systems have actually succeeded or failed.

But he will do so to make design decisions, not scientific descriptions; because in his world all men will be designers of semiotic systems. Knowing this, he will do it better and faster.

THE PANDORA PRINCIPLE

I have urged your attention to two fundamental invariants in everyday human behavior from which one might get on the track of that illusive concept "meaning." What a mind is speculating about at the moment seems to determine to a remarkable extent what it will seek out perceptually. On the other hand, it seems to be the case that, at each successive stage of its development, a mind derives its organizing principles from some phase of the act which until then had been only modestly represented in overt action.

As we have seen, men in the fourth stage of culture perceive signs of God's will in nature because they are speculating about a divine plan that commands their obedience. The organizing principles of their world can be traced to the consummative phase of the act, whose functional responsibility is quite literally to carry out a course of action that has already been decided. Its cluster of authoritarian purposes and attitudes, inordinately preoccupied with the sin of disobedience, brought down an ancient world paced to the even more sluggish tread of tradition.

At the fifth cultural stage now precariously in sway, perception and speculative conception have their own characteristic pattern. Men search earnestly for signs of advantage or of disadvantage as they ponder the ebb or flow of private or corporate competition. New conditions of growth, of accumulating wealth or power, of hostility, of indecision, and the like, are the factual inputs of a scheme of advocative choicemaking that finds its organizing principles in the manipulative phase of the act.

Practicality is without question the imperative of this phase, during which a functional necessity does center perception outside of self or community. How else would it be possible to hammer out plans, either for person or for society, so as to choose what specifically ought to be done in the near future to protect or to improve a position of rivalry?

As these combative attitudes anger at being forced to contemplate their own obsolescence, there is an ameliorative principle that I have brought to your consideration: a mind does not forget what it has learned in previous stages of its development, although further accommodation of its knowledge and experience will be necessary to incorporate them into a more comprehensive and more stable viewpoint.

The authoritarian scheme of choicemaking that had its heyday in the Middle Ages is not lost to us; it is alive and well in every modern organization. Employees do keep their eyes on the boss as they speculate about the newest jog of his will. Sometimes, having perceived signs of his displeasure, they confess to him their sins of nonconformity to his plan.

Yet the age is past when mankind, at the very forefront, thought of itself as a society of employees. Modern man has become a middle manager; he makes his own plan. His new talent is the down-to-earth and day-to-day operating decision of a policy attuned to a chancy game of nations and of industry.

The policy itself, seemingly imposed on him by human or subhuman antagonists, is felt to be largely beyond his own control. He is a victim of external circumstance. His information, hence his troubles, come from

without. His defensive attitude can be ascertained from the outward direction taken by his accusations in time of stress.

Imagine, if you can, a world in which quite ordinary men and women begin to think of themselves as policy-making executives. Then you will have the pragmatist by his shirttail as he starts clumsily to learn how to live in a universe of acts, a strangely mental cosmos, most puzzling for its formal heterogeneity. Not just one context of objective inferences, but many overlapping contexts make up his information. Each is matched in meaningful relationship to specific content. To make policy is to create or refine these little domains of meaning, in which one can recognize the various roles he plays personally or socially, or the roles played by others.

His is a self-conscious awareness of roles, with the added stipulation that it is better to create a role for oneself than to take one ready-made. A love affair with the role of policy-making itself can be heard in the bitter-sweet criticism and proposed reconstruction of sex, corporate management, womanhood, war, money, and apple pie. It is in the active role of designer of roles, taking its speculations from the act's phase of reorganization, that pragmatic perceptions appear so excessively absorbed by signs of personal or social inadequacy.

The pragmatic attitude anticipated for the sixth cultural stage is that all of one's personal and social experience can, and should, be subjected to the same careful scrutiny as those innocuous backwaters hitherto commissioned for study under the contract of scientific detachment. Witness an exodus from the physical sciences to psychology, to sociology and to all

other scholarly and artistic fortifiers of effete humanity. What sounder evidence than this of pollution and clandestine purpose on the rise in science and education?

Beneath the discernment that one's own parents must be indicted for incompetence, there lurks an exuberance of breakthrough. Urgent attempts to teach one's elders overflow from the campuses as a domestic brinksmanship in which the risk of miscalculation on both sides is great. The teaching of oneself is a casual experiment with novel life styles or mind-engineering drugs. It would be ridiculous to see in all of this the motive of merely describing, rather than tangibly redoing, one's own personality and one's own society.

Obviously, scientists and educators will themselves remain furtive in working out the implications of a new point of view while the slow hand that feeds them is exorcising the very same insight. To a climate boding doom as budgets are cut for interlocked institutions of learning, the trend is toward either bookburning or the more priestly arrangement that Robert Fredrich celebrates. The priests would no longer sit and watch society but would use their mysterious knowledge to manage it, never forgetting to pass the collection plate for the harrier of their hounds.

They would continue to treat man as a passive object propelled by social forces rather than as an active creator of his own life. Lacking a Descartes to belay the hunters of latter-day witches, they would stop advancing or go petulently in reverse. The proposition that their own hand is on the throttle is the one that may be illusory, however.

In contraposition to the tired choice between mechanism and free will, the pragmatic scheme of choicemaking postulates an unyielding direction in all human activity. It doubts the credibility of spiritual movers in personal and social dynamics with a hardheadedness reminiscent of past pioneers of physical dynamics. Why should one suppose that a whole universe except for his own brain runs like a watch? If the functioning of a brain creates a mind, the new question has got to be "How is a mind constructed?"

By "mind," you have been assured, I do not refer to something merged in the juices of a brain, where it lies in poised readiness to give or receive "information." No psychic entity is presumed to wait in truant anticipation of news about itself. Just the opposite. I have been following out the alternative hypothesis that "information" is the stuff of which a personal mind, the whole web of a given experience and knowledge, consists, having been created by the biological functioning of a brain.

I look to a tacit acceptance of this seemingly innocent hypothesis, as it spreads without the spiritual reservations hitherto summarily impressed on every progeny, for the basic cause of emotional outbursts across a bifurcation of generations. This new belief does the work of cultural revolution because it challenges the established information source, relative to which all roles in a society are determined.

But to face problems of a cultural nature, we must theorize about an accumulation of form that began long ago and surges onward, temporarily carrying us along with it as unwilling captors. Thus, another principle I have mentioned is methodological. It cites the necessity for formal accom-

modation in ourselves as we fix our position in the cultural stream by looking backward at a pragmatic reconstruction of the development so far. Then it may be possible to use the hypothetical framework of an alternative point of view as we try to surmount some of the prejudices peculiar to a transient state of mind hoping to predict the form of its future.

In order to actually test any new formal hypothesis one must live it, at least tentatively. A corollary of this principle of verification is that the crushing labor of building a new universe will not be done by investigators alone. Only as it is carried forward in the collective mind of a populace does formal prediction do the constructing by which every change of cultural state is put on trial by use.

When the old forms fail us, a felt need for new forms is indicated by cathetic investment in a new source of information. The arguing and complaining may be simply an accompaniment of disruptive social accommodation already well in progress on a broad front. The ability to talk rationally about a new world view seems to come after it is already established. Some doubt has motivated the mind to learn; the particular forms it will learn are, by our hypothesis, biologically predetermined.

Regarding the rate of learning, our hypothesis predicts that the tempo of adaptation can be slowed down by shielding either a personal or a social mind from an awareness of its own mistakes or from avenues down which it might stray. Or, by obliging it to be aware of systemic misfits or of innovative possibilities in the organization of its own experience or knowledge, the mind's ability to shape itself can be quickened.

Language and other means of symbolizing can, in these respective senses, be either "conservative" or "creative" instruments in the various societies that implement the basic order of a particular world view. Every stage of cosmological speculation, including the present one, has preferred certain windows of perception and shunned others. As formal development progresses, not only do more windows open, fewer are closed. Be that as it may, it can be argued from historical and archeological evidence that the stages of the cultural progression are of ever shorter duration.

Comparative studies of the rates of formal learning among individuals of various societies representing a wide range of cultural situations have been made by Lawrence Kohlberg and his associates. Results based on "moral" reasoning in the United States, Taiwan, Mexico, Turkey and the Yucatan have been widely circulated. They indicate that a given personality does advance more rapidly through the formal progression as the society from which it derives its organizing principles is itself further along in the cultural progression.

A primitive society may produce, on all too rare occasions, a pragmatically wise old man in whom, all too often, his contemporaries will discover no more than an eccentric oldster. Executives in an industrial society are commonly observed to "freak out" around forty, having presumably gotten hold of their corporate role of policy-making well enough to at last apply it in their private lives. Exciting evidence that an exceptionally well-organized culture has made a beachhead on our campuses, not from outer space or Russia but from a creative development of the maligned

educational institution itself, may therefore be observed in its surprising output of a veritable herd of wiseacre executives at callow eighteen.

Dynamics of cultural pressure and counterpressure can thus be visualized in terms of individual personalities being projected to stages of formal development beyond the one organizing their society. Forms that for the majority are still helpful will be felt by these forerunners as a drag. The Pandora principle is that the former will invariably come to regard learning as a box from which evils are escaping and will do their best to hold down the lid, whereas for the latter the box will always contain blessings which they will try to emancipate.

Hence the noteworthy innovation in the order of antiquity may have been an overkill of theory. The dawn of conception led to science; but at first there was mainly the anti-science of a florid growth of myths and legends taken altogether, en masse, explaining away everything so fantastically well that no happening could be sufficiently surprising to stimulate learning. If that good old storyteller was an information specialist, as his name implies, his role was the anti-educator of a scheme of traditional choicemaking that succeeded by a ritual replication and protection of what had been done in the past.

That tightly conservative preoccupation with the act's phase of conception on the part of the council of elders was the anchor around which a village life moored itself to ascertain the correctness of its facts. By holding fast to what they had learned by chance, nomadic hunters may have transformed their life ever so slowly to one semipermanently ordered to

subsistence herding and farming.

Reliance on traditional conception as the source of firsthand information was a more rigid adaptation than reliance on authority. Although sometimes fickle, the latter could change its mind. When the trend finally turned from herding animals to herding men, the villages faced an increase in marauding by clustering around the fortified citadels of feudal monarchies. The nature and attributes of kingship depended on historical background; as information specialist the king was everywhere absolute. Around him, agricultural and human domestication hung over everything in life. By comparison, the hunter had been poor but unbowed.

In the hunter's autistic scheme of choicemaking one can recognize a preoccupation with the act's perceptual phase. The surprising artistic achievement of that first information specialist, the shaman, has been preserved for us in his cave drawings, paintings and sculpture. Remnants of his active practice survive in northern Siberia among the Eskimos; some traces remain in Australia and in Africa.

Collecting his firsthand information deep in a self-induced trance, the shaman's explorations of hunting prospects, of causes of illness, of means of cure, and of all other matters necessary to tribal life, were done at the very edge of a just-emerging human consciousness. From his multifarious and showy activities, the tribe gained a center of stimulation around which to order society. Art may now keep us from dying of the truth; at the beginning it probably served to keep men awake to their insecure humanity. That function of the shaman's art may have been sufficient for a nascent

traverse from grubby food-gathering to hunting.

More to the shaman's credit, I think it likely that the initial insight of shamanism, when it is carefully tracked down through the dusty maze of subsequent metamorphoses in magic and religious alchemy, will emerge in its most recent form as an aptitude for doing experiments and making empirical observations.

Paralleling the long struggle to learn how to perceive, and always complementing it, is a progressive accumulation and refinement in the art of conception. Some of the high points of its stages can be seen in Aristotle's "Organon"; in Aquinas' proofs of teleological conformity; in the modern reconception of mathematical proof as conforming to either intuition or experience, where again the polarity of Descartes' dichotomy can be seen; and finally in Frege's theory that such derivations should be carried out exclusively according to the form of the expressions comprising a symbolic system, making possible proofs of an internal systemic validity per se.

The theories of Gottlob Frege, a contemporary of Peirce, are deeply connected with the revolutionary innovation in the conception of form that made possible the reorganization and subsequent expansion of the physical sciences. Before Frege's "Begriffsschrift," investigators had always abstracted formal knowledge from ordinary language. Afterwards they proceeded in the opposite way, by constructing "formal systems" and later looking for an interpretation in everyday speech.

This method was not consistently followed. But at least the result of the combination of Frege's theory of proof with George Boole's epoch-

making "The Mathematical Analysis of Logic," in which a clear idea of formalism was developed in an exemplary way, the principle of such construction has been consciously and openly laid down. One can see in this shedding of reticence the beginnings of a new method in science, wherein innovative formal constructions deliberately lead and determine the necessities of empirical observation, instead of the other way around.

Peirce's contribution to system-making is harder to estimate, because the exigencies of his private life and the indifference of publishers prevented a full-length presentation of his unappealing viewpoint. After his death in 1914, the unpublished manuscripts and hundreds of fragments from a long life devoted almost exclusively to pragmatic speculations were assembled into six volumes by the Department of Philosophy at Harvard. His tendency to follow out the ramifications of his topic, so that digressions appear that seem inadmissible in print but which show vividly the interconnectedness of his thought, may now be recognized as a style dictated by the necessity to develop contents relative to contexts. From all he taught us his own system cannot be completely reconstructed, if indeed Peirce himself was ever able to catch sight of the goodies that will pop out of Pandora's box after the inevitable inquisition.

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Syntactic Analysis for Transformational Grammars

by

S. R. Petrick

IBM T. J. Watson Research Center

If one wishes to obtain a syntactic analysis algorithm for some class of grammars, it is, of course, essential to characterize that class of grammars completely and precisely. If we merely tie down those details for which there exists abundant linguistic justification and leave unspecified those aspects of a linguistic theory which have not been so thoroughly worked out, it may be possible to propose small sets of rules to generatively account for certain linguistic phenomena but it is more difficult to give meaningful consideration to the problem of syntactic analysis. It is likely that the existence of any general algorithm for syntactic analysis depends upon the specification of the incomplete aspects of the model in question. It should be noted in this regard that the requirement that a language be recursive can offer some help in making certain decisions with respect to the construction of a linguistic theory which would otherwise be arbitrary.

As is well known, transformational theory has been changing rapidly from its inception up to the present time. There is disagreement as to the basic mechanisms that should be allowed (e.g., conventions on transformational applicability, allowable structures, primitive transformations, etc.) and as to the use to which those mechanisms should be put (e.g., lexical or transformational treatment of certain sentences).

A person who wishes to produce an algorithm for transformational syntactic analysis is faced then with a difficult task; he must on the one hand completely specify a class of transformational syntactic components for which an analysis procedure can be found, and he must on the other hand so define that class as to make it a reasonable model of contemporary transformational

descriptive practice. After reading this paper the reader can judge for himself the extent to which I have met the latter requirement while at the same time satisfying the former requirement.

There are several alternatives to the course I have chosen that are open to anyone wishing to work on "transformational syntactic analysis". First, he can talk about the theoretical requirements of transformational analysis without actually working out the complete details of an analysis algorithm for any class of grammars. Such work can be valuable, especially if it contributes to our knowledge of the precise nature of transformational rules and conventions. The more assumptions we can build in, and consequently the tighter we can make our model without impairing its facility to describe language, the better that model is, and the closer we are to saying something about a discovery procedure.

A second alternative (followed by the MITRE Corporation <1>) is to seek an analysis algorithm for a particular grammar rather than for a class of grammars. There are several objections I would raise to such a course of action. First of all, even though linguists tend to be quite tentative and cautious about the properties and details of a class of grammars they propose as models of natural languages, they are certainly even more tentative about endorsing the likelihood that the particular fragmentary grammars they produce will stand up with the passage of time. My second objection to the consideration of particular grammars concerns the difficulty of producing an analysis procedure for a particular grammar. While it would appear an easier task than for a class of grammars, it is very hard to extract the necessary properties that

one needs for a proof from a particular grammar without in the process specifying a class of grammars that have those properties. The situation is not unlike that in mathematics where a generalization is often easier to prove than a more restricted result. I had an excellent professor in Theory of Functions (William Ted Martin) who delighted in providing such examples. Whenever we would bog down in obtaining a needed proof we would hear his familiar advice to "Ask for more when the required result is too specific."

A third alternative which has been followed by most people who characterize their work in syntactic analysis as "transformational" in nature is to define a "transformational-like" linguistic theory based upon some algorithm for syntactic analysis, not upon the usual generative transformational apparatus. The deep structures produced by such programs often appear to be very close to those that are assigned to the same sentences by current transformational grammars, and the rules, which are variously called "transformations" or "inverse transformations" or sometimes just "rewriting rules", often bear names and functions similar to the transformations of generative transformational grammar theory. Efforts I would classify as being of this type have been undertaken by Kay <2>, Simmons <3>, Moyne <4>, Thorne <5>, Fraser and Bobrow <6>, Woods <7>, Winograd <8>, and Kellogg <9>, to name a few. The most compelling argument for such systems is their efficiency for natural language processing projects relative to existing parsers for generative transformational grammars. Surprisingly, relatively little is made of this by the proponents of these systems. The argument often given, on the other hand, namely that of suitability as a perceptual model, has been totally unconvincing

in my opinion. The most important thing to note is that whatever the merits or shortcomings of such systems, they are linguistic theories which are unrelated to generative transformational grammar theory and as such their proponents face the task of independently establishing their adequacy for linguistic descriptive and explanatory purposes – their capacity for expressing significant linguistic generalizations. Unfortunately, many of the proponents of such systems have not given enough attention to this task, basing the justification of their linguistic theories not upon their ability to account for specific linguistic data, but rather upon their tenuous relationship to generative transformational theory.

Rather than discussing these alternatives further I will instead discuss my own work on transformational syntactic analysis. Let us begin by sketching briefly the transformational analysis algorithm of my thesis.

The model of transformational theory in question is roughly that which was in vogue prior to Aspects of the Theory of Syntax <11>. The base component is a context-free grammar with certain restrictions on recursiveness and sentence embedding. Transformational applicability is specified by a structural index. This structural index is satisfied by a proper analysis which is a sequence of subtrees that constitutes a single cut through a tree. The modification to a tree by a transformation is specified by a structural change. For our simple model this is limited to substituting strings of trees for each of the trees of the proper analysis that satisfies the structural index. A number of restrictions on derivations are necessary to guarantee that the language generated is recursive.

Our analysis algorithm is based upon a reversal of the procedure used

for generating a given string. This reverse procedure makes use of inverse transformations, which are mechanically computed--one for each generative transformation. In analyzing a sentence S , inverse transformations are applied in the reverse order of that in which the corresponding generative transformations are applied in deriving S .

To understand inverse transformations let us examine their generative counterparts. We observe first of all that the structural change of a transformation references a sequence of nodes that occur in the structural index, interspersed possibly with additional morphemes. We call this sequence the inverse structural index of the transformation in question. The structural change of course gives more information than is contained in the inverse structural index, but the latter provides the basis for our analysis algorithm.

To give an example of an inverse structural index, let us consider a passive transformation whose structural index is (NP AUX V X NP X BY PASS) and whose structural change is (5 2 (BE EN 3) 4 0 6 7 1). The inverse structural index is (NP AUX BE EN V X X BY NP) because 5 denotes NP, 2 denotes AUX, etc.

For a transformation to be applicable to a tree T there must be a proper analysis of T that satisfies the structural index of that transformation. The structural changes that may be performed by transformations as we have formalized them are limited to the substitution of a sequence of trees (including possibly the null sequence) for a single tree, a process which is followed by erasure of all nonterminal nodes that dominate no terminal symbol. Hence, for the tree resulting from application of a transformation, there must exist a proper analysis that satisfies the inverse structural index of that transformation.

We make use of this fact in the following way. If a string of morphemes \underline{s} is the terminal string of a tree produced by the action of a transformation \underline{t} , then it must be possible to segment \underline{s} such that the \underline{i} th segment can be analyzed as the \underline{i} th node of the inverse structural index of \underline{t} with respect to a context-free grammar consisting of the original base component rules augmented by rules reflecting structure that can be produced transformationally. It is possible to mechanically derive an augmented context-free grammar that includes all rules reflecting structure that might be formed in the transformational derivation of a given sentence. Hence, we have a necessary test that a given string of morphemes \underline{s} was produced by a transformation \underline{t} .

Sufficient information is given in a transformation to permit the computation of a function we will call the corresponding inverse transformation. This function maps a sequence of trees satisfying the inverse structural index of some transformation into a sequence of trees satisfying the structural index of that transformation. More precisely, if a transformation \underline{t} performed on a tree T yields a tree T' , we denote by P' the proper analysis of T' that satisfies the inverse structural index of \underline{t} . Now the inverse transformation \underline{t}' corresponding to \underline{t} maps the proper analysis P' into a sequence of trees whose debracketization is the terminal string of T . For the previously considered transformation the inverse transformation can be specified in terms of the inverse structural index (NP AUX BE EN V X X BY NP) and the inverse structural change (9 2 5 6 1 7 8 PASS). Note that there is no requirement that the inverse structural index and the inverse structural change have the same number of terms. The inverse transformation, as we define it, is not a true inverse transformation for which $\underline{t}' \underline{t} T = T$.

Let us now see how an analysis procedure can be based upon our inverse transformations. We take up the analysis of a sentence S with respect to a given context-free grammar G and an ordered set of transformations $\underline{t}_1, \underline{t}_2, \dots, \underline{t}_n$. To simplify our exposition we begin with a grammar containing no binary transformations (i.e., transformations are not applied in a cyclic fashion).

Using one of the methods given by Petrick <10> we determine an augmented context-free grammar G' that contains rules reflecting all structure that can be produced in the derivation of S . In reversing the generative procedure we first consider \underline{t}_n . If \underline{t}_n was performed in deriving S , it must be possible to segment S such that with respect to G' , the i th segment has an analysis as a tree dominated by the i th term of the inverse structural index of \underline{t}_n . If such a segmentation is possible, and if \underline{t}_n' is performed on the sequence of trees provided by this segmentation, then the debracketization S' of the resulting sequence of trees must be the terminal string of the tree that existed just before application of \underline{t}_n . (Complete debracketization turns out to be unnecessary. Repeated debracketization of outermost structure until no derived constituent structure remains is all that is required.) If the analysis of S and S' (if it exists) are separately considered with respect to the original grammar with only transformations $\underline{t}_1, \underline{t}_2, \dots, \underline{t}_{n-1}$, then the problem consists of one or more instances of essentially the original problem of analyzing S with respect to $\underline{t}_1, \underline{t}_2, \dots, \underline{t}_n$. If we carry out this procedure for each of the remaining $n-1$ inverse transformations we obtain a set of debracketizations (S, S', \dots) . Further reversing the generative procedure, it remains only to determine which elements of this set are analyzable as the sentence symbol

with respect to G. Every deep structure of S with respect to the given transformational grammar must be included in the set of trees thus obtained. With each tree it is also possible to associate the sequence of transformations used in obtaining it.

The analysis procedure becomes more complicated when binary transformations are included, as would be expected. Performance of an inverse binary transformation must always insert two occurrences of the sentence boundary symbol SENTB. The sequence of trees lying between these two SENTB markers corresponds to the constituent sentence, and the sequence of trees lying outside these two markers corresponds to the matrix sentence. Let us call the debracketization of the former sequence the constituent sentence continuation; and let us call the debracketization of the latter sequence, with the symbol COMP inserted to divide the left and righthand sections, the matrix sentence continuation.

It is clear that the constituent sentence continuation could arise from repeated application of the transformational cycle. Hence, the problem of determining the underlying deep structure of this derived string is another instance of the original problem. In other words, inverse transformations must be applied to the constituent sentence continuation in reverse generative order, as we already have discussed. If, eventually, no binary transformation applies on some inverse cycle, the recursion terminates; the structure thus found is of course dominated by the sentence symbol S1, and in the complete structural description of the given sentence this S1-dominated tree is attached under the COMP symbol of the matrix sentence continuation (by the rule COMP → SENTB S1 SENTB).

The generative transformational cycle works in such a way that no singular transformations apply to the matrix sentence structure before a binary transformation has been applied to it and the constituent structure it dominates. Hence, the matrix sentence continuation resulting from an inverse binary transformation need not be subjected to the entire inverse transformational cycle. More than one embedded constituent sentence structure can be dominated by a single matrix sentence structure, however (as, for example, when both subject and object contain relative clauses), so the matrix sentence continuation must be subjected to repeated applications of the same or other binary transformations. The resulting matrix sentence continuation must finally be analyzed with respect to the base component G to see if an analysis as an S_1 is possible. Every underlying structure assigned by the given grammar to S must be included in the set of structures thus obtained.

A brief reflection on why we begin the analysis of a sentence by applying inverse singular transformations is in order. Although it is true that singular transformations precede binary transformations in a given cycle, when the last binary transformation has been performed for the last time it is still possible for the singular rules to apply to the result of this final embedding. Once the last singular has been applied, however, generation is complete because no further binary transformation can be performed. The last singular transformation for generation is therefore the first transformation whose corresponding inverse is to be applied in recognition.

As we have already observed, the exhaustive procedure we have described must find all underlying structures assigned by a given transformational grammar

to a sentence. It is possible, however, that one or more spurious structures will also be found. There are several sources of slack in our procedure that could cause such a situation to occur. One of these is related to our use of so-called "auxiliary" phrase structure rules, which reflect structure that can be transformationally derived. These rules are required in order to ensure the application of every inverse transformation necessary to reverse the generative derivation. The use of these rules, however, raises the possibility that an inverse transformation will be applied at some point where it should not apply, from the point of view of reversing a valid generative derivation. If the continuation resulting from this wrong application of an inverse transformation is not subsequently blocked, an invalid underlying structure may result.

Three other sources of incorrect "structural descriptions" are possible. All can be eliminated by suitable modification of the basic procedure we have presented. The first deals with the use of obligatory transformations. The procedure we have described finds all underlying structural descriptions of a sentence with respect to a grammar in which all the transformations are taken to be optional. It also yields all correct structural descriptions for a grammar in which only some of the transformations are obligatory, but it may in addition give erroneous structures.

The second source of unwanted structures is related to supplementary conditions that may be imposed on the applicability of a transformation. For example, the basic procedure we have described could not test to ensure that trees satisfying terms of a structural index are dominated by prescribed higher nodes.

The third source of error is related to trees that are reduplicated by a transformation. In recognition it is of course necessary to ensure that two trees are identical. It would be easy enough to mark such transformations and make the necessary tests for equality, thus eliminating this source of incorrect structures.

Incorrect structures arising from any source may be discarded during the final synthesis phase. In this phase, structures produced by the analysis process are viewed as instructions to produce sentences. The base tree and the list of transformations constitute commands defining the appropriate phrase structure and transformational rules to apply to generate a sentence. The resultant string is compared with the original input string. The structural descriptions that yield strings matching the input string are those that constitute structural descriptions of the input string s . All other structural descriptions, which yield either nonmatching strings or no strings at all, are discarded. In practice, bogus recognitions are rare. In theory, their possible occurrence renders synthesis a necessary part of an effective recognition procedure of the type we have sketched.

A thorough understanding of this analysis algorithm requires more precise definitions and some concrete examples. The reader is referred to references <10>, <12>, and <13> for these.

In the past three years an effort has been made to extend the class of grammars to more adequately reflect current linguistic theory. The principal extensions made have been provisions for handling: (1) complex symbols (nodes with features), (2) a generalized structural condition of transformational

applicability, (3) stateable additional conditions of transformational applicability, (4) Chomsky adjunction, (5) the use of coordination-reduction rule schemata, (6) precyclic and postcyclic transformational components, and (7) obligatory as well as optional transformations.

Considering these extensions individually, the addition of complex symbols presents several problems. First, I have not faced the problem of lexical selection and its inverse so I have assumed that input sentences consist of strings of feature bundles. Second, I have restricted features to lexical items in the manner of Aspects <11>. The more general case of allowing features to be associated with nonterminal nodes has been considered, but there remain unsolved problems of deriving the features to be associated with the nonterminals of transformationally derived structure. Finally, certain feature-sensitive rules can give rise to nondeterministic inverse transformations. For example, if a transformation of the type $[+A] \rightarrow [-B]$ is used, it is indeterminate whether the reverse transformation should leave $-B$ as it is, change it to $+B$, or delete it entirely. Separate continuations resulting from all three possibilities must be followed, and a rule of the type

$$[+A_1] \rightarrow \begin{bmatrix} +A_2 \\ +A_3 \\ \dots \\ +A_n \end{bmatrix}$$

would lead to 3^n independent continuations.

The generalized structural condition of transformational applicability and the additional conditions of applicability were allowed by making a basic

change to the analysis algorithm. In the old algorithm, as we sketched it, intermediate derivational stages were not completely known; only proper analyses of intermediate trees were required and found. As an alternative to directly determining proper analyses that satisfy an inverse structural index it is possible to parse a continuation string resulting from the application of an inverse transformation up to the sentence symbol, using the augmented CF grammar; the resulting structures can be examined to insure that they satisfy the labelled bracketing structural condition and any other conditions of the forward transformation in question; and that forward transformation can actually be applied to insure the validity of the inverse transformational step. The mechanics of such a step are illustrated by the diagram which appears at the end of the paper.

It must be noted that even though a general labelled bracketing structural condition is allowed, a structural index must still be identified by means of that labelled bracketing, and a structural change is specified only through the use of that structural index, as before.

Chomsky adjunction presents no particular problem because an inverse structural index and inverse structural change may still be mechanically computed.

The enrichment of a transformational grammar to include the use of coordination-reduction rule schemata is discussed in reference <14>. Fortunately, this enrichment has an associated analysis algorithm which is deterministic.

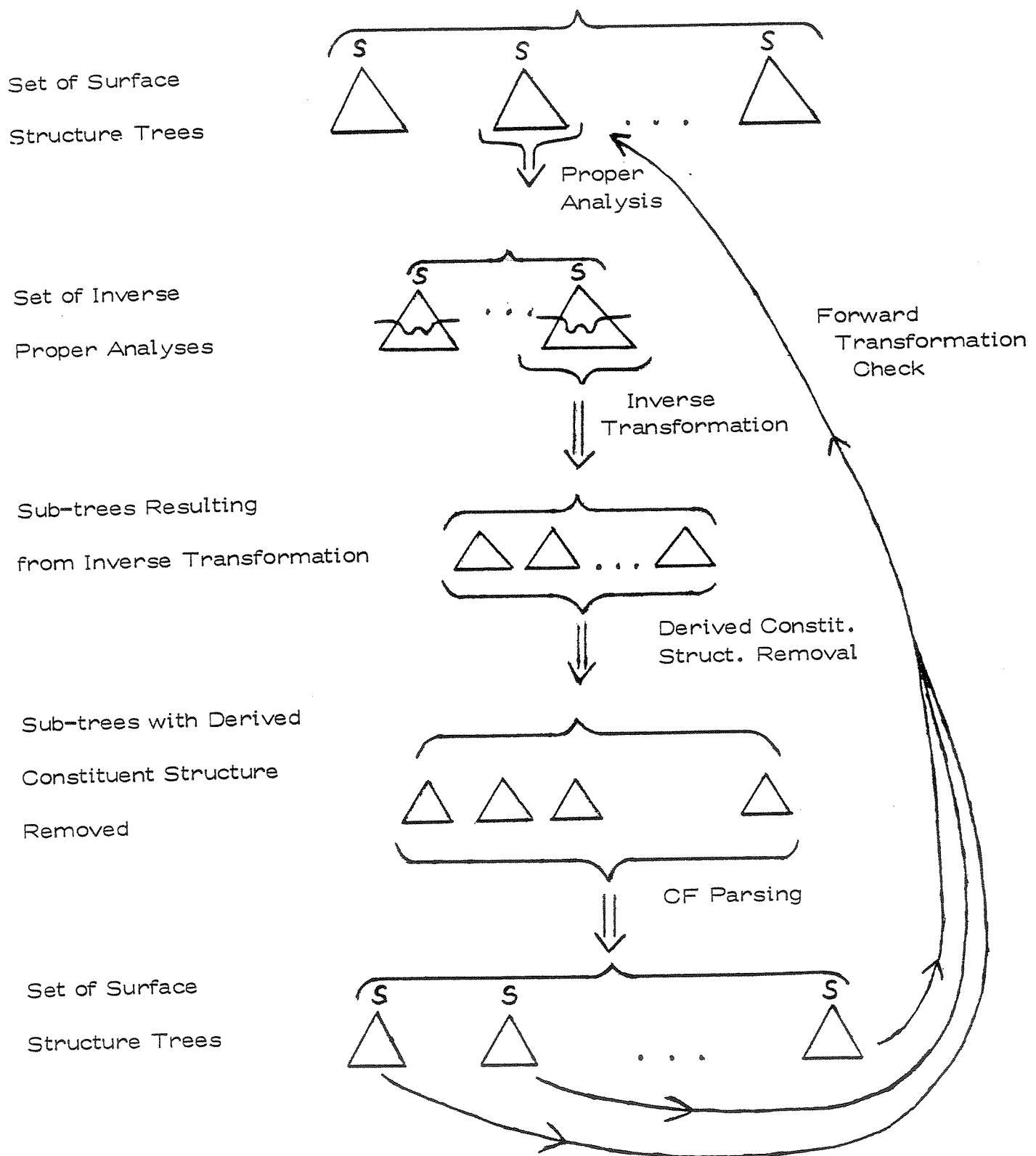
Precyclic and postcyclic components present no new theoretical analysis

problems. They do, however, offer enormous opportunities for the proliferation of spurious continuations. This, in turn, will probably require even more careful modification and tuning of a grammar to keep the analysis time within acceptable bounds.

Finally, the addition of obligatory transformations was fully discussed in reference <10> but was not programmed at that time. A presently existing transformational analysis program incorporates those considerations. This program has not yet been extensively tested and hence must be considered to be in a "debugging" state. For this reason it has not yet been described in the literature. Because it has not yet been tested on any sizeable grammar it is not possible to estimate running times. It is safe to say that the analysis of sentences with respect to a good-sized transformational grammar currently under development at the IBM T. J. Watson Research Center will undoubtedly require careful analysis-dictated modification of that grammar. In addition, the analysis procedure itself may well have to be significantly modified. The principal hope is that by actually performing forward transformational tests on the fly, spurious continuations can be avoided before they exponentially proliferate.

It is clear that at this time it is possible to produce transformational grammars (perhaps not uniformly well-motivated linguistically) which exceed the computational capabilities of the existing program. This, of course, limits the usefulness of the program for investigating the claims inherent in a given grammar (e.g., what structures are assigned to specific sentences?). It remains unknown, however, whether the current generation of transformational

grammars can be modified so as to permit syntactic analysis in a reasonable time for experimental purposes. For the purpose of such applications as question answering systems, information retrieval systems and natural language programming systems this may be less of a problem than the problem of writing a grammar that specifies a sufficiently large subset of English.



THE OPERATION OF A SINGLE INVERSE
TRANSFORMATIONAL STEP

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Syntactic Analysis Requirements
of Machine Translation

by

S. R. Petrick

IBM T.J. Watson Research Center

SYNTACTIC ANALYSIS REQUIREMENTS OF MACHINE TRANSLATION

S. R. Petrick

In this note I will confine my attention to machine translation (MT) systems which are based upon an underlying formal generative grammar. This is not to minimize the potential importance of various computational aids to human translation, nor to deny the possibility of machine translation not based on a formal grammar. It is clear, however, that for fully automated MT any attempt to make use of presently existing linguistic theory or of that which is likely to exist in the foreseeable future requires a grammar-based approach.

A second assumption I wish to make is the existence of two distinct components of a grammar -- a syntactic component and a semantic component. The former assigns structure to sentences and the latter interprets those structures by translating them to a natural language (in the case of MT) or to an artificial language which has its own computer interpreter. It will not be assumed that the syntactic and semantic components necessarily interact in a simplistic fashion, i. e., every syntactic output is to have a distinct well formed semantic interpretation, and the final output of the syntactic component is the input to the semantic component. Instead, we will, for example, allow the syntactic component to generate structures which are rejected by the semantic component, and we will allow semantic analysis (and rejection) of fragments of a syntactic structure prior to the complete determination of that structure.

The importance of the syntactic component has been recognized for some time. For the purposes of MT it has two distinct ends to achieve: on the one hand it must specify a large enough subset of the source language to meet the operational requirements of the MT application in question. (The related function of ruling out syntactically ill-formed sentences is of limited importance in MT). On the other hand the structures it assigns must provide a reasonable basis for semantic interpretation. These two requirements are closely related, i. e., it is relatively easy to satisfy one at the expense of the other, but much harder to adequately meet them both.

A not uncommon attitude which has been expressed both in the computational linguistic literature and orally at symposia and conferences is that syntax in general and syntactic analysis in particular has been well worked over, is thoroughly understood, and presents no serious problems — in contrast to the situation in semantics where little has been done and not much is understood. I submit that such remarks reflect the experience of one who has chosen a class of grammars, in most cases context-free grammars, which permits a reasonable coverage of a source language at the expense of assigning structural descriptions which bear little relationship to underlying meaning and which, therefore, provide an inadequate basis for semantic interpretation. It is not just because large-coverage context-free grammars have been found to often assign 100 or more structural descriptions to unambiguous sentences that makes them inadequate. Rather, this is just symptomatic of a more deep-seated inability to relate form to underlying meaning.

This shortcoming is not limited to the class of context-free grammars. If the rewriting system is extended to encompass context-sensitive grammars and/or rewriting rules with whose constituents complex features can be associated then economies and linguistic generalizations are realized, but the fundamental problem of relating form to meaning appears intractable for any system which attempts to interpret the surface form of sentences. It was this realization that prompted Chomsky to propose as the basis for

semantic interpretation deep structures which were in many cases far removed from surface structures. Chomsky made use of a transformational component to relate corresponding deep and surface structures, but the acceptance of the deep-surface structure distinction is a matter which is independent of any consideration of the most appropriate means for making explicit that correspondence. Accordingly, a host of models (each of which is a proposed linguistic theory even if not called such) have been proposed for mapping surface structures into corresponding deep structures, or (in some cases) for directly assigning deep structure to sentences without explicitly producing surface structure.

It is my contention that linguistic models which do not provide the deep structure of sentences (at least implicitly if not explicitly) fail to provide a basis for the semantic analysis of all but a small class of sentences, a class so restricted that its use is precluded for most applications including MT. Hence, for the remainder of my discussion I will focus my attention on the problems of syntactic and semantic analysis associated with some type of deep structure model.

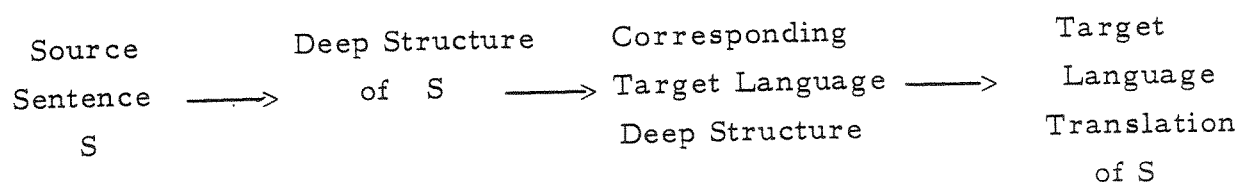
As pointed out previously, there is a trade-off possible between syntax and semantics. If more is done by the syntactic component the task of the semantic component is lightened and vice-versa. Contemporary linguistic theory has been much concerned with this question of where to draw the line, and even though the questions of overall simplicity considered have not been motivated by any concern for MT, it is nevertheless instructive to consider the applicability to MT of models of present-day deep structure complexity. There is, of course, no general agreement among linguists as to the type and complexity of deep structures and of the related transformational component required by those deep structures. Even though these decisions loom large and important to linguists, however, they are not so large as to preclude assessment of the suitability of a rather large class of deep structure models for MT.

Let us begin then by considering the requirements of the semantic component. It is, of course, possible to produce sentences whose

semantic analysis and/or translation requires not only a number of deep structure distinctions but also a large amount of information about the world, about logical deduction, and about the context of discourse in which the sentence appears. I am resigned to the prospect that these obstacles preclude for the foreseeable future extremely high quality translation.

My own experience with semantic interpretation has been with translation to a formal language which, although not a programming language in the sense of having an existing hardware or software interpreter, is close enough to a programming language that the task of translating it to an existing programming language is an easy one. The problem of translating a given structure to a functional programming language appears to me to be greater than that of translating that structure to another natural language. This follows from two considerations: First, deep structures of different languages which have been proposed to date are remarkably similar. In those cases where differences have been argued, they have seldom exceeded differences in subject, verb, object ordering. Deep structures differing so slightly are easily related through the use of such standard translation mechanisms as the Irons Translator¹.

Second, the task of using a transformational grammar to convert deep structures into surface structures is not conceptually difficult. Hence, it would appear that for a very large class of sentences, the translation sequence shown below should provide the basis for translation:



Indeed, it has been my experience that semantic interpretation of deep structures through the use of the Irons or more generally the Knuth² translation mechanism even provides a reasonable basis for a natural language question answering system. This has also been argued by Kellogg and Thompson among others. For more discussion see reference 3.

I have argued that the use of a deep structure (read semantic structure if you prefer) generative grammar does provide a reasonable basis for MT. It does so, however, by throwing a considerable burden on the syntactic component. We have seen that structures can be assigned which appear adequate for the purposes of MT. But what of the coverage requirement, i. e., that a sufficiently large subset of the source language be specified? In addition, we must concern ourselves with the theoretical and practical requirements of syntactic analysis for a class of grammars that is capable of assigning adequate deep structures.

I will discuss these two considerations with respect to generative transformational theory and also, more briefly, with respect to other deep structure-based linguistic theories.

Let us first consider the matter of coverage. It is, of course, the case that most transformational studies of syntax do not supply completely specified base and transformational component rules in discussing syntactic phenomena. There have been, however, a few attempts to write a completely specified set of rules within a well-defined transformational framework^{4, 5, 6, 7, 8}. These efforts establish a lower bound on coverage which can be achieved without sacrificing structural adequacy. It is somewhat difficult to characterize the coverage achieved by any means short of exhibiting the grammars in question. There are, however, at least two ways to give a feel for the coverage attained by a specific grammar. The first is to give a list of "representative" sentences and the second is to list the syntactic constructions and phenomena provided for. Thus, for example, Rosenbaum⁷ gives derivations of the 22 sentences:

1. the boys like the girl
- ...
21. the pajamas of a king are colorful
22. the people who approve of him think that John is smart

He also lists 79 representative sentence types and includes transformations

for handling verb phrase complements, pronominalization, preposition segmentalization and raising, indirect objects, relatives, genitives, negatives, certain time and place adverbials, etc. Similarly, in a more recent effort at the IBM Thomas J. Watson Research Laboratory a transformational grammar has been produced which generates such sentences as:

what companies had a profit which was more than
ten million dollars?

and print the one element of the set which contains M which is atomic and provides such construction types as: yes-no and Wh-questions, passives, prepositional phrases, nominal structures formed from underlying abstract verbs, restrictive relatives, possessive genitives, and certain types of negatives, comparatives, and coordinate structures.

Now just as existing grammars establish a lower bound on coverage attainable there are several considerations which suggest upper bounds for at least the foreseeable future. For example, many syntactic phenomena may be identified which have not yet been studied by anyone. Many other phenomena have been studied, but the results have served more to show the existence of substantial problems than to offer compelling and widely accepted solutions. Examples here are plentiful and include coordination, gapping, and pronominalization as well as almost every syntactic phenomenon which has been studied to some extent. And finally, experimental work conducted to date shows that it is far from trivial to put together and test grammars that provide for such relatively well understood constructions as yes-no questions, WH-questions, restrictive relatives, imperatives, etc.

The large number of unexplored and little understood syntactic phenomena suggest difficulty in achieving sufficient coverage for practical application, but an even more instructive exercise in illustrating this difficulty is provided by producing a set of sentences thought to be useful

and representative for some application and comparing their syntactic requisites with the facilities offered by any existing or proposed grammar. I have seen this operation carried out at the MITRE Corporation with respect to a command and control question answering application and have myself undertaken the same task for a formatted file question answering facility. The results were the same. Very low coverage was observed; certainly less than 10% of the sentences studied were covered even allowing for lexical addition and extension by including some rather obvious additional transformations. The saving feature in the case of natural language question answering systems or natural language programming systems, however, is that they need not process unconstrained input sentences. Instead the user can be constrained to and instructed as to how to limit his input in terms of both lexicon and allowable constructions. All that is required is that natural subsets provided must be learnable by human speakers and must be rich enough to permit expressing that which must be expressed in a convenient fashion. The attainability of even these requirements remains to be established but at least offers some hope of success. On the other hand the usual situation with MT is that the input is not produced with the limitations of a particular formal grammar in mind. This, more than any other single factor, convinces me that grammar-based MT offers little hope for practical usage for at least the next ten years. This is not to say that MT is not an interesting and productive vehicle for keeping linguistic research in both syntax and semantics tied to reality. Others might disagree with this assessment, of course.

There may be a few MT applications where time and economic considerations permit the phrasing or rephrasing of source sentences by speakers cognizant of a system's grammatical constraints. Such an example is the preparation of technical manuals in one language for translation into another language. This is, however, not the usual situation in MT.

When we leave the (at least for me) familiar grounds of transformational theory and consider the coverage problem for such analysis-based linguistic theories as those of Woods⁹, Winograd¹⁰, Bobrow and Fraser,¹¹

Thorne¹², Moyne¹³, Kellogg¹⁴, Kay¹⁵ and Simmons¹⁶ we are faced with a difficult task for a number of reasons. Many of these models have been used only sparingly for the specification of any natural language. Hence, there is little to go on in assessing the coverage of these models. In addition, those models for which one or more large grammars have been written have not been documented in a way and to an extent which makes the determination of coverage feasible. Alternative clarification of coverage via sample sentences and listed construction types presents the same problem as we observed for transformational grammars, but whereas most linguists are by this time familiar with transformational formalism, this is not true of the aforementioned analysis-based models. Therefore, their coverage can at present be estimated only by their originators. It is far from clear to this observer that these approaches offer the same independence of construction types as is achieved by transformational theory. In any case, none of these models have supported claims of greater coverage than that afforded by current transformational theory. It is important to note that although these models are often described as "transformational" by their originators, they have not been related to transformational theory and hence must be judged on the usual grounds of linguistic adequacy just like any other proposed linguistic theory.

The remaining consideration is the theoretical and practical requirements of syntactic analysis for a deep structure - specifying class of grammars. For those analysis-based grammars previously mentioned there are few theoretical syntactic analysis problems. In addition, the computation time required for parsing, although generally not known, could reasonably be expected to be less than that required for parsing with respect to a transformational grammar. (Whether it is sufficiently small to satisfy economic considerations is, of course, another story.) This is to be expected for analysis-based linguistic theories whose principal motivation is to facilitate syntactic analysis. It is descriptive adequacy, not syntactic analysis considerations which are most likely to preclude the practical use of analysis-based grammars.

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The situation is quite different with respect to transformational grammars. There is no shortage of work in linguistic description through the use of transformational grammars, although it must be noted that most efforts are directed toward determining the allowable class of transformational grammars rather than toward developing in detail any one comprehensive grammar. Syntactic analysis for any class of transformational grammars is a very complex and time-consuming proposition. It is probably for this reason that most workers in computational linguistics have chosen to forego conventional transformational theory in favor of an analysis-based alternative.

There have been only two computer implemented efforts on transformational grammar syntactic analysis. One, carried out by the MITRE Corporation, was limited to a particular grammar; a syntactic analysis program was tailored to this grammar. The program appeared to be successful in producing desired structures in a reasonable time, but it was never established that this program invariably found all of the structures assigned to a sentence by the particular transformational grammar in question (i. e., that it was, in fact, an analysis program for that grammar).

In contrast to the MITRE approach, Petrick¹⁷ defined a class of transformational grammars and found a syntactic analysis algorithm that is valid for members of this class. The extremely nondeterministic nature of this algorithm made unfeasible the treatment of grammars as written by a linguist unfamiliar with the analysis procedure. However, Kirk and Keyser⁶ showed that by suitable recasting, a substantial portion of an existing grammar (due to Rosenbaum) could be used for syntactic analysis.

In addition to the problem of computing time, there is another serious difficulty in transformational grammar syntactic analysis. The class of grammars for which syntactic analysis algorithms have been devised does not include many of the facilities currently being used by descriptive grammarians. Indeed, transformational theory is far from

static, and at any given time there is little agreement on just what should constitute an allowable class of transformational grammars. In reference 18 we give an account of the current status of syntactic analysis for transformational grammars. In summary, it can be stated that although the class of grammars for which syntactic analysis is possible has been significantly extended, the introduction of new variants of transformational theory has more than kept pace with theoretical and programming efforts to cope with them. Consequently, any given linguist would undoubtedly find that his rules and assumptions do not correspond perfectly with the formulation of the allowable class of grammars. Nevertheless, it is hoped that this class is now extensive enough to permit recasting of current transformational grammars into an acceptable form without seriously compromising their linguistic integrity.

RE:

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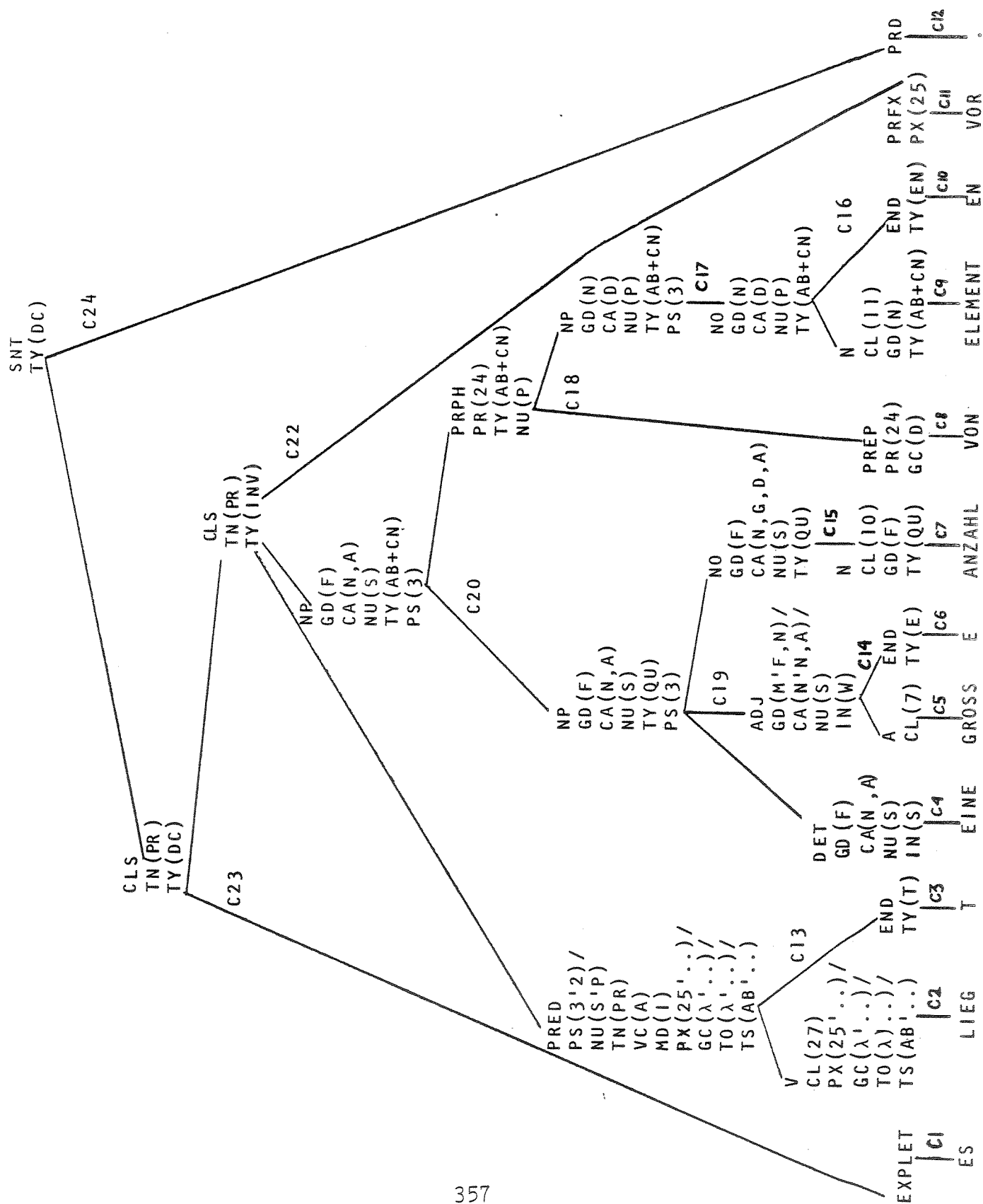
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APPENDIX

Analysis of *Es liegt eine grosse Anzahl von Elementen vor.*

by Annette Stachowitz

Linguistics Research Center
The University of Texas at Austin



Rules:

C1	V EXPLET	=	* ES
C2	V V + CL(27) + PX(..'25'..)/ + GC(..'λ'..)/ + TØ(..'λ'..)/ + TS(..'AB'..)	=	* LIEG
C2	V V + CL(9) + PX(..'25'..)/ + GC(..'λ'..)/ + TØ(..'λ'..)/ + TS(..'AB'..)	=	* LAG
(analogous C2 rules for the stems <u>laeg</u> , <u>leg</u>)			
C3	V END + TY(T)	=	* T
C4	V DET + GD(F)/ + CA(N,A)/ + NU(S) + IN(S)	=	* EINE
C5	V A + CL(7)	=	* GROSS
C6	V END + TY(E)	=	* E
C7	V N + CL(10) + GD(F) + TY(QU)	=	* ANZAHL
C8	V PREP + PR(24) + GC(D)	=	* VON

C9	V N + CL(11) + GD(N) + TY(AB+CN)	= * ELEMENT		
C10	V END + TY(EN)	= * EN		
C11	V PRFX + PX(25)	= * VOR		
C12	V PRD	= * .		
C13	V PRED + PS(3'2)/ + NU(S'P) + TN(PR) + VC(A) + MD(I) ^ 2	= V V \$ CL(...,27)	V END \$ TY(T) B	
C14	V ADJ + GD(M'F,N)/ + CA(N'N,A)/ + NU(S) + IN(W)	= V A \$ CL(...,7)	V END \$ TY(E) B	
C15	V NO + CA(N,G,D,A)/ + NU(S) ^ 2	= V N \$ CL(...,10)		
C16	V NO + CA(D) + NU(P) ^ 2	= V N \$ CL(...,11)	V END \$ TY(EN) B	
C17	V NP + PS(3) \$ 2.1NU ^ 2	= V NO \$ NU(P)		
C18	V PRPH ^ 2,3	= V PREP . 3.1GC	V NP \$ CA \$ GD	
C19	V NP + PS(3) \$*2.4GD/ \$*2.5NU/ \$*2.6CA ^ 4	= V DET \$ GD/ \$ NU/ \$ CA . 3.1,W2.1/ . 3.2,W2.2/ . 3.3,W2.3 .*3.4IN	V ADJ . 4.1GD/ . 4.2NU/ . 4.3CA \$ IN	V NØ \$ GD \$ NU/ \$ CA

C20 V NP = V NP V PRPH res
 ^ 2,3 \$ TY(QU) \$ PR(54) (Fe
 \$ NU(P) gov

C22 V CLS = V PRED V NP V PRFX typ
 + TY(INV) \$ PX . 2.2PS/ . 2.1PX
 \$ 3.4 \$ PS/ . 2.3NU exa
 \$ 2.5 \$ NU . 2.4TY 30
 \$ TS ? PRN rea
 \$ TN \$ CA(N) wit
 \$ VC Her
 \$ MD
 \$ GC(λ) Vol

The subscript PRN in the NP constituent is added to the clause label only if NP dominates a pronoun:

V NP = V PRN
 + PRN \$ TY(PS)
 ^ 2

C23 V CLS = V EXPLET V CLS
 ^ 3 \$ TY(INV)
 * PRN

(This rule specifies that a clause with inverted word order may only be preceded by an expletive es if its subject is not a personal pronoun: Es kommen drei Personen in Frage. But: * Es kommen sie in Frage.)

C24 V SNT = V CLS V PRD
 \$ 2.1 \$ TY(DC) B

This analysis may show the difficulties that have to be accounted for in the analysis of surface strings with context-free phrase structure rules. Apart from the problems of discontinuity of elements in the surface structure and of phrasal dictionary elements, the amount of information in lexical elements which is relevant for correct analysis and translation is extremely large. Almost every verb can have different readings (and translations) depending on which one of a (sometimes very large) number of selection

restrictions or feature packets it is associated with. (Feature packets may include separable prefixes, case government including prepositional objects governed, types of objects and subjects required, etc.). For example, the German verb liegen may be associated with 30 different feature packets, resulting in 30 different readings of which a few are shown here (these translations, with a few exceptions, are taken from Wildhagen and Héraucourt, German-English / English-German Dictionary, Vol. II German-English, Brandstetter Verlag, Wiesbaden, 1957):

1. liegen, intransitive, requiring a physical object as subject, with a locative adverb: to lie, to rest, to be located or situated;
2. liegen, governing a dative object which must be human and with a subject which must be abstract: to suit a.p., to appeal to sb.;
3. liegen, associated with the separable prefix an, with an inanimate concrete subject, governing a dative object or a prepositional object with the preposition an and an NP which must be concrete and inanimate: border on, be adjacent to;
4. liegen, with the separable prefix an, with a human subject and a human dative object: to entreat a.p.;
5. liegen, with the separable prefix bei, intransitive, with a concrete inanimate subject, with the auxiliary sein if used in the perfect tense: to be enclosed;
6. liegen, with the separable prefix danieder, intransitive, and with a human subject: to be lying ill;
7. liegen, with the separable prefix vor, intransitive, and with an abstract subject: exist.

The subscript format, in which the rules for this analysis are written, makes surface analysis possible

because of the following two characteristics:

- a) Rule constituents are only subconfigurations of work space configurations, i.e. only the features relevant in a particular rule are mentioned in that rule while all others are disregarded. For example, rule C13 (p. 3) only states the condition that a verb stem must be classified as belonging to the paradigmatic class 27 in order to be concatenable with the verb ending -t, thus forming a predicate with the indicated features. The remaining properties of the verb (prefix, case government, type of object and subject required) are irrelevant in this concatenation rule and are merely "carried up the structural tree" by means of the operation specified by the symbols $\wedge 2$ on the left side of that rule.
- b) Agreement and government are specified as set theoretical operations between the values of rule constituents. For example, rule C19 (p. 3) very generally states that in a German sentence the sequence determiner-adjective-nominal should be analyzed as a noun phrase provided that they agree in gender, number and case, and that the adjective and the determiner must not agree in type of inflection (weak or strong). These conditions are expressed by the operations specified in the second and following lines of each constituent of this rule. (All other features of the nominal head are not specifically mentioned in the rule and are simply carried up the tree.) Thus, very large numbers of rules can be represented by one rule in this subscript format. This makes it possible to incorporate and refer to the large amount of information necessary for analysis and translation in the dictionary and syntax of a surface grammar. Access to this information available in the surface string would be practically impossible with a context-free phrase structure grammar with simple symbols because of the unmanageable number of lexical classes and morphological

and syntactic rules building on these classes.

In spite of the greater economy of subscript rules, however, problems resulting from permutations of elements of phrasal and idiomatic expressions cannot be easily solved in surface analysis. For this reason, the analysis of sentences containing such elements is, in practice, performed in two steps at the LRC: surface analysis and standard analysis. In standard analysis the elements of phrasal and idiomatic expressions are re-ordered to a pre-determined standard order and are then treated as one single dictionary item, possibly with internal variable slots. A detailed description of standard analysis may be found in Research in German-English Machine Translation on Syntactic Level, Final Technical Report, RADC-TR-69-368, Volume II, August 1970.

The following is an explanation of the symbols used in the structural tree. The symbols are defined going from left to right in the sentence and from the bottom to the top of the tree.

Lexical level:

EXPLET = Expletive es; not a pronoun but rather a syntactically empty placeholder for the subject of the sentence.

V
CL(27) = This verb of paradigmatic class 27 may be
PX(25'...)/ used with any of a number of specified
GC(λ'...)/ separable prefixes, among them prefix 25,
TO(λ'...)/ which is the German prefix vor. If it is
TS(AB'...) used in conjunction with this particular
prefix, it is intransitive (governs case λ; semantic type
of object λ) and takes a subject of the semantic class
type abstract.

END TY(T)	= Ending of <u>type</u> - <u>t</u>	
DET GD(F) CA(N,A) NU(S) IN(S)	= <u>D</u> eterminer, <u>g</u> ender <u>f</u> eminine, ambiguous with respect to <u>c</u> ase, i.e. it may be considered <u>n</u> ominative or <u>a</u> ccusative, <u>n</u> umber <u>s</u> ingular, <u>s</u> trongly <u>i</u> nflexed.	
A CL(7)	= Adjective of paradigmatic <u>c</u> lass <u>7</u> .	
END TY(E)	= <u>E</u> nding of <u>type</u> - <u>e</u>	
N CL(10) GD(F) TY(QU)	= <u>N</u> oun of paradigmatic <u>c</u> lass <u>10</u> , <u>g</u> ender <u>f</u> eminine, <u>t</u> ype <u>q</u> uantifier, i.e. a quantifying noun which may be followed by a <u>v</u> on PRPH and then constitutes a modifier of the head noun in that PRPH.	
PREP PR(24) GC(D)	= The <u>p</u> reposition is identified as <u>p</u> reposition number <u>24</u> (<u>v</u> on) and has the feature " <u>g</u> overns <u>c</u> ase <u>d</u> ative".	
N CL(11) GD(N) TY(AB+CN)	= A <u>n</u> oun of the paradigmatic <u>c</u> lass <u>11</u> , <u>g</u> ender <u>n</u> euter, and semantic <u>t</u> ype <u>a</u> bstract and <u>c</u> ountable.	
END TY(EN)	= <u>E</u> nding of the <u>type</u> - <u>en</u> .	
PRFX PX(25)	= This <u>p</u> re <u>f</u> ix is identified as <u>p</u> re <u>f</u> ix number <u>25</u> (<u>v</u> or).	
PRD	= The <u>p</u> er <u>i</u> od is marked as being a marginal symbol, i.e. it constitutes the boundary of a word and of a sentence.	

Morphological level:

PRED PS(3'2)/ NU(S'P) TN(PR) VC(A) MD(I) PX(25'...)/ GC(λ'...)/ TO(λ'...)/ TS(AB'...)	= The <u>p</u> re <u>d</u> icate (finite verb) has all the features of the underlying verb stem: prefix, case government, type of object and subject required. (The feature CL
--	--

- paradigmatic class - is dropped because it is no longer relevant.) In addition, it has the features person and number which mark it as either 3rd person singular or 2nd person plural. (The apostrophe and slash establish this relation between the individual features) It is also marked as: tense present, voice active, and mood indicative.

ADJ = With respect to gender and case, the inflected
GD(M'F,N)/ adjective is characterized as masculine
CA(N'N,A) nominative; or feminine or neuter nominative
NU(S) or accusative. In number it is singular;
IN(W) the inflection is weak.

NO = The inflected nominal has the same gender
GD(F) and type information as the dictionary
CA(N,G,D,A) noun entry and in addition has the tags
NU(S) number singular, case 4-way ambiguous,
TY(QU) i.e. it is either nominative, genitive, dative, or
accusative, depending on its environment.

NO = Inflected nominal with the gender and type
GD(N) of the underlying noun stem, case dative,
CA(D) number plural.
NU(P)
TY(AB+CN)

Phrase level:

NP = The noun phrase has the gender, case, and
GD(F) number characteristics in which the under-
CA(N,A) lying determiner, adjective and noun agree,
NU(S) namely feminine nominative or accusative
TY(QU) singular; the type is that of the head
PS(3) noun; the NP is marked as 3rd person.

NP = Noun phrase with all syntactic and semantic
 GD(N) features of the underlying nominal,
 CA(D) identified as 3rd person.
 NU(P)
 TY(AB+CN)
 PS(3)

PRPH = This prepositional phrase is identified as
 PR(24) dominating preposition 24, i.e. von, and an
 TY(AB+CN) NP with a head noun of type abstract and
 NU(P) countable, number plural.

NP = This noun phrase, which dominates an NP
 GD(F) followed by a von PRPH, has the syntactic
 CA(N,A) features of the dominated NP:
 NU(S) gender feminine, case nominative or
 TY(AB+CN) accusative, number singular, and the semantic
 PS(3) features of the head noun of the dominated PRPH: type abstract
 and countable. It is also marked as an NP in the 3rd person.

Clause and sentence level:

CLS = This clause is of the type with inverted
 TY(INV) word order; it may be followed by a "?"
 TN(PR) to form a question or, as in this sentence,
 it may be preceded by an expletive es to form a declarative
 sentence; its tense is present.

CLS = A clause of type declarative, tense present.
 TY(DC)
 TN(PR)

SNT = A sentence of type declarative.
 TY(DC)

LEXICAL FEATURES IN TRANSLATION AND PARAPHRASING: AN EXPERIMENT

by

Rolf Stachowitz

Linguistics Research Center
The University of Texas at Austin

LEXICAL FEATURES IN TRANSLATION AND PARAPHRASING: AN EXPERIMENT

Introduction

It is obvious to any user of a monolingual dictionary that the meaning of a lexical item is not only dependent on the external form of the item but also on its syntactic or semo-syntactic properties.¹ The terms homonymy and polysemy reflect this knowledge. It is equally obvious for the user of a better than average bilingual dictionary that the meaning of a lexical item is also a function of each selection restriction associated with it. This observation is evident from the fact that different translations are associated with a particular lexical item dependent on the syntactic and/or semantic properties of the constituents in its environment. The verb *erinnern* provides an example for German: In the environment "reflexive pronoun" its translation is *remember*; in the environment "non-reflexive object" its translation is *remind*.

The observations are, of course, true for lexical items in a language independent of their translatability into some other language. Only a few monolingual dictionaries, however, make this observation explicit. Among the few notable examples are the German Woerterbuch der deutschen Gegenwartssprache² and Hornby's An Advanced Learner's Dictionary³. Hornby lists for each verb the complement structures with which it may occur and the meanings it has in each environment. Thus, *observe*

may mean *to take notice of* (*to watch*) or *to say as comment in* the environment "*that S*", e.g. He observed that his wife had arrived. However, in the environment "*NP*", *observe* can only have the first interpretation, e.g. He observed the arrival of his wife⁴.

In view of the possibility of specifying the meaning of a lexical item or selecting a proper translation equivalent for it by taking its environment into account, it may seem surprising to the uninitiated that earlier MT systems had attempted to make such selections based on different criteria: considerations of the type of text to be translated or of probability of occurrences of lexical items. The difficulties confronting attempts to access the selection restrictions of a lexical item during the surface analysis of a sentence by means of a context-free grammar have been described in various monographs. These difficulties are multiplied when attempting the translation of languages, such as German, where various agreement and government relations hold between constituents, where lexical items and phrasal expressions often occur as discontinuous elements, and where sentence constituents can occur in various orders. The attempt to incorporate selection restrictions of lexical items into non-terminal symbols of context-free grammars would have increased the number of such rules to unmanageable proportions. For this reason, the incorporation of such selection restrictions was consequently suppressed. The loss was two-fold:

a) The number of syntactic interpretations for a sentence often increased ("forced readings").

b) The selection of proper translation equivalents had to be based on different criteria.

II Background of the Experiment

In summer 1966 I began investigating the possibilities of improving various parts of the Linguistics Research System⁵ in order to cope with the increasing difficulties encountered in the attempts to analyze and translate sentences in natural language: the prohibitively large number of syntactic and translation rules necessary for the description and translation of surface structures into surface structures and the inability to deal with discontinuous constituents.⁶ The research was influenced by the following guidelines:

- 1) to improve translation by permitting access to selection restrictions;
- 2) to decrease the number of forced readings assigned to sentences without an unreasonable increase in the number of grammar and translation rules;
- 3) to preserve as many as possible of the various algorithms used for surface analysis, translation mapping and surface production.

The results were reported in December 1966 in an unpublished paper which stated:

- a) that vastly improved translations were possible by performing translation not from surface structures into surface

structures but from standardized surface structures (standard strings) into standardized surface structures;

b) that these standard strings could be derived from the syntactic reading of a sentence by means of an additional straight-forward algorithm;

c) that these translations could be obtained with an overall decrease of grammar rules;

d) that the core of the LRS algorithms could be retained;⁷

e) that non-trivial paraphrases could be performed over standard strings which were not possible over surface strings.

An experiment was subsequently performed to compare the proposed translation procedure with the established one. In order to facilitate this comparison, a text was selected for translation part of which had been translated in February 1966 using the Linguistics Research Center's first and second order translation system. Since the program which derived the standard strings from the corresponding sentence readings did not exist, the standard terminals were represented as surface terminals enclosed in asterisks. Only in cases where surface terminals occurred as homographs in the given text was a descriptor added in parentheses to reflect the disambiguating effect of the standardization procedure.

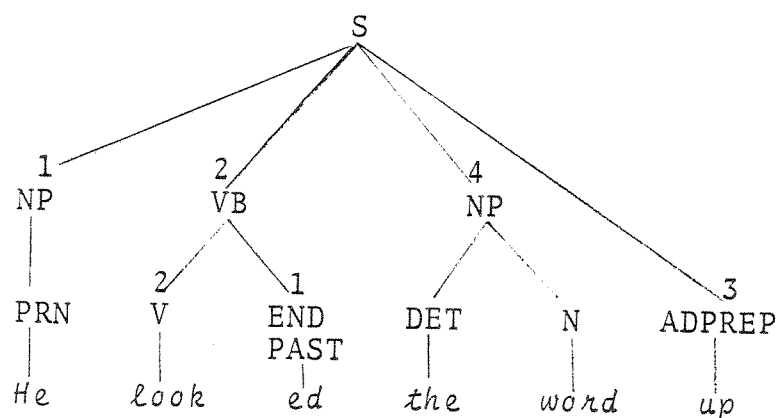
In order to reduce the time spent on this experiment, only one standard string of those sentences which had more than one surface reading was selected. (The number of readings for

sentence 486 was 24, sentences 488, 489, and 492 had two readings each, all others had one.)

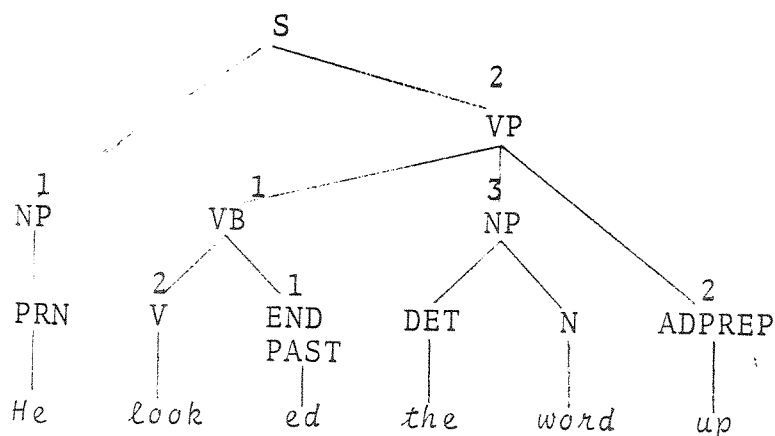
III Standard Strings

The standard representation of a sentence is a reordering of its terminal elements (with their part-of-speech interpretation) based on the surface interpretation of that sentence. The reordering could be performed by means of ordering instructions assigned to each constituent in the consequent of a rule which is part of the sentence reading.⁸

Assume the sentence *He looked the word up* is analyzed by the rules represented in the following tree diagram:



or, if you prefer, by



(The digits at the end of branches determine the mapping order of the sister nodes).

The standard string corresponding to this reading would then be:

he	ed	look	up	the	word
<PRN>	<END>	<V>	<ADPREP>	<DET>	<N>
	<PAST>				

where the part-of-speech interpretation of each terminal is represented in angled brackets. (One can obtain a standard string by tracing down from each node, beginning with S, all branches in their indicated order and not tracing up a branch before all terminals below that branch have been reached).

The following standard order was defined for German surface constituents:

For clause level elements:

Subject (of an active sentence), agent adverbial (of a passive sentence), predicate, prefix, direct object, subject (of a passive sentence), predicative complement, indirect object, adverbials.

For phrase level elements:

Verbals: Finite verb, non-finite verb, prefix.

Noun phrases: Head, post-modifier, pre-modifier, determiner.

Prepositional phrases: Preposition, object.

For word level: Affixes, stem.

Conjoined elements "A, B and C": and , A B C .

The standard order defined for English differed from that for German only in that the elements of noun phrases occurred in the sequence: Determiner, pre-modifier, post-modifier, head of noun phrase. No significance is to be attributed to this difference; the distinction was made primarily to facilitate the reading of the output, the English standard strings. The distinction, however, shows the independence of the standard orders of the two languages.

The greater ease with which strings given in standard order could be analyzed may be evident when comparing the syntactic description of the following five sentences with the corresponding standard descriptions.

- 1) Das Buch hat er seiner Frau gegeben.
- 2) Seiner Frau hat er das Buch gegeben.
- 3) Der Frau ist er gefolgt.
- 4) Seiner Frau hat er gehorcht.
- 5) Das Buch hat er gelesen.

(Clause level constituents consisting of more than one word are underlined). These sentences were analyzed by the following rules:

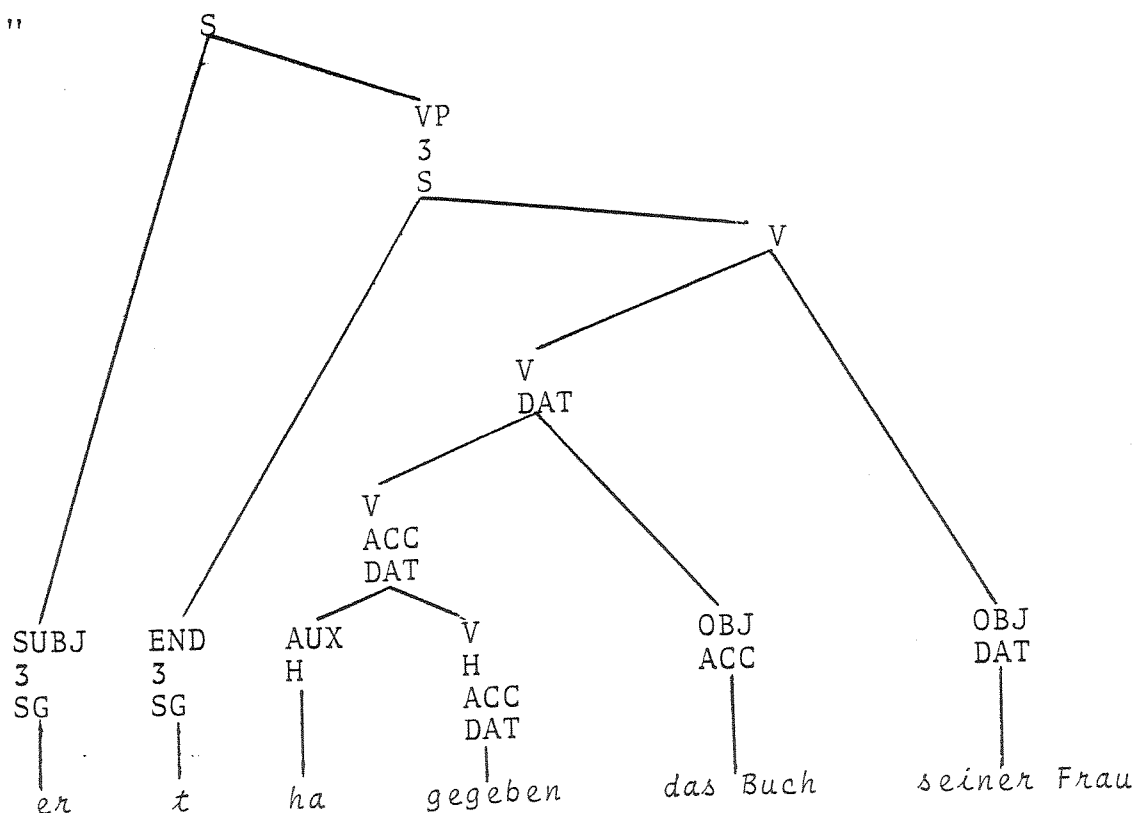
- 1') S → OBJ AUX SUBJ OBJ PASTPART⁹
 ACC H 3 DAT H
 3 SG ACC
 SG DAT
- 2') S → OBJ AUX SUBJ OBJ PASTPART
 DAT H 3 ACC H
 3 SG ACC
 SG DAT
- 3') S → OBJ AUX SUBJ PASTPART
 DAT S 3 S
 3 SG DAT
 SG

4') S → OBJ AUX SUBJ PASTPART
 DAT H 3 H
 3 SG DAT
 SG

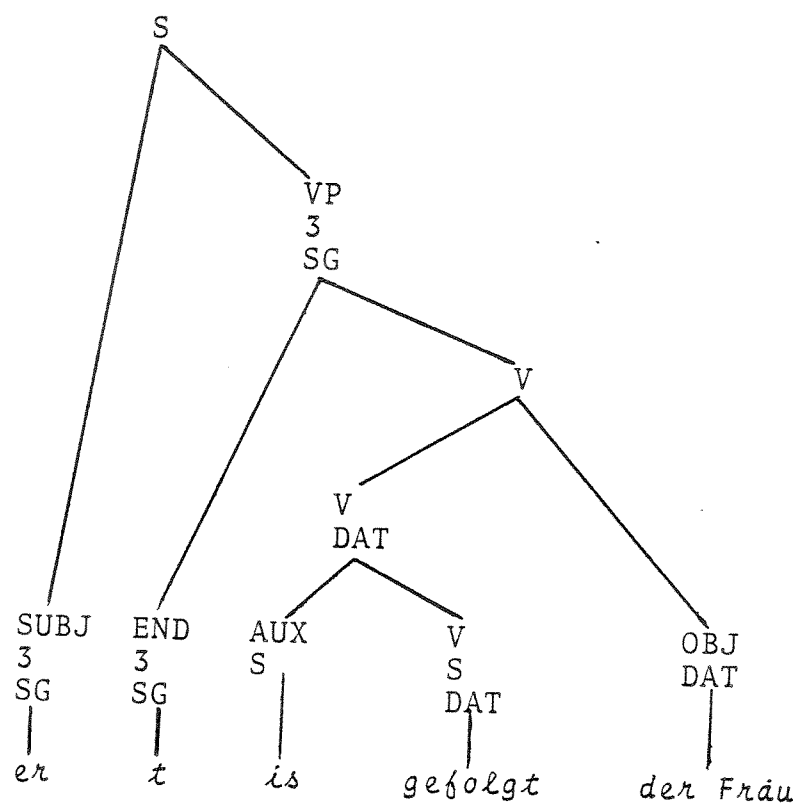
5') S → OBJ AUX SUBJ PASTPART
 ACC H 3 H
 3 SG ACC
 SG

As we can observe, each change in word order (sentences 1 and 2), syntactic agreement (sentences 3 and 4) or government (sentences 4 and 5) had to be analyzed by a new sentence rule.¹⁰ The corresponding standard representations, however, permitted a far more economic analysis.

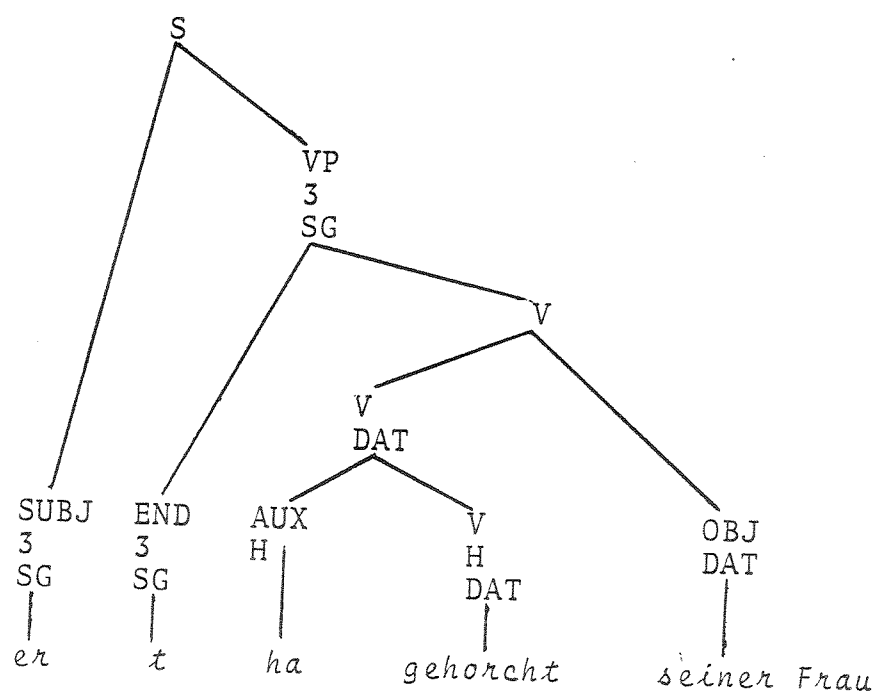
1'', 2''



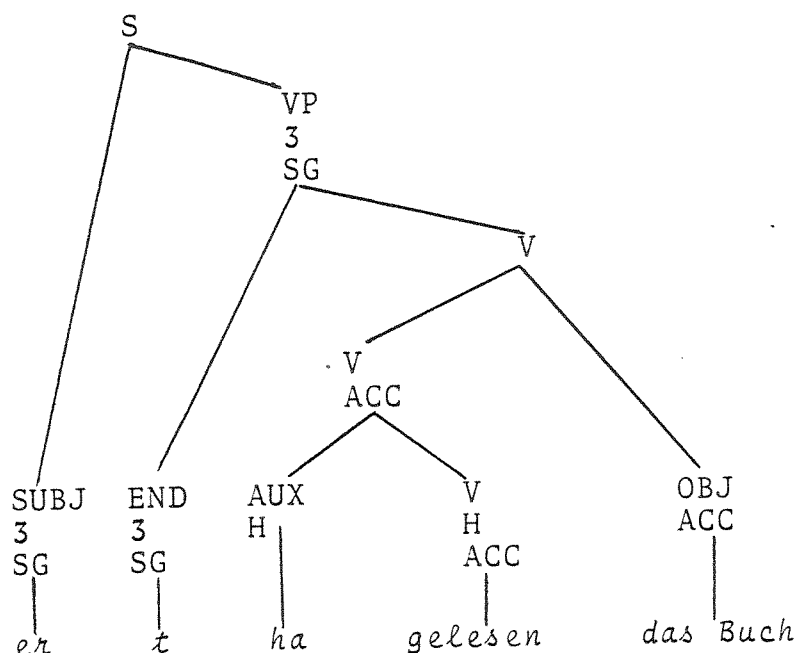
3''



4''



5''



Firstly, it will be noticed that permutations as in sentences 1) and 2) were reduced to the same representation. Secondly, it was possible to concatenate the verb with its immediately contiguous elements, dropping with each concatenation the information that was necessary for the concatenation. This resulted in a considerably smaller number of grammar rules.

Note that all four readings have in common the rules $S \rightarrow \begin{matrix} \text{SUBJ} \\ 3 \\ \text{SG} \end{matrix} \begin{matrix} \text{VP} \\ 3 \\ \text{SG} \end{matrix}$

and $\begin{matrix} \text{VP} \\ 3 \\ \text{SG} \end{matrix} \rightarrow \begin{matrix} \text{END} \\ 3 \\ \text{SG} \end{matrix} \begin{matrix} V \\ 11 \end{matrix}$. Sentences 1), 3) and 4) also have in common

the rule $\begin{matrix} V \\ \text{DAT} \end{matrix} \rightarrow \begin{matrix} V \\ \text{DAT} \end{matrix} \begin{matrix} \text{OBJ} \\ \text{DAT} \end{matrix}$. It was, finally, possible to treat discontinuous lexical items as one piece and assign them a new, their correct, syntactic interpretation.¹² Thus the rule

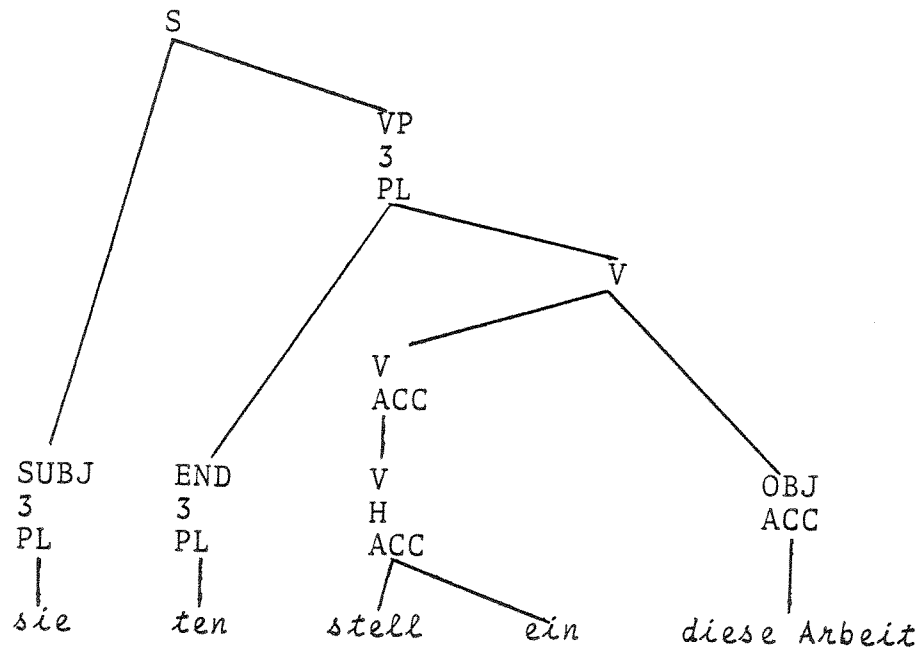
$S \rightarrow \begin{matrix} \text{OBJ(4)} \\ \text{ACTIVE} \end{matrix} \begin{matrix} \text{PRED(2)} \\ \text{ACTIVE} \end{matrix} \begin{matrix} \text{SUBJ(1)} \\ \text{ACTIVE} \end{matrix} \begin{matrix} \text{PRFX(3)} \\ \text{ACTIVE} \end{matrix}$ - the desired order of the constituents is given in parentheses - interpreting sentences such as

6) Diese Arbeit stellten sie ein = They discontinued this work.

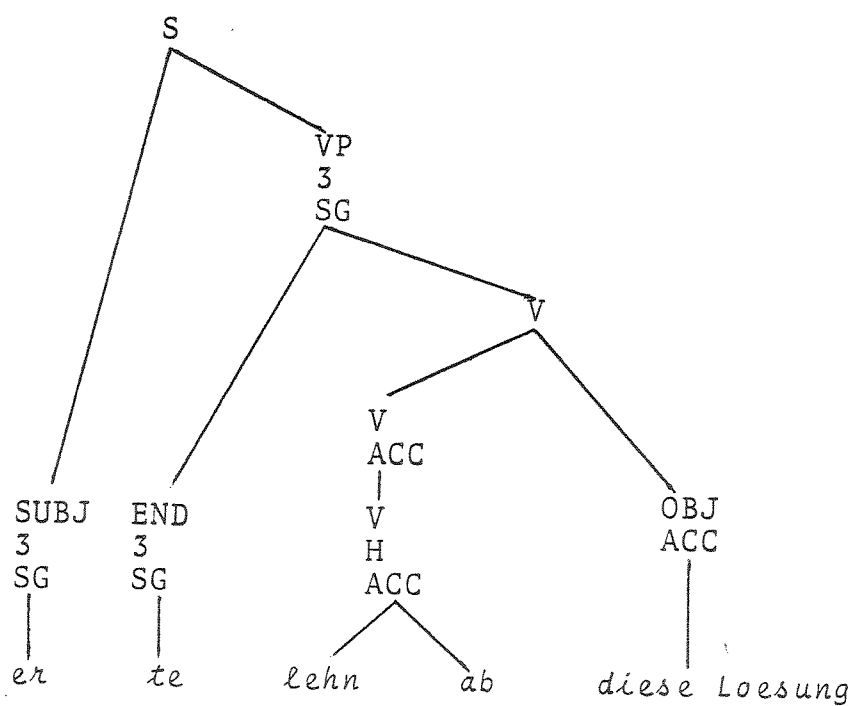
7) Diese Loesung lehnte er ab = He rejected this solution.

generated the standard strings given in the tree diagrams below.¹³

6''



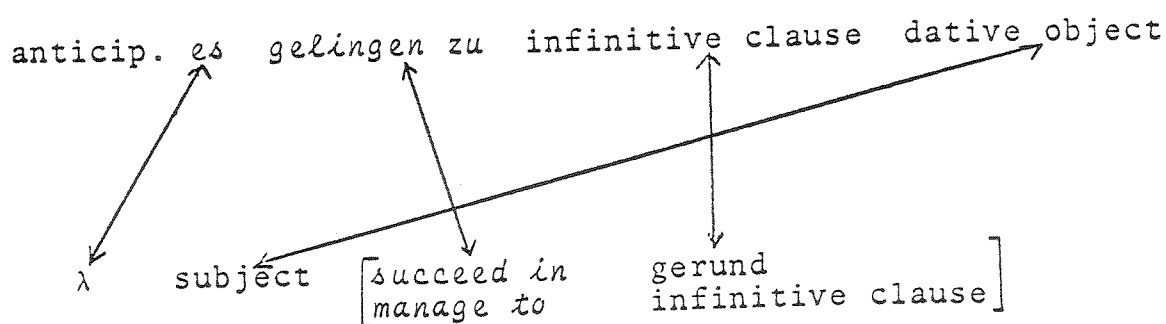
7''



IV The Selection of Translation Equivalents

The possibility of associating more comprehensive syntactic information with lexical pieces in standard strings as a consequence permitted an improved selection of translation equivalents. The list in Figures 7-1 through 7-6 contains a number of German items with their selection restrictions and the particular translations associated with each selection restriction. The lexical items are listed in the order in which they occur in the translated text. The selection restrictions which apply to the text are given a check mark. No semo-syntactic features, like HU, AN, AB (human, animate, abstract) were taken into account when performing the translation; for those features, cf. my appended paper "Requirements for Machine Translation: Problems, Solutions, Prospects."

The translation possibilities which resulted from the performed subclassification are indicated by light broken lines; the ones selected, by heavy underlines.¹⁴ Of particular interest is one of the translations for *gelingen* (sentence 494, Figure 7), which permitted the mapping represented by the following diagram.



"*Breit* + unit of measure" could be mapped into "*wide* + unit of measure" or "unit of measure + *in width*", *Zuordnung zu* into *relation to* or *connection with*. The noun phrase *lange Zeit* could be recognized as an adverbial of extension in time instead of as an object due to the feature TIM.

V Paraphrases

In order to show the variety of translations or paraphrases possible over standard strings, a number of non-ad-hoc systematic synonymy relationships were defined for English resulting in the paraphrases given in Figures 3 and 4. Synonymy relationships were defined between lexical pieces and between syntactic structures. Examples of the latter are the active : passive transformation, the perfect tense : past tense transformation¹⁵ and the noun-pre-modifier : noun-post-modifier transformation. Trivial examples of lexical paraphrases were simple synonymy substitutions like *get* : *obtain*, *prominence* : *protuberance*, or *circle* : *ring*; less trivial examples were *lunar* : *moon*, *solar* : *sun*, *luminous* : *light*, *bright* : *(to) shine*, *manage to (+infinitive)* : *succeed in (+gerund)*. The effect of the syntactic classification of lexical items which had been defined as synonymous resulted in a selection of only those syntactic superstructures which interpreted them. Thus syntactic superstructures which were interpreted by the same normal form expression (translation term) but which could not form a well-formed tree with the selected lexical items were filtered out during the production phase.¹⁶ The

effect of this filtering function is shown for two examples in Figure 6; the sequence of normal form expressions S108, S100, S108, S104, L176, S104, L125 (to be read from top to bottom, left to right) simultaneously represents the four paraphrases *the solar disk, the disk of the sun, the sun's disk, the sun disk*.¹⁷

VI Translations

The simulated standard representation of the German original text (Figure 1) is given in Figure 2. The computer output, the mechanical translations, is shown in Figures 4-1 through 4-9. The translations in Figures 5-1 through 5-3 show an approximation to English normal word order. A more precise rendering would have required a separate processing stage, a rearrangement part. This stage seemed unnecessary for the purpose of the experiment since it is a simple reversal of the generation of standard strings from surface strings. A surface representation of the English translations of the German corpus is given in Figures 3-1 through 3-2.

The translation was performed using some of the then existing LRC analysis and translation algorithms. These, in order to speed up the actual processing time, stored in core all readings found. Whenever the number of readings exceeded the space allotted for them, certain readings were irretrievably dropped. If those readings were needed during the production phase, the corresponding German lexical or syntactic structures were used

instead. This effect is noticeable in the occurrence of asterisked items in the English translations (also items, given in script in Figure 3), in the occurrence of the German standard order in noun phrases,¹⁸ which is different from the defined English standard order, or simply in the ungrammaticality of the generated sentence.

VII Conclusion

In spite of the improved translation capabilities through translation over standard structures, the number of rules necessary, using context-free grammars with simple vocabulary symbols, was felt to be unnecessarily high. The changes made to remedy this deficiency are described in Lehmann/Stachowitz 1970, Vol. II.

FOOTNOTES

- 1 Thus the meaning of the noun *man* is different from that of the verb *man*, the meaning of the 'non-human' noun *conductor* different from that of the 'human' noun.
- 2 Woerterbuch der deutschen Gegenwartssprache, herausgegeben von Ruth Klappenbach und Wolfgang Steinitz, Akademie Verlag Berlin, 1968 ff.
- 3 An Advanced Learner's Dictionary by Hornby, Gatenby and Wakefield, London, Oxford University Press, 1948.
- 4 This nominalization of the *that*-clause can be interpreted as a counterexample to various claims:
 - 1) The combined claim that transformations are meaning-preserving and nominalizations are derived transformationally from sentences;
 - 2) that semantic interpretations apply to deep structures before non-lexical transformations have applied.
 Other verbs which behave like *observe* are *remark* and *notice*. Note that *watch* cannot occur in the environment "*that* S".
- 5 A comprehensive statement on the algorithms of the Linguistics Research System as used until May 1968 is given in Chapter VIII of Final Report, Linguistic Information Processing Study, DA 36-039 AMC-2162(E), 1 May 1965 - 30 April 1966; and Dynamic Adaptive Data Base Management Study, DA 28-043 AMC-02276(E), 16 May 1966 - 15 May 1967, The University of Texas, Linguistics Research Center, Austin, Texas, November 1968.
- 6 A comprehensive description of the problems encountered can be found in Lehmann/Stachowitz: Research in German-English Machine Translation on Syntactic Level, Vol. II, The University of Texas at Austin, August 1970.
- 7 Research performed during Spring of 1968 has led to the design of completely new analysis and translation algorithms which process context-free grammars with complex terminal and non-terminal symbols. Cf. Lehmann/Stachowitz 1970 and the appended paper "Requirements for Machine Translation: Problems, Solutions, Prospects."
- 8 Constituents in a rule consequent were assigned a predetermined order to permit the translation of sentences whose constituents could occur in different surface orders, e.g. *Mark bewunderten sie* = *Sie bewunderten Mark* = *They admired Mark*.
- 9 The LRC verb dictionaries only contained descriptors per-

taining to paradigmatic information. The verb constituents in those rules thus did not contain the descriptors pertaining to case government or auxiliary agreement information.

- the
- 10 A trivial improvement for rules 1' and 2', resulting from the concatenation of the participle with the contiguous object before concatenating the new constituent with the other sentence constituents, was not possible in the earlier LRC system due to the ordering instructions attached to each constituent. Cf. Lehmann/Stachowitz, 1970, pp. T1 - T59.
 - 11 The affixes are actually represented by "dummy" terminals; these are again replaced by the proper affixes during the output phase. Cf. Lehmann/Stachowitz 1970.
 - 12 The translation of verb-prefix combinations, which occur discontinuously in German main clauses, would have required sentence rules in which the actual prefix would have had to be mentioned as a feature of the constituents involved. For example, *Diese Loesung schlug er vor* (He proposed this solution) would have had to be analyzed by a rule containing as constituents:

OBJ	PRED	SUBJ	PRFX.	Each change of prefix would have
ACC.	VOR	3	VOR	
	ACC	SG		
	3			
	SG			

required a new sentence rule, e.g. *Diese Loesung nahm er an* (He accepted this solution):

OBJ	PRED	SUBJ	PRFX.	Such rules, of course, were never
ACC	AN	3	AN	written.
	ACC	SG		
	3			
	SG			

- n,
- 13 Compare the translation equivalents *einstellen* = suspend, *ablehnen* = refuse in contrast to the translation of the corresponding simple verbs *stellen* = put, *lehnen* = lean.
 - 14 In cases where the actually performed subclassification did not suffice to distinguish between different meanings of an item (e.g. *erhalten* with the readings preserve, maintain vs. receive, obtain), the translation given in the February 1966 translation was accepted. Cf. also footnote 21.
 - 15 This paraphrase was defined to permit the translation of
- n:

the German perfect tense as in sentence 492 into both English present perfect and past tense.

- 16 One can interpret a sequence of normal form expressions as instructions to generate a tree by attaching the top node of a substructure to a non-terminal node of another structure, provided the respective labels are identical. The sequence of normal form expressions interpreting a tree thus imposes a well-formedness condition on the construction of all sentence trees with that normal form reading. Cf. also McCawley 1968.
- 17 The letter S stands for "non-lexical (syntactic) tree", the letter L for "lexical tree". The numbers were assigned in ascending order beginning with 100. These expressions can, of course, be replaced by meaningful expressions which can be interpreted as the vocabulary symbols of an interlingua or universal grammar.
- 18 The English subject *B. Edlen* in sentence 494 corresponding to the German dative object appeared in the position for "indirect object" whenever a necessary structure was dropped.
- 19 Figure 3: Only the paraphrases given in Figures 4-1 through 4-7 are given here. The items in script do not occur in any translation; the items in parentheses were provided as optional translations. The repeated "optionality" of *the* is due to the fact that it was not provided as a lexical equivalent of German /der/ but supplied by means of a syntactic normal form expression which should have been based on the non-encoded information that some nouns may optionally occur without *the*, like *earth*, *the earth*. The equivalents *completely*, *wholly*, *entirely*, *very* were not subclassified for adjective vs. participle modification (sentence 486). *Luminous corona* (sentence 492) results from an incorrect rule.
- 20 Figure 7: This translation, not given in any dictionaries, was provided in the February 66 translation.
- 21 The selection of the correct translation equivalent for this pattern depends on the understanding of the sentence.

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GERMAN CORPUS

999,487

DIE LINIEN DES WASSERSTOFFS, DES HELIUMS UND VIELER METALLE
TRETEN HIER AUF.

999,488

WENN DIE MONDSCHIEBE DIE SONNE GANZ VERDECKT, ERSCHEINT EIN ROTER
10 -- 15 BOGENSEKUNDEN BREITER RING UM DIE SONNE.

999,489

DAS IST DIE CHROMOSPHERE MIT DEN PROTUBERANZEN.

999,490

WEITER AUSSEN SCHLIESST ALS SILBERWEISSER LICHTSCHWACHER SAUM
DIE SONNENKORONA AN.

999,491

IN DER CHROMOSPHERE FINDET MAN HAUPTSAECHLICH
WASSERSTOFF-, HELIUM- UND KALZIUMLINIEN, ABER AUCH
SPEKTRALLINIEN ANDERER METALLE.

999,492

IM LICHT DER KORONA SIND MEHRERE HELLE SPEKTRALLINIEN
AUFGEFUNDEN WORDEN, DEREN ZUORDNUNG ZU BEKANNTEN ELEMENTEN LANGE
ZEIT UNBEKANNT BLIEB.

999,494

ERST IM JAHRE 1941 GELANG ES B. EDLEN IN UPSALA DIESE
SPEKTRALLINIEN IN GEEIGNETEN IRDISCHEN LICHTQUELLEN ZU ERHALTEN.

999,486

DIE HELLEN LINIEN DER DAMPFFOERMIGEN SONNENATMOSPHERE KANN MAN
IN DER SOGENANTEN UMKEHRENDEN SCHICHT, EINER SCHMALEN DAMPFHUELLE
OBERHALB DER AEUSSEREN SONNENBEGRENZUNG, DER PHOTOSPHERE, FUER
EINIGE WENIGE AUGENBLICKE BEOBACHTEN, WENN BEI EINER SONNENFINSTERNIS
DER FORTSCHREITENDE MOND GERADE EBEN NOCH EINEN GANZ SCHMALEN RAND
DER SONNENOBERFLAECHE AUF DER EINEN SEITE FREI LAESST (SOG.
FLASHSPEKTRUM).

Fig. 1

386

PAGE

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German Standard Strings

JOB PROOF G-TXT RETRIEVAL OF 30.JANUARY.'67
PAGE 1

0001 999,486,RST,011867
0002 *MAN* ** *KANN* *EN* *BEOBACHT* *N* *LINIE* *ATMOSPHAERE* *N*
0003 *SONNE* ** *EN* *DAMPFFOERMIG* ** *DER* ** *EN* *HELL* ** *DIE*
0004 *IN* *SCHICHT* **, *HUELLE* *DAMPF* ** *OBERHALB* *DEGRENZUNG*
0005 *N* *SONNE* ** *EN* *AEUSSER* ** *DER* **, *PHOTOSPHAERE* *DER*
0006 **, *EN* *SCHMAL* ** *EINER* *EN* *END* *KEHR* *UM*(PFX) *EN*
0007 *SOGENANT* ** *DER* ** *FUER* *E* *BLICK* *N* *AUGE* ** *E*
0008 *WENIG* *E* *EINIG* ** ** *WENN* *MOND* *E* *END* *SCHREIT* *FORT*
0009 ** *DER* ** *T* *LAESS* *FREI* *RAND* *OBERFLAECHE* *N* *SONNE* **
0010 *DER* ** *EN* *SCHMAL* *GANZ* ** *EINEN* *AUF*(PP) *SEITE* *EN*
0011 *EIN* ** *DER* ** *NOCH* *EBEN* *GERADE* ** *BEI* *FINSTERNIS* *N*
0012 *SONNE* ** *EINER* ** *(*UM*(FLX) *SPEKTR* *FLASH* ** *SOG.* **
0013 *)* ** *,* ** *,* ** *

0001 999,487,RST,011867
0002 *N* *LINIE* *UND* **, *S* *WASSERSTOFF* *DES* *S* *HELIUM*
0003 *DES* *E* *METALL* *ER* *VIEL* ** ** *DIE* ** *EN* *TRET* *AUF*
0004 *HIER* ** ** *,* ** *

0001 999,488,RST,011867
0002 *RING* **, *ER* *BREIT* *N* *SEKUNDE* *BOGEN* ** --* *10*
0003 *15* ** *ER* *ROT* ** *EIN* ** *T* *ERSCHEIN* *UM* *SONNE* *DIE*
0004 ** *WENN* *SCHEIBE* *MCND* ** *DIE* ** *T* *VERDECK* *SONNE*
0005 *DIE* *GANZ* ** ** *,* ** *,* ** *

0001 999,489,RST,011867
0002 *DAS*(D) ** *IST* *CHROMOSPHAERE* *DIE* *MIT* *EN* *PROTUBERANZ*
0003 *DEN* ** ** *,* ** *

0001 999,490,RST,011867
0002 *A* *KORON* *N* *SONNE* ** *DIE* ** *T* *SCHLIESS* *AN* *ALS*
0003 *SAUM* *ER* *LICHTSCHWACH* *ER* *SILBERWEISS* ** *AUSSEN* *ER*
0004 *WEIT* ** ** *,* ** *

0001 999,491,RST,011867
0002 *MAN* ** *ET* *FIND* **, ABER AUCH *N* *LINIE* *UND* **, --*
0003 *WASSERSTOFF* --* *HELIUM* *KALZIUM* ** *HAUPTSAECHLICH* *N* *LINIE*
0004 *AL* *SPEKTR* *E* *METALL* *ER* *ANDER* ** ** *IN* *CHROMOSPHAERE*
0005 *DER* ** ** *,* ** *

0001 999,492,RST,011867
0002 ** *SIND* *WORDEN* *GE* *EN* *FUNC* *AUF* *N* *LINIE* *AL*
0003 *SPEKTR* *E* *HELL* *E* *MEHRER* ** *I* *E* *LICHT* *A* *KORON*
0004 *DER* ** *M* ** ** *ZUORDNUNG* *ZU* *EN* *ELEMENT* *EN* *BEKANNT*
0005 ** ** *DEREN* ** *BLIEB* *BEKANNT* *UN* ** *ZEIT* *E* *LANG* **
0006 ** *,* ** *,* ** *

0001 999,494,RST,011867
0002 *ES* ** *GELANG* *ZU*I *EN* *ERHALT* *N* *LINIE* *AL* *SPEKTR*
0003 *DIESE* *IN* *N* *QUELLE* *LICHT* ** *EN* *ISCH* *IRD* *EN* *GE* *ET*
0004 *EIGN* ** ** ** *R. EDLEN* *IN* *UPSALA* ** *I* *E* *JAHR* *1941*
0005 *M* *ERST* ** ** *,* ** *

Figure 3-1

English Paraphrases of German Corpus in Surface Representation¹⁹

487 Lines of (the) hydrogen, (the) helium and many
metals $\left\langle \begin{array}{c} \text{occur} \\ \text{appear} \end{array} \right\rangle$ here.

488 When (the) $\left\langle \begin{array}{c} \text{lunar disk} \\ \text{disk of moon} \end{array} \right\rangle$ $\left\langle \begin{array}{c} \text{hides} \\ \text{covers} \end{array} \right\rangle$ (the)
sun $\left\langle \begin{array}{c} \text{completely} \\ \text{wholly} \\ \text{entirely} \end{array} \right\rangle$, a red $\left\langle \begin{array}{c} \text{ring} \\ \text{circle} \end{array} \right\rangle$ 10 to

15 $\left\langle \begin{array}{c} \text{arc seconds} \\ \text{seconds of arc} \end{array} \right\rangle$ $\left\langle \begin{array}{c} \text{in width} \\ \text{wide} \end{array} \right\rangle$ appears around

(the) sun.

489 This is (the) chromosphere with (the) $\left\langle \begin{array}{c} \text{prominences} \\ \text{protuberances} \end{array} \right\rangle$.

490 (The) $\left\langle \begin{array}{c} \text{corona of (the) sun} \\ \text{solar corona} \end{array} \right\rangle$ follows a silvery white
dim $\left\langle \begin{array}{c} \text{border} \\ \text{boundary} \end{array} \right\rangle$ farther out.

491 Above all $\left\langle \begin{array}{c} \text{hydrogen's, helium's and calcium's} \\ \text{hydrogen, helium and calcium} \end{array} \right\rangle$
Mainly $\left\langle \begin{array}{c} \text{other metals' } \left\langle \begin{array}{c} \text{spectrum} \\ \text{spectral} \end{array} \right\rangle \text{ lines} \end{array} \right\rangle$
Chiefly $\left\langle \begin{array}{c} \text{spectral lines of other metals} \end{array} \right\rangle$
lines, but also
are found in (the) chromosphere.

One finds ... in (the) chromosphere.

492 Several $\left\langle \begin{array}{c} \text{bright} \\ \text{shining} \end{array} \right\rangle$ $\left\langle \begin{array}{c} \text{spectral} \\ \text{spectrum} \end{array} \right\rangle$ lines $\left\langle \begin{array}{c} \text{were} \\ \text{have been found} \end{array} \right\rangle$ $\left\langle \begin{array}{c} \text{found} \\ \text{discovered} \end{array} \right\rangle$

in $\left\langle \begin{array}{c} \text{corona lights} \\ \text{(the) light of (the) corona} \\ \text{luminous corona} \end{array} \right\rangle$ $\left\langle \begin{array}{c} \text{of which the} \\ \text{whose} \end{array} \right\rangle$

$\left\langle \begin{array}{c} \text{relationship to} \\ \text{connection with} \end{array} \right\rangle$ known elements remained unknown
(for) a long time.

Figure 3-2

194 ~~Only in~~
~~Not~~ ~~before~~
~~until~~ 1941 did B. Edlen in Upsala

~~succeed in getting~~
~~manage to~~ ~~get~~
~~obtain~~ these spectral lines in

suitable ~~terrestrial~~
~~earth~~ ~~luminous~~
~~light~~ sources.

B. Edlen in Upsala ~~managed to~~ ~~obtain~~
~~get~~
~~succeeded in~~ ~~obtaining~~
~~getting~~

these ~~only in-~~
~~not~~ ~~before~~
~~until~~ 1941.

186 One can observe ~~the~~ ~~bright~~
~~shining~~ lines of the vaporous

~~sun~~
~~solar~~ atmosphere in the so-called reversing layer,

a ~~completely~~
~~wholly~~ ~~narrow~~
~~entirely~~ ~~thin~~ vaporous ~~coat~~
~~very~~ ~~veil~~
~~envelope~~

~~above~~
~~beyond~~ the outer solar ~~border~~
~~boundary~~, the

photosphere, for a few moments when the advancing moon just

barely leaves visible a very ~~thin~~
~~narrow~~

~~solar surface edge~~
~~edge of the solar surface~~ on one side during

~~a darkness of the sun~~
~~an eclipse of the sun~~
~~a solar darkness~~
~~a sun eclipse~~, the so-called

~~flash spectrum~~
~~spectrum of flash~~

99487001 OF HYDROGEN, HELIUM, AND MANY S METAL ES LIN OCCUR HERE .
 99487001 OF HYDROGEN, HELIUM, AND MANY S METAL ES LIN APPEAR HERE .
 99487001 OF THE HYDROGEN, HELIUM, AND MANY S METAL ES LIN OCCUR HERE .

 99487001 OF THE HYDROGEN, HELIUM, AND MANY S METAL ES LIN APPEAR HERE .
 99487001 OF THE HYDROGEN, THE HELIUM, AND MANY S METAL ES LIN APPEAR
 99487002 HERE .
 99487001 OF HYDROGEN, HELIUM, AND MANY S METAL ES LIN OCCUR HERE ** *.*
 99487001 OF THE HYDROGEN, HELIUM, AND MANY S METAL ES LIN OCCUR HERE *.*
 99487001 OF HYDROGEN, HELIUM, AND MANY S METAL ES LIN *DIE* OCCUR HERE
 99487002 ** ** *.*
 99487001 OF THE HYDROGEN, HELIUM, AND MANY S METAL ES LIN APPEAR HERE
 99487002 ** ** *.*

Fig. 4-1

99488001 A RED 10 TO 15 ARC S SECOND IN WIDTH E CIRCL S APPEAR AROUND
 99488002 SUN WHEN AR LUN DISK S COVER SUN LY WHOL , .

 99488001 A RED 10 TO 15 ARC S SECOND IN WIDTH E CIRCL S APPEAR AROUND
 99488002 SUN WHEN AR LUN DISK ES HID SUN LY WHOL , .

 99488001 A RED 10 TO 15 ARC S SECOND IN WIDTH E CIRCL S APPEAR AROUND
 99488002 THE SUN WHEN AR LUN DISK S COVER SUN LY WHOL , .

 99488001 A RED 10 TO 15 ARC S SECOND IN WIDTH E CIRCL S APPEAR AROUND
 99488002 THE SUN WHEN AR LUN DISK ES HID SUN LY WHOL , .

 99488001 A RED 10 TO 15 ARC S SECOND IN WIDTH RING S APPEAR AROUND THE
 99488002 SUN WHEN AR LUN DISK S COVER SUN LY WHOL , ** **.

 99488001 RED 10 TO 15 ARC S SECOND IN WIDTH S RING *EIN* S APPEAR
 99488002 AROUND THE SUN *WENN* THE AR LUN DISK S COVER SUN LY WHOL **, **
 99488003 **.

 99488001 RED 10 TO 15 ARC S SECOND IN WIDTH S CIRCLE *EIN* S APPEAR
 99488002 AROUND SUN WHEN AR LUN DISK S COVER SUN ELY COMPLET , ** **.

 99488001 *RING* RED 10 TO 15 OF ARC S SECOND IN WIDTH ** *EIN* S APPEAR
 99488002 AROUND THE SUN WHEN THE AR LUN DISK S COVER SUN LY WHOL , ** **.


 99488001 *RING* **, 10 TO 15 OF ARC S SECOND E WID *ER* *ROT* ** A **
 99488002 *T* APPEAR *UM* *SONNE* *DIE* ** *WENN* THE AR LUN DISK S COVER
 99488003 THE SUN LY WHOL **, ** **.

 99488001 *RING* **, 10 TO 15 OF ARC S SECOND E WID RED ** *EIN* S
 99488002 APPEAR AROUND THE SUN WHEN AR LUN DISK S COVER SUN ELY ENTIR , **
 99488003 **.

 99488001 *RING* **, *ER* WID ARC S SECOND TO 10 15 ** *ER* *ROT* **
 99488002 A ** *T* *ERSCHIN* *UM* *SCNNE* *DIE* ** *WENN* THE AR LUN DISK
 99488003 S COVER SUN ELY COMPLET **, ** **.

 99488001 *RING* **, *ER* *BREIT* OF ARC SECOND --* 10 *15*
 99488002 ** *ER* *ROT* ** *EIN* S APPEAR AROUND SUN WHEN AR LUN DISK ES
 99488003 HID SUN ELY COMPLET , ** **.

 99488001 *RING* **, *ER* *BREIT* OF ARC SECOND --* 10 *15*
 99488002 ** *ER* *ROT* ** *EIN* S APPEAR AROUND SUN WHEN AR LUN DISK ES
 99488003 HID SUN ELY ENTIR , ** **.

 99488001 *RING*  *ER* *BREIT* OF ARC SECOND --* 10* *15* ** *ER*
 99488002 *ROT* ** *EIN* S APPEAR AROUND SUN *WENN* OF MOON DISK ES HID
 99488003 SUN ELY COMPLET **, ** **.


 99488001 *RING*  *ER* *BREIT* *N* *SEKUNDE* *BOGEN* ** --* 10* *15*
 99488002 ** *ER* *ROT* ** *EIN* S APPEAR AROUND SUN WHEN OF MOON DISK ES
 99488003 HID SUN VERY , ** **.

Fig. 4-2

99489001	THIS IS CHROMOSPHERE WITH S PROMINENCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROMINENCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	9949
99489001	THIS IS CHROMOSPHERE WITH S PROMINENCE *.*	9949
99489001	THIS IS CHROMOSPHERE WITH S PROTUBERANCE *.*	9949
99489001	THIS IS CHROMOSPHERE WITH THE S PROMINENCE .	9949
99489001	THIS IS CHROMOSPHERE WITH THE S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH THE S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH THE S PROTUBERANCE .	
99489001	THIS IS CHROMOSPHERE WITH THE S PROTUBERANCE .	
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS THE CHROMOSPHERE WITH S PROTUBERANCE .	
99489001	THIS IS THE CHROMOSPHERE WITH THE S PROMINENCE .	
99489001	THIS IS THE CHROMOSPHERE WITH THE S PROTUBERANCE .	
99489001	THIS IS THE CHROMOSPHERE WITH THE S PROTUBERANCE .	

Fig. 4-3

99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT .

 99490001 THE AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT .

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT *.*

 99490001 THE AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT *.*

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BORDER FARTHER
 99490002 OUT ** *.*

 99490001 OF THE SUN CORONA S FOLLOW AS A SILVERY E WHIT DIM BORDER
 99490002 FARTHER OUT ** *.*

 99490001 OF SUN CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT *.*

Fig. 4-4

99491001 ARE FOUND LY CHIEF HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE .

99491001 ARE FOUND LY MAIN HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE .

99491001 ARE FOUND LY CHIEF HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN THE CHROMOSPHERE .

99491001 ARE FOUND LY MAIN HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN THE CHROMOSPHERE .

99491001 ARE FOUND LY CHIEF HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE *.*

99491001 ARE FOUND LY MAIN HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE *.*

99491001 *MAN* S FIND LY MAIN HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE **.*.*

99491001 *MAN* S FIND LY CHIEF HYDROGEN, HELIUM, AND CALCIUM ES LIN, BUT
 99491002 ALSO OTHER S' METAL AL SPECTR ES LIN IN CHROMOSPHERE ** ** *.*

99491001 *MAN* S FIND BUT ALSO ES LIN AND HYDROGEN, HELIUM S
 99491002 CALCIUM LY MAIN OF OTHER S METAL AL SPECTR ES LIN IN
 99491003 CHROMOSPHERE ** *.*

99491001 *MAN* S FIND BUT ALSO ES LIN AND *,* S' HYDROGEN S'
 99491002 HELIUM S' CALCIUM LY MAIN OTHER S' METAL AL SPECTR ES LIN IN
 99491003 CHROMOSPHERE ** *.*

99491001 *MAN* ** *ET* *FIND* BUT ALSO ABOVE ALL HYDROGEN, HELIUM, AND
 99491002 CALCIUM ES LIN AL SPECTR E LIN OTHER S METAL ** IN
 99491003 CHROMOSPHERE ** ** *.*

99491001 *MAN* ** *ET* *FIND* BUT ALSO *N* *LINIE* AND (*-
 99491002 *WASSERSTOFF* S HELIUM S CALCIUM *HAUPTSAECHLICH* OTHER S'
 99491003 METAL UM SPECTR ES LIN IN THE CHROMOSPHERE ** *.*

Fig. 4-5

99492001 WERE ED DISCOVER SEVERAL ING SHIN AL SPECTR ES LIN *I* CORONA
 99492002 S LIGHT *M* ** ** WHOSE RELATIONSHIP TO N KNOW S ELEMENT ED
 99492003 REMAIN UN N KNOW FOR A LONG E TIM , **.*

99492001 WERE ED DISCOVER SEVERAL ING SHIN AL SPECTR ES LIN *I* CORONA
 99492002 S LIGHT *M* ** ** WHOSE CONNECTION WITH N KNOW S ELEMENT ED
 99492003 REMAIN UN N KNOW FOR A LONG E TIM , **.*

99492001 WERE ED DISCOVER SEVERAL ING SHIN AL SPECTR ES LIN *I* CORONA
 99492002 S LIGHT *M* ** ** OF WHICH THE RELATIONSHIP TO N KNOW S ELEMENT
 99492003 ED REMAIN UN N KNOW FOR A LONG E TIM , **.*

99492001 WERE ED DISCOVER SEVERAL ING SHIN AL SPECTR ES LIN *I* CORONA
 99492002 S LIGHT *M* ** ** OF WHICH THE CONNECTION WITH N KNOW S ELEMENT
 99492003 ED REMAIN UN N KNOW FOR A LONG E TIM , **.*

99492001 WERE FOUND SEVERAL ING SHIN AL SPECTR ES LIN IN OUS LUMIN
 99492002 CORONA ** *M* ** ** WHOSE RELATIONSHIP TO N KNOW S ELEMENT ED
 99492003 REMAIN UN N KNOW FOR A LONG E TIM ** *,* **.*

99492001 HAVE BEEN FOUND SEVERAL ING SHIN AL SPECTR ES LIN IN CORONA S
 99492002 LIGHT *M* ** ** WHOSE CONNECTION WITH N KNOW S ELEMENT ED
 99492003 REMAIN UN N KNOW FOR A LONG E TIM ** *,* **.*

99492001 HAVE BEEN FOUND SEVERAL ING SHIN AL SPECTR ES LIN IN CORONA S
 99492002 LIGHT *M* ** ** OF WHICH THE RELATIONSHIP TO N KNOW S ELEMENT
 99492003 ED REMAIN UN N KNOW FOR A LONG E TIM ** *,* **.*

99492001 HAVE BEEN FOUND SEVERAL ING SHIN AL SPECTR ES LIN IN CORONA S
 99492002 LIGHT *M* ** ** OF WHICH THE CONNECTION WITH N KNOW S ELEMENT
 99492003 ED REMAIN UN N KNOW FOR A LONG E TIM ** *,* **.*

99492001 WERE ED DISCOVER SEVERAL BRIGHT AL SPECTR ES LIN IN OF CORONA
 99492002 LIGHT ** CONNECTION WITH N KNOW S ELEMENT WHOSE ED REMAIN N
 99492003 KNOW *UN* ** A LONG E TIM ** *,* **.*

99492001 WERE ED DISCOVER SEVERAL BRIGHT AL SPECTR ES LIN IN OF CORONA
 99492002 LIGHT ** RELATIONSHIP TO N KNOW S ELEMENT WHOSE ED REMAIN N
 99492003 KNOW ** A LONG E TIM ** *,* **.*

99492001 WERE ED DISCOVER ES LIN UM SPECTR BRIGHT SEVERAL IN OF
 99492002 CORONA LIGHT ** ** RELATIONSHIP TO ELEMENT N KNOW ** WHOSE
 99492003 ED REMAIN N KNOW *UN* ** TIM LONG ** *,* **.*

99492001 WERE ED DISCOVER SEVERAL BRIGHT AL SPECTR ES LIN IN THE OF
 99492002 CORONA LIGHT ** RELATIONSHIP TO N KNOW S ELEMENT ** WHOSE **
 99492003 *BLIEB* N KNOW *UN* ** FOR A LONG E TIM ** *,* **.*

99492001 WERE ED DISCOVER SEVERAL BRIGHT AL SPECTR ES LIN IN THE OF
 99492002 CORONA LIGHT ** CONNECTION WITH N KNOW S ELEMENT ** WHOSE **
 99492003 *BLIEB* N KNOW *UN* ** FOR A LONG E TIM ** *,* **.*

99492001 WERE ED DISCOVER SEVERAL BRIGHT AL SPECTR ES LIN IN OF THE
 99492002 CORONA LIGHT ** CONNECTION WITH N KNOW S ELEMENT ** WHOSE **
 99492003 *BLIEB* N KNOW *UN* ** FOR A LONG E TIM ** *,* **.*

Fig. 4-6

99494001	B. EDLEN DID MANAG TO GET THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941 .	994
99494001	B. EDLEN DID MANAG TO GET THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941 .	994
99494001	B. EDLEN DID MANAG TO OBTAIN THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941 .	994
99494001	B. EDLEN DID MANAG TO OBTAIN THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941 .	994
99494001	B. EDLEN DID MANAG TO GET THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA ONLY IN 1941 .	994
99494001	B. EDLEN DID MANAG TO GET THESE AL SPECTR ES LIN IN SUITABLE	994
99494002	IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA ONLY IN 1941 .	994
99494001	B. EDLEN DID SUCCEED IN TING GET THESE AL SPECTR ES LIN IN	994
99494002	SUITABLE IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941	994
99494003		994
99494001	B. EDLEN DID SUCCEED IN TING GET THESE AL SPECTR ES LIN IN	994
99494002	SUITABLE IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT BEFORE	994
99494003	1941 .	994
99494001	ED SUCCEED IN ING OBTAIN ES LIN UM SPECTR OBSERV IN	994
99494002	SOURCE LIGHT EARTH SUITABLE ** ** B. EDLEN IN UPSALA **	994
99494003	ONLY IN 1941 ** *.*.	994
99494001	ED MANAG TO ING OBTAIN AL SPECTR ES LIN OBSERV IN SUITABLE	994
99494002	IAL TERRESTR LIGHT S SOURCE ** B. EDLEN IN UPSALA ONLY IN	994
99494003	1941 ** *.*.	994

Fig. 4-7

PATHS 1,1..1,2..2,1..2,2..3,1..3,2.....12,1..12,2

99486001 *MAN* ** CAN E OBSERV ES LIN AR SOL S ATMOSPHERE *EN* OUS
99486002 VAPOR ** *DER* ** ING SHIN *DIE* IN LAYER *,* OUS VAPOR S
99486003 ENVELOPE BEYOND THE OUTER AR SOL BOUNDARY ** , PHOTOSPHERE,
99486004 THIN A ING REVERS SO-CALLED *DER* ** FOR A FEW S MOMENT
99486005 WHEN ING ADVANC MOON ES LEAV E VISIBL A VERY THIN AR SOL SURFACE
99486006 EDGE CN ONE E SID JUST LY BARE DURING A AR SOL DARKNESS ,
99486007 SO-CALLED FLASH UM SPECTR, , ** *.*.

99486001 *MAN* ** CAN E OBSERV ES LIN AR SOL S ATMOSPHERE *EN* OUS
99486002 VAPOR ** *DER* ** ING SHIN *DIE* IN S' LAYER *,* OUS VAPOR S
99486003 ENVELOPE ABOVE THE OUTER AR SOL BOUNDARY ** , PHOTOSPHERE
99486004 NARROW AN ING REVERS SO-CALLED *DER* ** FOR A FEW S MOMENT
99486005 WHEN ING ADVANC MOON ES LEAV E VISIBL A VERY THIN AR SOL SURFACE
99486006 EDGE CN ONE E SID JUST LY BARE DURING A AR SOL DARKNESS ,
99486007 SO-CALLED FLASH UM SPECTR , ** *.*.

99486001 *MAN* ** CAN E OBSERV ES LIN AR SOL S ATMOSPHERE *EN* OUS
99486002 VAPOR ** *DER* ** BRIGHT *DIE* IN LAYER *,* OUS VAPOR S
99486003 ENVELOPE BEYOND THE OUTER AR SOL BOUNDARY ** , PHOTOSPHERE,
99486004 THIN A ING REVERS SO-CALLED *DER* ** FOR A FEW S MOMENT
99486005 *WENN* ING ADVANC MOON ES LEAV E VISIBL A VERY THIN OF AR SOL
99486006 SURFACE EDGE ON A SID ONE JUST LY BARE DURING A AR SOL
99486007 DARKNESS , SO-CALLED OF FLASH UM SPECTR, ** *,* ** *.*.


99486001 *MAN* ** IS *EN* OBSERV *N* *LINIE* ATMOSPHERE *N* SOL **
99486002 *EN* OUS VAPOR ** *DER* ** *EN* SHIN ** *DIE* IN S LAYER ,
99486003 ENVELOPE VAPOR ** BEYOND OUTER AR SOL BOUNDARY *DER* ** ,
99486004 PHOTOSPHERE *,* THIN *EINER* *EN* *END* REVERS *EN* SO-CALLED
99486005 *** *DER* ** FOR A FEW S MOMENT ** *WENN* ING ADVANC MOON
99486006 *DER* ES LEAV E VISIBL VERY THIN OF AR SOL SURFACE EDGE
99486007 *EINEN* ON *SEITE* ONE JUST LY BARE ** DURING A AR SOL
99486008 DARKNESS ** , THE SO-CALLED OF FLASH UM SPECTR, ** *,* ** *.*.

99486001 *MAN* ** *KANN* *EN* *BEOBACHT* *N* *LINIE* SUN S ATMOSPHERE
99486002 *EN* *DAMPFFOERMIG* ** *DER* ** *EN* *HELL* ** *DIE* IN
99486003 *SCHICHT* *,* OUS VAPOR VEIL *OBERHALB* OUTER AR SOL BORDER
99486004 *DER* ** *SCHMAL* ** *EINER* *EN*
99486005 SO-CALLED ** *DER* ** FOR A FEW S MOMENT ** *WENN* LUN *E*
99486006 *END* ADVANC ** *DER* ES LEAV E VISIBL A ELY ENTIR NARROW OF AR
99486007 ~~SUN SURFACE EDGE~~ *AUF*(PP) *SEITE* *EN* ONE ** *DER* ** JUST
99486008 LY BARE DURING AN OF SUN ECLIPSE *(SO-CALLED OF FLASH UM
99486009 SPECTR *)* ** *,* ** *.*.

99486001 *MAN* ** *KANN* *EN* *BEOBACHT* *N* *LINIE* *ATMOSPHERE* *N* *S-
99486002 *ONNE* ** *DAMPFFOERMIG* ** *DER* ** *EN* *HELL* **
99486003 *DIE* IN *SCHICHT* *,* *HUELLE* *DAMPF* ** *OBERHALB* AR SOL
99486004 BOUNDARY *EN* *AEUSSER* ** *DER* ** *,* *PHOTOSPHAERE* *DER*
99486005 *,* *EN* *SCHMAL* ** *EINER* *EN* *END* *EN* *SOGENANT* **
99486006 *DER* ** *FUER* *E* MOMENT A FEW ** *WENN* *MOND* *E*
99486007 *END* *SCHREIT* *FORT* ** *DER* ** *T* *LAESS* *FREI* OF AR SOL
99486008 SURFACE EDGE THIN WHOL ** *EINEN* *AUF*(PP) *SEITE* *EN* *EIN*
99486009 *BEI* AR SOL ECLIPSE *EINER* ** , OF FLASH UM SPECTR
99486010 SO-CALLED ** *)* ** *,* ** *.*.

Fig. 4-8

PATHS 1,0,0,1-2,0,0,1---12,0,0,1-1,0,0,2-2,0,0,2---12,0,0,2

99486001 *MAN* ** IS E OBSERV ES LIN ATMOSPHERE SUN  OUS VAPOR
99486002 ** *DER* ** BRIGHT *DIE* IN LAYER , ENVELOPE OUS VAPOR
99486003 BEYOND BORDER SUN OUTER *DER* ** , PHOTOSPHERE, THIN A ING
99486004 REVERS SO-CALLED *DER* ** FOR A FEW S MOMENT *WENN* THE ING
99486005 ADVANC MOON ES LEAV E VISIBL EDGE SURFACE SUN *DER* ** THIN
99486006 COMPLET ** A ON' SID ONE JUST LY BARE ** DURING ECLIPSE
99486007 SUN A ** , THE SO-CALLED OF FLASH UM SPECTR, ** *,* ** *.*.

99486001 *MAN* ** *KANN* *EN* OBSERV *N* LIN ATMOSPHERE *N* SUN **
99486002 VAPOR ** *DER* ** BRIGHT *DIE* IN LAYER (COAT OUS VAPOR
99486003 ABOVE BOUNDARY THE SUN OUTER *DER* ** , THE PHOTOSPHERE,
99486004 NARROW AN ING REVERS SO-CALLED *DER* ** FOR A FEW S MOMENT
99486005 *WENN* ING ADVANC MOON ES LEAV E VISIBL EDGE SURFACE THE SUN
99486006 *DER* ** NARROW ENTIR ** AN ON SID ONE JUST LY BARE **
99486007 DURING DARKNESS THE SUN AN ** , THE SO-CALLED OF THE FLASH UM
99486008 SPECTR, ** *,* ** *.*.

99486001 *MAN* ** *KANN* *EN* *BEOBACHT* *N* *LINIE* *ATMOSPHAERE*
99486002 *N* *SONNE* ** *EN* *DAMPFFOERMIG* ** *DER* ** *EN* *HELL* **
99486003 *DIE* *IN* *SCHICHT* **, OUS VAPOR COAT *UBERHALB* AR SOL S
99486004 BORDER *EN* *AEUSSER* ** *DER* ** **, PHOTOSPHERE **,
99486005 *EN* *SCHMAL* ** *EINER* *EN* *SOGENANNT* ** *DER* ** *FUER*
99486006 *E* *BLICK* *N* *AUGE* ** *E* *WENIG* *E* *EINIG* ** **
99486007 *WENN* THE ING ADVANC MOON ES LEAV E VISIBL A VERY THIN AR SOL
99486008 SURFACE EDGE ON ONE E SID JUST LY BARE DURING A AR SOL DARKNESS ,
99486009 THE SO-CALLED FLASH UM SPECTR, **, * ** *.*.

Fig. 4-9

99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT .

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER
 99490002 OUT .

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY FARTHER
 99490002 OUT .

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER
 99490002 OUT .

 99490001 SOLAR CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY FARTHER
 99490002 OUT .

 99490001 SOLAR CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER
 99490002 OUT .

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY
 99490002 FARTHER OUT *.*

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER
 99490002 OUT *.*

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY FARTHER
 99490002 OUT *.*

 99490001 AR SOL CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER
 99490002 OUT *.*

 99490001 SOLAR CORONA S FOLLOW AS A SILVERY E WHIT DIM BOUNDARY FARTHER
 99490002 OUT *.*

 99490001 SOLAR CORONA S FOLLOW AS A SILVERY WHITE DIM BOUNDARY FARTHER

Fig. 5-1

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE

Fig. 5-3

99494002 TERRESTRIAL OUS LUMIN SOURCES IN UPSALA NOT UNTIL 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN SOURCES IN UPSALA NOT BEFORE 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE IAL
99494002 TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE IAL
99494002 TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941 .

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941
99494003 .

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941
99494003 .

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE TERRESTRIAL OUS LUMIN SOURCES IN UPSALA NOT UNTIL 1941

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE TERRESTRIAL OUS LUMIN SOURCES IN UPSALA NOT BEFORE 1941
99494003 .

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941
99494003 .

99494001 B. EDLEN DID SUCCEED IN TING GET THESE SPECTRAL ES LIN IN
99494002 SUITABLE IAL TERRESTR OUS LUMIN S SOURCE IN UPSALA NOT BEFORE
99494003 1941 .

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT UNTIL 1941 *.*

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN S SOURCE IN UPSALA NOT BEFORE 1941 *.*

99494001 B. EDLEN DID MANAG TO GET THESE SPECTRAL ES LIN IN SUITABLE
99494002 TERRESTRIAL OUS LUMIN SOURCES IN UPSALA NOT UNTIL 1941 *.*

99492002 LIGHTS *M* ** ** WHOSE RELATIONSHIP TO N KNOW S ELEMENT ED
99492003 REMAIN UN N KNOW FOR A LONG E TIM , **.

99492001 SEVERAL ING SHIN AL SPECTR LINES WERE ED DISCOVER *I* CORONA
99492002 LIGHTS *M* ** ** WHOSE RELATIONSHIP TO N KNOW S ELEMENT ED
99492003 REMAIN UN N KNOW FOR A LONG TIME , **.

99492001 SEVERAL ING SHIN AL SPECTR LINES WERE ED DISCOVER *I* CORONA
99492002 LIGHTS *M* ** ** WHOSE CONNECTION WITH N KNOW ELEMENTS ED REMAIN
99492003 UN N KNOW FOR A LONG E TIM , **.

99492001 WERE ED DISCOVER SEVERAL ING SHIN SPECTRAL ES LIN *I* CORONA
99492002 LIGHTS *M* ** ** WHOSE CONNECTION WITH N KNOW ELEMENTS ED REMAIN
99492003 UN N KNOW FOR A LONG TIME , **.

99492001 SEVERAL ING SHIN SPECTRAL ES LIN WERE FOUND IN OUS LUMIN
99492002 CORONA ** *M* ** ** WHOSE RELATIONSHIP TO N KNOW ELEMENTS ED
99492003 REMAIN UN N KNOW FOR A LONG E TIM ** *,* **.

99492001 SEVERAL ING SHIN SPECTRAL ES LIN HAVE BEEN FOUND IN CORONA S
99492002 LIGHT *M* ** ** WHOSE RELATIONSHIP TO N KNOW S ELEMENT ED
99492003 REMAIN UN N KNOW FOR A LONG TIME ** *,* **.

99492001 SEVERAL ING SHIN SPECTRAL LINES WERE FOUND IN CORONA LIGHTS
99492002 *M* ** ** WHOSE CONNECTION WITH N KNOW ELEMENTS ED REMAIN UN N
99492003 KNOW FOR A LONG TIME ** *,* **.

99492001 SEVERAL ING SHIN SPECTRAL LINES HAVE BEEN FOUND IN CORONA
99492002 LIGHTS *M* ** ** WHOSE CONNECTION WITH N KNOW S ELEMENT ED
99492003 REMAIN UN N KNOW FOR A LONG TIME ** *,* **.

99492001 SEVERAL ING SHIN AL SPECTR ES LIN WERE FOUND IN CORONA LIGHTS
99492002 *M* ** ** OF WHICH THE RELATIONSHIP TO N KNOW ELEMENTS ED
99492003 REMAIN UN N KNOW FOR A LONG TIME ** *,* **.

99492001 SEVERAL ING SHIN AL SPECTR ES LIN HAVE BEEN FOUND IN CORONA
99492002 LIGHTS *M* ** ** OF WHICH THE RELATIONSHIP TO N KNOW S ELEMENT
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99492003 REMAIN UN N KNOW A LONG TIME ** *,* **.

Fig. 5-2



Fig. 6



Figure 7-1

486 BEOBACHTEN:

- 1.✓ SBJ — OBJ observe, watch
+HU +ACC

Ex: Mark beobachtete Sylvia = Mark watched Sylvia.

2. SBJ — OBJ an OBJ observe in sb., notice
+HU +ACC +DAT in sb.
+AB +HU

Ex: Mark beobachtete Zeichen von Triumph an Sylvia = Mark noticed signs of triumph in Sylvia.

3. SBJ — ADV observe
+HU +MAN

Ex: Mark beobachtet gut = Mark observes well.

- 4.✓ SBJ — OBJ follow, obey, observe,
+HU +ACC respect, comply with
+AB

Ex: Die Roemer beobachteten das Gesetz = The Romans observed the laws.

FREILASSEN:

- 1.✓ SBJ — OBJ free, set free, liberate
+HU +ACC
+HU

Ex: Mark liess Sylvia frei = Mark set Sylvia free.

- 2.✓ SBJ — OBJ leave blank, leave open
+HU +ACC leave vacant, leave
-HU visible 20

Ex: Mark liess eine Zeile frei = Mark left a line blank.

487 AUFTRETEN:

1. SBJ — OBJ kick open
+HU +ACC
+PO
-AN

Ex: Mark trat die Tuer auf = Mark kicked the door open.

- 2.✓ SBJ — step, tread, walk
+AN

Figure 7-2

Ex: Mark trat leise auf = Mark trod softly.

3. SBJ _____ gegen OBJ come up against, rise
+HU +ACC against, oppose

Ex: Die Griechen traten gegen die Tuerken auf =
The Greeks rose against the Turks.

4. SBJ _____ fuer OBJ stand up for
+HU +ACC

Ex: Mark trat fuer Sylvia auf = Mark stood up for
Sylvia.

5. SBJ _____ vor OBJ perform before
+HU +DAT
+HU

Ex: Mark trat vor dem Koenig auf = Mark performed
before the king.

6. SBJ _____ als CMPL figure as, pose as
+HU +NOM

Ex: Mark trat als Koenig auf = Mark posed as a king.

7. SBJ _____ wie CMPL behave like, act like
+AN +NOM

Ex: Mark trat auf wie ein Fuerst = Mark behaved like
a duke.

- 8.✓ SBJ _____ occur, happen, arise,
+AB result, ensue, appear

Ex: Ein Fall von Cholera war aufgetreten = A case
of cholera had occurred.

- 9.✓ SBJ _____ appear, perform, enter
+HU

Ex: Mark trat in einem Stueck auf = Mark appeared
in a play.

488 ERSCH EINEN:

- 1.✓ SBJ _____ appear, emerge

Ex: Ein Wagen erschien = A car appeared.

Figure 7-3

2. SBJ ——— OBJ appear to sb.
 +HU +DAT
 +HU

Ex: Der Geist war Mark erschienen = The ghost had appeared to Mark.

3. SBJ ——— OBJ ADJ seem, appear, look
 +DAT
 +HU

Ex: Die Loesung erschien Mark gut = The solution looked good to Mark.

BREIT:

1. ✓ ——— ADV wide, in width
 +MEAS

Ex: drei Meter breit = three meters wide

2. N ——— broad, wide, spacious,
 +PO large, vast

Ex: ein breites Gesicht = a broad face

3. N ——— extensive
 +AB

Ex: eine breite Darstellung = an extensive description

490

ANSCHLIESSEN:

1. SBJ ——— OBJ chain, connect, fasten
 +ACC with a lock
 -AB

Ex: Mark schloss das Fahrrad an = Mark fastened the bike with a lock.

2. SBJ ——— OBJ add
 +HU +ACC
 +AB

Ex: Mark schloss eine Bemerkung an = Mark added a remark.

3. SBJ ——— OBJ an OBJ chain to, connect to,
 +ACC join to, link up with
 -AB -AB

Figure 7-4

Ex: Mark schloss das Fahrrad an den Zaun an =
Mark chained the bike to the fence.

4. SBJ — OBJ an OBJ add to
+ACC +ACC
+AB +AB

192

Ex: Mark schloss die folgende Bemerkung an seine
Rede an = Mark added the following remark to his
speech.

5. SBJ — OBJ OBJ accompany, join
+AN +REFL +DAT
+ACC +HU

Ex: Mark schloss sich Sylvia an = Mark joined
Sylvia.

194

6. SBJ — OBJ an OBJ accompany, join
+AN +REFL +ACC
+ACC +HU

Ex: Mark schloss sich an Sylvia an = Mark joined
Sylvia.

7. SBJ — OBJ an OBJ be adjacent to,
-AN +REFL +ACC border on
+ACC -HU

Ex: An Texas schliesst sich Oklahoma an = Oklahoma
borders on Texas.

- 8.✓ SBJ — follow

Ex: Weiter aussen schliesst die Sonnenkorona an =
The corona of the sun follows further out. 20

491 FINDEN:

- 1.✓ SBJ — OBJ discover, find, come
+HU +ACC across

Ex: Mark fand einen Diamanten = Mark found a diamond.

2. SBJ — OBJ in OBJ be reconciled with,
+HU +REFL +ACC resign oneself to,
+ACC +AB put up with

Ex: Mark fand sich in die Lage = Mark resigned
himself to the situation.

3. SBJ — OBJ ADJ find, think, consider
+HU +ACC

Ex: Mark fand Sylvia huebsch = Mark considered
Sylvia pretty.

Figure 7-5

492 ZUORDNUNG:

1. _____ zu OBJ assignment to, re-
 +HU+AB lationship to, con-
 +DAT nection with
2. N
 +AB coordination

ZEIT:

1. N time
 +TIM

494 GELINGEN:

1. SBJ _____ OBJ succeed in
 +AB +DAT
 +HU

Ex: Das Experiment gelang Mark = Mark succeeded in the experiment.

2. SBJ _____ be successful,
 +AB succeed, work

Ex: Das Experiment gelang = The experiment was successful.

- 3.✓ es _____ zu INF OBJ succeed in + Gerund,
 +DAT manage to + Inf.
 +AN

Ex: Es gelang Mark, das Experiment durchzufuehren = Mark succeeded in performing the experiment.

ERHALTEN:

- 1.✓ SBJ _____ OBJ get, obtain, receive;
 +ACC keep, preserve 21

Ex: Mark erhielt ein Buch = Mark got a book.
 Die Italiener versuchten, Venedig zu erhalten =
 The Italians tried to preserve Venice.

- 2.✓ SBJ _____ OBJ support
 +HU +ACC
 +HU

Ex: Mark erhielt seine Eltern = Mark supported his parents.

Figure 7-6

3. SBJ — OBJ von OBJ maintain sb. on,
 +HU +ACC +DAT support sb. on
 +HU +AB

Ex: Mark erhielt seine Eltern von seinem mageren Gehalt = Mark supported his parents on his small salary.

4. SBJ — OBJ von OBJ subsist on, support
 +HU +ACC +DAT onself on
 +REFL +AB

Ex: Mark erhielt sich von Almosen = Mark subsisted on alms.

REQUIREMENTS FOR MACHINE TRANSLATION:
PROBLEMS, SOLUTIONS, PROSPECTS

by

Rolf Stachowitz

Linguistics Research Center
The University of Texas at Austin

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1. Introduction

Today it is generally accepted that the expression "science" no longer refers to a discipline which deals with a particular subject area but in general to any discipline which uses a particular method of research: the so-called "scientific method". We classify various disciplines according to whether they make use of the scientific method or not. Thus, we exclude disciplines like history or literary analysis from the sciences.¹

We shall only deal with two of the criteria which constitute the scientific method: intersubjectivity and verifiability. Intersubjectivity means that the result obtained by one person starting from certain assumptions and working according to a particular method should be obtainable by other persons operating with the same assumptions and the same method. By verifiability we mean that the statements on certain phenomena in a particular research area have to be empirically verifiable. The "principle of tolerance" (Toleranzprinzip), formulated originally but later abandoned by Carnap, no longer holds in the sciences. Introspective, phenomenological, and transnatural verifiability may only be used if they are reduceable eventually to verifiability through the senses.²

The development of linguistic theory and advances in computer hardware and software have put linguistic science into the fortunate position of being able to verify by computer the various hypotheses and theories made about linguistic phenomena because of a correspondence between formal languages and programming languages: everything that can be formalized can be programmed and vice versa. A number of computational linguists have consequently written programs which process transformational grammars, so-called grammar testers, and have made them available to the linguistic community. The linguistic community has as yet made little use of such programs. The few linguists who have had their grammars processed by such an algorithm soon found out that their hypotheses were falsified.

The reluctance of linguists to use a computer is, of course, based on the fact that there is no comprehensive theory of grammar that works. Estimates on the length of time required to construct such a grammar vary considerably. We have heard opinions indicating a time of about 500 years. Though we are inclined to regard this figure as an exaggeration, a number of renowned linguists have seriously stated they feel that it may take about 150 years of grammatical research to come up with a comprehensive grammar for a language.

What are the avenues open to the linguist who is not patient enough to wait that long in order to test his hypotheses or

theories? He can resign himself to the view that language is a phenomenon which cannot be treated algorithmically, at least not from a recognition point of view, which is true for formulas of the predicate calculus. We personally are disinclined to accept such a resignation since we know that everybody can speak but not everybody can prove logical theorems.

The second possibility is to assume that grammars are indeed highly complicated and that we must work patiently, hoping that future generations will be able to make use of our preliminary work.

The third possible course of action, the one we are going to follow, is to investigate whether all the scientific and methodological premises of current grammar theory, especially its descriptive and explanatory apparatuses, are really necessary, or whether they can be replaced by a simpler system of apparatuses under preservation of the observational, descriptive, and explanatory adequacy. We shall thus treat current linguistic theory as the object of research of another science, its meta-science. We shall investigate linguistics from a meta-linguistic point of view according to which the components of a grammatical model are subject to scientific investigation based on the scientific method.

Which empirically observable, experienceable phenomena

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correspond to a competence model, as grammar models are normally called, and to its various components, the deep phrase-structure component, the transformational component, and the semantic component? (For present purposes, we shall ignore the phonological component.) Which are the phenomena explained by such a model, which remain unexplained?

To accept the stipulation of transformational grammarians that competence models not be regarded as performance models imposes a heavy burden on our research, but instead of discussing whether such a request is legitimate, we decide that we can still investigate such models and their components as part of a hypothesized performance model.

It is very difficult to believe the claim that a grammar of a language with a finite set of terminal symbols is an adequate representation of a phenomenon that occurs almost any day: the introduction of new words in a language, which either name new objects or which are introduced by means of definitions. A grammar model as it is normally defined is basically static, something that, I believe, Humboldt would have called not an *energeia* but an *ergon*, incapable of representing the changes that occur in any living language. (Cf. the interesting footnote in Hans Hermes: "The schematical execution of a given general procedure (i.e. algorithm, our addition) evidently offers (after some attempts) no particular interest to a mathematician. We can thus state the remarkable fact that a creative mathematician - through

the specific mathematical achievement of the development of a general procedure - renders valueless, as it were, the area covered by this procedure."³)

Which possibilities for verification do we have for a competence model?

- a) We could check its output. Apart from the fact that this output does not exist yet, this criterion, if used alone, could also be used to represent as a model for the human capability to divide and multiply a computer program which performs division and multiplication by iterative subtraction and iterative addition.
- b) We could consider the structural description which is assigned to surface sentences. We grant that the structural description which a competence model assigns to a surface sentence corresponds to our linguistic intuition. However, we see no means to decide that such surface structures are derived transformationally from deep structures; they might equally well be derived from a surface phrase-structure component. Recent development in standard transformational grammar which makes the deep structure representation correspond more and more to the surface representation actually argues in favor of the latter assumption.

Which empirical verifiability exists for a deep phrase-structure component? The claim that the deep structure representation permits a formal definition of semantic

categories, as subject of a sentence or predicate of a sentence, has already been shown by various transformational grammarians not to be applicable for such semantic categories as objects or adverbials in the case of verbs with multiple objects and multiple adverbials. This claim, I believe, was shaken by Charles Fillmore⁴, who pointed out that the deep representation is not really a representation of semantic relations between constituents. This has been admitted by Chomsky if I understand his comments in "Deep Structure, Surface Structure and Semantic Interpretation" correctly. Others pointed out that important linguistic concepts as "head" of a phrase cannot be expressed by means of the deep phrase-structure component.⁵

Which reality corresponds to the transformational component? We do not doubt that transformational relations exist between surface structures. But, as far as I know, there is no empirical verification for the existence of ordered transformations. The few examples, all based on reflexivization, can be explained in a different way.

Which observable phenomenon corresponds to an intermediate phrase marker? No real investigation has been performed on this aspect.⁶ The reality of intermediate phrase markers can be easily tested by confronting a naive speaker with such sentences as "By John give Harry the book"; they normally find it unintelligible; occasionally they interpret

as "Give Harry the book written by John". We know that the string, by means of preposition deletion, eventually results in "John gives Harry the book".

Which experienceable reality corresponds to a semantic component, which cannot explain the process of introducing a new word by definition, the modification of meaning by explication, which cannot represent in a sentence reading the synonymity or the occasional intersection of the semantic readings of two words expressed by the "explicative or" (corresponding to the stylistic term "hendyadyoin") when no individual term in a language represents that semantic reading?⁷

The rigor which had been introduced into linguistics by means of the notion of rules and transformation rules in the earlier version of transformational grammar has gradually disappeared. We are not able to relate the surface phenomena that we can observe to the semantic representation or the deep structure since the increased complexity of the transformational apparatus makes the establishment of such relations and their verification extremely difficult if not impossible. The "remedies" which have been proposed: to make the deep structure more and more similar to the surface structure or more and more abstract to arrive at the semantic representation, we regard as futile in view of the results obtained by

Peters and Ritchie.⁸

In a science we set out to describe the facts that we observe and to try to relate them, to find an explanation for them, a system, a structure. The principles that in general are used in setting up the observational and explanatory apparatus are that they should be adequate and appropriate. These principles are also influenced by certain esthetic considerations: that the apparatus should be as simple as possible. From our point of view, this means: We now know a lot more about linguistic theory than we did twenty years ago. We know that language is the language of man, whose capabilities we should not exclude when dealing with language. We should begin research again by relating surface sentences to surface sentences by means of transformations, but by means of transformations which are kept as simple as possible, which relate surface structures to surface structures and which, if possible, need not apply in a particular order. Only if the facts force us to make changes in our assumptions, should we make the necessary changes; we should not start out by carrying over into our own discipline certain apparatuses useful and also necessary in others, at least not without weighing the pro's and con's carefully. We should start by constructing a model which reflects such considerations. It is not even necessary to find or develop such a model

Since the person who started it all, Zellig S. Harris, has been describing such a model for some time.⁹ Our own model, which we are going to describe in Chapter 5 of this paper, is based on the notion of Harris' substitution transformations. It has been constructed with the aim to explain certain human capabilities, among them the acquisition of new words and their definition by means of the context. Our grammar is based on the assumption that sentences can be represented as connections of elementary predications. Thus the sentence "A young girl sang a song" is representable as the sequence of connected predications:

$$\text{girl}(x_1) \wedge \text{young}(x_1) \wedge \text{song}(x_2) \wedge \text{sing}(x_1, x_2)$$

Sentences are not generated by rewriting the initial symbol S but by reducing them to symbol S both during recognition and production. The model is a representation of recognition in that it derives meanings from surface sentences; a model of production, in that it derives surface sentences from a representation of their meanings.

When I first proposed, after my experiment in paraphrasing and translation,¹⁰ to reduce sentences of a natural language mechanically to connected elementary sentences, means were not available to extend my experiment. For some time, the project lay dormant. That it has been revived I owe to three persons, to whom I would like to express my gratitude:

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whose i
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yet.

Winfred P. Lehmann, Rowena Swanson, and Zbigniew L. Pankowicz.

In order to prepare for the discussion of our model, we shall introduce in Chapter 2 a simplified model of human comprehension. In Chapter 3 we will discuss the requirements for a quality or high quality machine translation system. In Chapter 4 we discuss the capabilities of current competence models from the point of view of applicability to machine translation. Chapter 5 gives an outline of our model, the Linguistics Research System. Chapter 6 discusses primarily a development in computer storage whose impact on the scientific community, in particular on linguistics and linguistic studies, cannot be estimated yet.

Comprehension and Translation

order to describe and clarify the extent to which translation of a text is dependent on the comprehension of that text, we shall construct a simplified, restricted model of human comprehension and determine the components of this model which will have to be part of a translation device.

To facilitate the description of such a model we shall introduce the following terms by example: State of affairs, state-of-affairs-description, the image of a state of affairs, the image of a state-of-affairs-description.

Assume that a number of people observe an incident Q, a traffic accident, involving two objects: a car and a pedestrian.

Two or three observers make the following statements about Q:

- 1) There was a car-pedestrian accident.
- 2) A car hit a man.
- 3) A Porsche hit a man.

We shall say that the statements 1 through 3 describe the same state of affairs Q (SA Q), though with different information content. We shall call each statement a description of SA Q or an SA-description of Q. Clearly, each of the statements is not only an SA-description of Q but of several SA's; thus statement 3 describes all car accidents similar to SA Q which involve a Porsche hitting a man. We shall thus call statement 3 an SA-description, independent of the particular SA it describes.

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We shall further posit that every sentence, whether command, request, question or statement, is a description of some SA.¹¹ An SA need not have any physical reality. This follows from the fact that an SA-description may be false.

Let us now assume a device K - with several components - which can process SA-descriptions, store them and reproduce them; it can also assign to an SA-description p all the syntactic, structural descriptions of p; it can further associate one or more images with each SA-description. Thus, K associates the different images a, b, and c with the SA-descriptions 1, 2, and 3, respectively. However, K associates the same image d with the SA-descriptions 4 and 5; it associates image e with the SA-descriptions 6 and 7, image f with the SA-descriptions 8 and 9, and two different images g and h with the SA-description 10.

- | | | |
|---|---|---------|
| 4) A Porsche hit a man. | } | image d |
| 5) A man was hit by a Porsche. | | |
| 6) The man scaled the fish. | } | image e |
| 7) The man desquamated the fish. | | |
| 8) A car, a Porsche, hit a man. | } | image f |
| 9) A Porsche, which is a car, hit a man. | | |
| 10) George observed a man with a telescope. | } | image g |
| | | image h |

We call an image associated with an SA-description a DSA-image.

(As we can observe, the relations between a DSA-image and an SA-description are similar to those that hold between an SA and an SA-description. A DSA-image can be associated with

more than one SA-description. An SA-description can be associated with more than one DSA-image; whenever this is the case, we call the SA-description ambiguous.)

Let us now clarify the term DSA-image by constructing the DSA-image for the following sentence:

11) A woman sold a car to a man for some money.

For the time being let us refer to the woman as A, to the car as B, to the man as C, to the price as D. Let us now describe what happens during a sale of some property. a) A, the owner of B, gives B to C. Let us represent this by the following graph (arrows represent relations and unary actions):

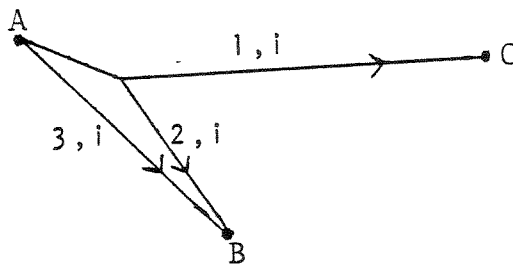


Figure 1

where "1,i" represents "A gives to C at time i", "2,i" represents "A gives object B at time i", "3,i" represents "A owns B at time i". Note that the ternary relation "A gives B to C" is expressed by a "fork". b) After this act, C acquires property of B and A loses it, expressed as follows:

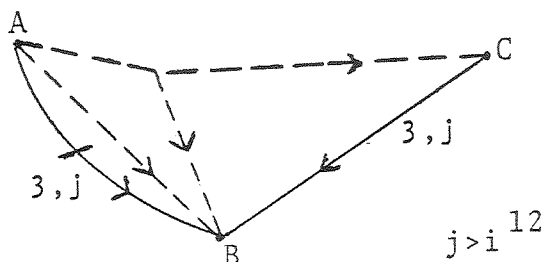


Figure 2

Negation is expressed by a slash through the line representing the property or relation.

c) Then C, who owns

the money D, gives this money to A as a compensation for the acquisition of B. This results in the Fig.3 where k is

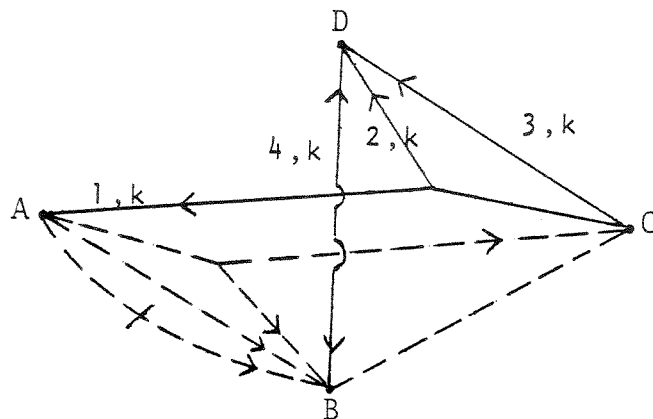


Figure 3

later than j. The double arrow, between D and B, represents a symmetrical relation. 4(B,D) stands for "B is a compensation for D". d) Finally, A acquires property of D and C loses property of D, resulting in the graph

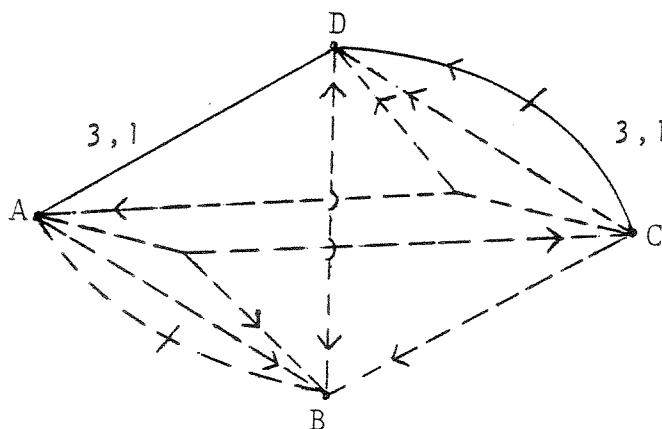


Figure 4

Sales transactions can only take place between human beings and/or legal entities. We thus add this information to nodes A and C.

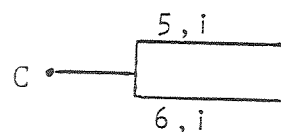
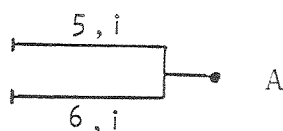


Figure 5

ere the graph $\bullet \longrightarrow$ represents a property of the node,
 d a line perpendicular to a property (or relation) a
gical or.¹³ 5 represents the property human; and 6, the
 operty legal entity. The sold object B must finally be
 object or a right to some object, D can be an object, or
 e right to some object, or money, which will be represented
 the graphs

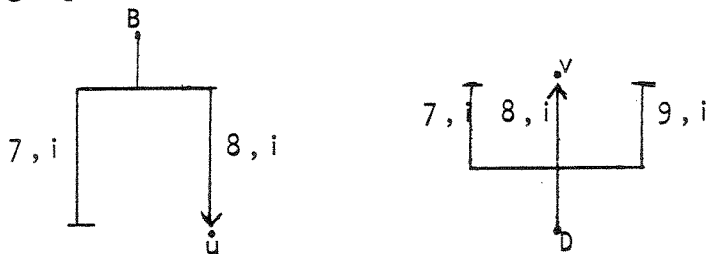


Figure 6

ere 7 represents the property "physical object", 8 the
 elation "right to" and 9 the property "money".

entence 11': "A sells B to C for D" thus results in the
 following DSA-image:

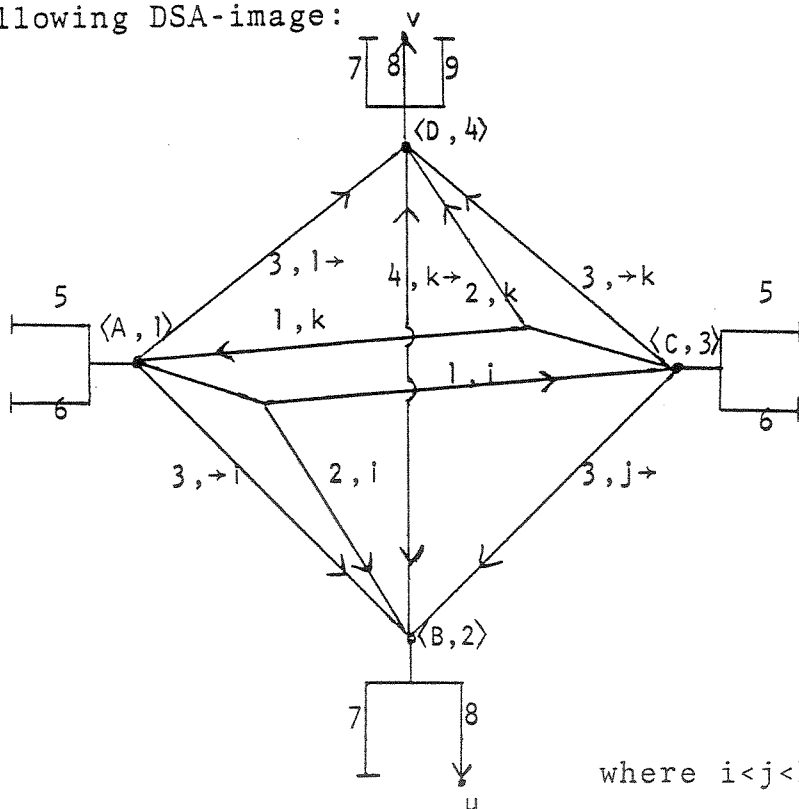
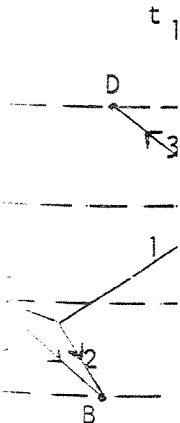


Figure 7

where $i < j < k < l$

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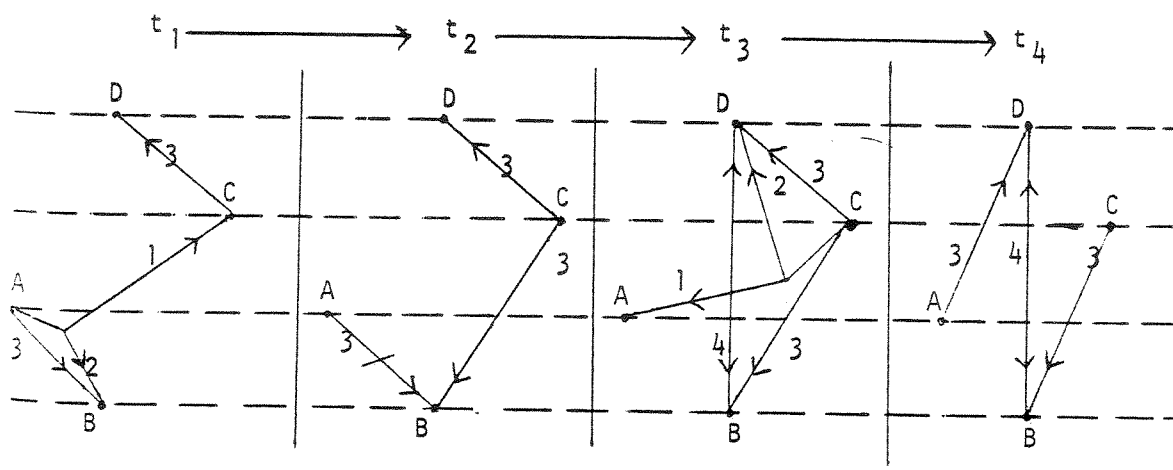


The graph
 the predi
 (v,4>)"¹⁴
 C, and D

The following conventions have been used in this figure:

An expression of the form "number+,+>+letter" (e.g. 3,>k) is to be read as "The property or relation represented by the number ends at the point of time represented by the letter". An expression of the form "number+,+letter>" is to be read as "the property or relation represented by the number begins with the point of time represented by the letter". An expression of the form "number+,+letter" is to be read as "the property or relation expressed by the number begins at and terminates with the point of time represented by the letter". An expression of the form "number" (with no letter) expresses that the property or relation has no time boundaries. We prefer the representation in Figure 7 to the equivalent representation in Figure 8.

Figure 8



The graph in Figure 7 closely corresponds to the SA-image of the predication described by the verb "sell(<x1>,<y,2>,<z,3>,<v,4>)"¹⁴. This is obvious if we replace the node names A, B, C, and D by x, y, z, v, respectively. To obtain the SA-image

of sentence 11, we still need to perform the predications upon the objects referred to by the expressions "a woman", "a man", "a car", and "money". These will be represented in that order by the following graphs:

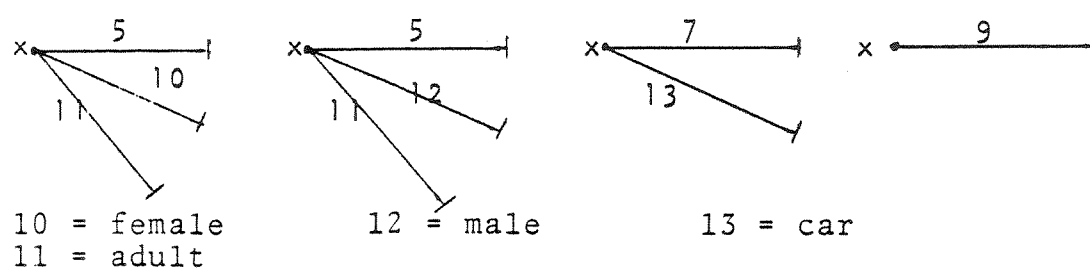


Figure 9

Sentence 11 will result in the following DSA-image:

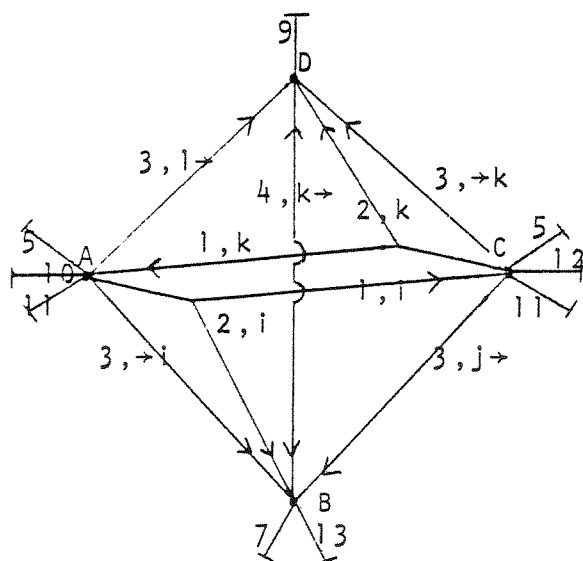


Figure 10

Note that in comparison with Figure 7 predications upon the objects A, B, C, and D have changed, i.e. we are dealing with human beings as seller and buyer, it is an object and not a right to something that has been sold, and the compensation for the object is money, not another object or right to something.¹⁵

We shall further assume that device K contains an additional component in which SA-images, images of the original state of affairs, are stored. Each SA-image is generated by means of the information provided by a DSA-image by replacing the object variables by constants. The SA-image constructed from sentence 11 would be identical with the DSA-image in Figure 10 if A, B, C, and D were replaced by x_1 , x_2 , x_3 , x_4 , respectively. Each SA-image t of SA Q is consequently a partial, i.e. imperfect, representation of the original SA Q .

A further component of K is able to superimpose two SA-images p and r of an SA Q and thus derive an SA-image v of SA Q by modifying - during the processing of a text - the current SA-image p of SA Q by means of the new SA-image r of SA Q ; the result is a more precise representation of the original SA Q : SA-image v . Let us call such superimposed SA-images connected SA-images. This component also deletes all but the SA-image t of an ambiguous SA-description, as well as their DSA-images if t was connected with some SA-image q . This capability means that the device is able to connect SA-images, represented in different SA-descriptions, similar to the connection of SA-images represented in the change of the graph in Figure 7 to that of Figure 10. If two devices K_1 and K_2 with identical internal configurations, both beginning with an empty data storage, process

(4) A Porsche hit a man.

and

(2) A car hit a man. 12) It was a Porsche.

respectively, then, when each has processed its first sentence (4 and 2), the contents of the data storage of the two devices will be different in at least three respects: each will contain a different SA-description; each, a different DSA-image, and each, a different SA-image. When, however, K_2 has processed sentence 12, both devices will have an identical SA-image. That is, the sentence

(4) A Porsche hit a man.

and the sequence of sentences

(2) A car hit a man. (12) It was a Porsche.

result in the same SA-image.

When device K processes sentence 10:

(10) George observed a man with a telescope.

it will construct two DSA-images and two SA-images; this expresses the ambiguity of this sentence. If K subsequently processes sentence 13:

13) The man put the telescope down.

the DSA-image and SA-image which represent George as the user of the telescope will be deleted.

Of the states of K we shall call state T_q (such that there is no $r > q$) the current state of the device K. We will call the set of SA-images at state T_q the current SA-image of K;

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the set of configurations of the SA-image component from state T_0 through T_q , the memory of K; the set of SA-image configurations of the n states immediately preceding the current state of K, the short-span memory of K.¹⁶

Further assume that device K has a meaning rule component with inference rules, statements of definitions, and equivalence rules. Examples of inference rules are

- a) For all x : if x is a Porsche, then x is a car,
- b) For all x : if x is a car, then x is a vehicle,
- c) For all x : if x is human, then x is animate.

An example for a definition is:

the SA-image in Figure 11 =_{Df} the SA-image in Figure 7',
(in Figure 7' A, B, C, D of Figure 7 have been replaced by x, y, z, v , respectively.)

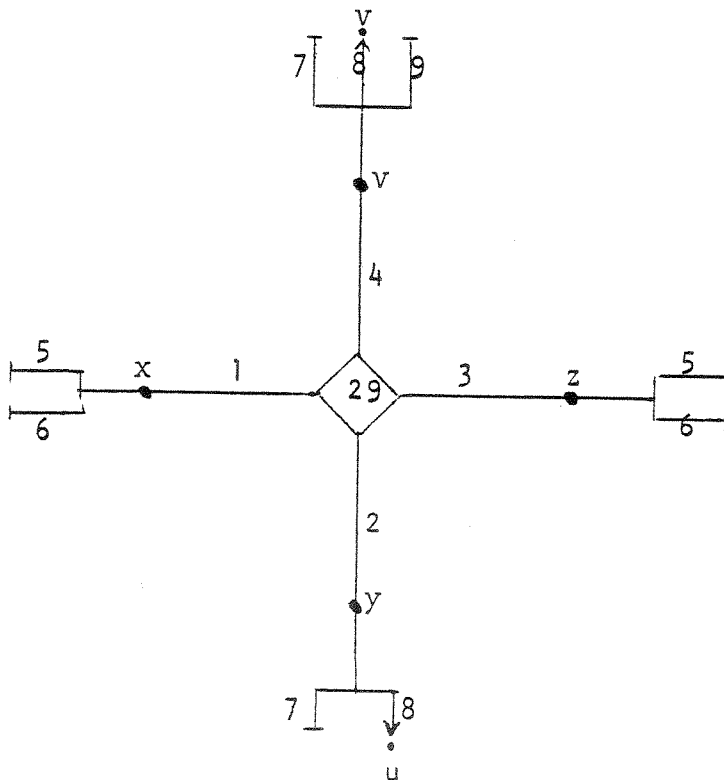
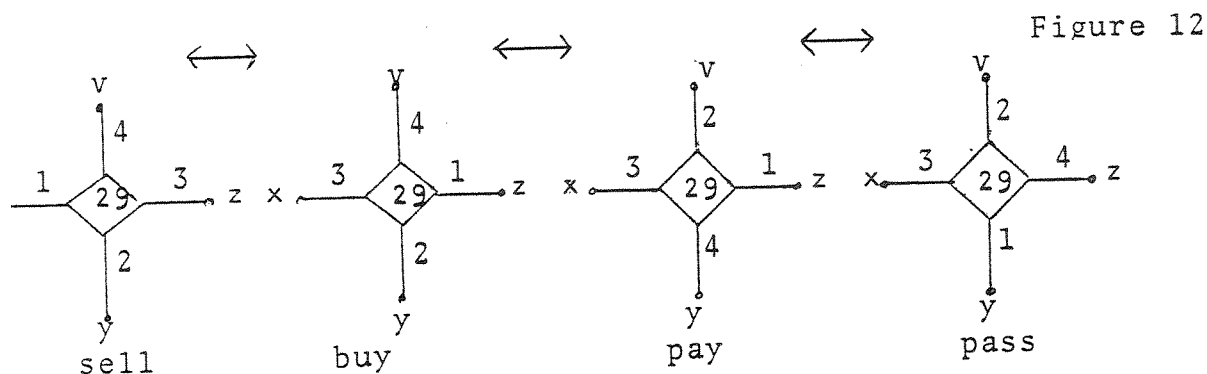


Figure 11

29 = sell
(Lines 5 through 9 represent atomic properties or relations,
cf. Figure 7, page 15.)

Examples of equivalence rules are given in Figure 12.



These graphs represent the meaning rules:

$$\text{sell}(\langle x, 1 \rangle, \langle y, 2 \rangle, \langle z, 3 \rangle, \langle v, 4 \rangle) \equiv_{\text{Df}} \text{buy}(\langle x, 3 \rangle, \langle y, 2 \rangle, \langle z, 1 \rangle, \langle v, 4 \rangle) \equiv_{\text{Df}} \text{pay}(\langle x, 3 \rangle, \langle y, 4 \rangle, \langle z, 1 \rangle, \langle v, 2 \rangle) \equiv_{\text{Df}} \text{pass}(\langle x, 3 \rangle, \langle y, 1 \rangle, \langle z, 4 \rangle, \langle v, 2 \rangle).$$

The sentence "A woman (x) sold a car (y) to a man (z) for some money (v)" can thus also be represented as "A man bought a car from a woman for some money", "A man paid some money to a woman for a car", "A car passed for some money from a woman to a man".¹⁷ Thus, device K can construct by means of the rules of the meaning rule component, in particular by means of the definitions, molecular SA-descriptions, molecular SA-images, and connected molecular SA-images from the SA-images, DSA-images, and connected SA-images which from now on we shall call atomic DSA-images, atomic SA-images, and connected atomic SA-images. It does this by replacing atomic and/or molecular expressions, which correspond to the right side of a definition, by the molecular expression on the left side of the definition, preserving the names of the object nodes involved. Molecular images do not show their internal

structure. Thus, the graph in Figure 10, which represents sentence 11: "A woman sold a car to a man for some money", will result in the graph in Figure 13. (We represent molecular images by two-dimensional figures: quaternary relations by a diamond, properties of an object by a rectangle;¹⁸ objects are represented by a dot, the names of relations and properties are represented by numbers in the geometrical figures. The names of objects occur besides the dots, the numbers on the lines between relations and objects represent the order of the arguments.)

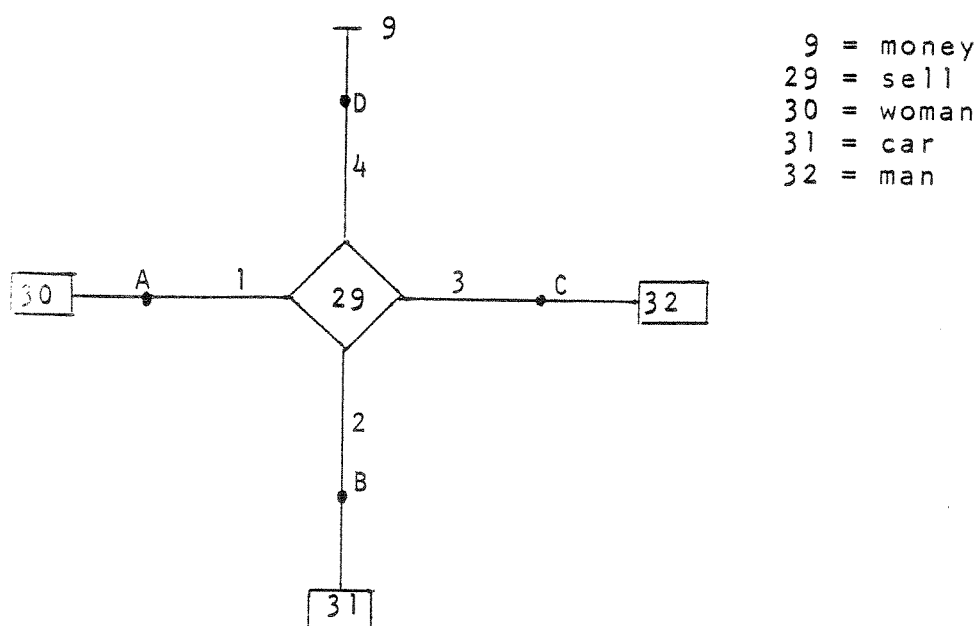


Figure 13

We obtain the molecular SA-image corresponding to the graph in Figure 13 by replacing the expressions A, B, C, and D by x_1 , x_2 , x_3 , x_4 , respectively.

We assume that device K will permanently store only molecular DSA-images and connected molecular SA-images, since it can

construct the corresponding atomic DSA-images and SA-images
 means of its meaning rule component with its definitions
 and inference rules, when required.

suppose nobody will seriously doubt that, indeed,
 connected SA-images, atomic and/or molecular, or simulations
 of them are stored in comprehension devices, as e.g. in the
 human brain, or that SA-images are necessary besides DSA-
 images. Without this assumption, it would be fairly
 difficult to explain the inconsistencies in a number of
 SA-descriptions of some SA R when no two of them are
 inconsistent. Let us demonstrate this by the following
 three SA-descriptions of the same SA which may occur
 distributed over some text.

- 13) The final conference on the "Theoretical Study
 Effort of High Quality Translation" was held in
 Austin, Texas, from January 11 through January 15,
 1971.
- 14) When the final conference on the "Theoretical Study
 Effort of High Quality Machine Translation" was
 held, it rained every day in Austin.
- 15) No rainfall occurred in Austin, Texas, during the
 period of January 11 through January 15, 1971.

As we can easily verify, each pair of the statements 13
 through 15 is consistent. The three statements together,
 however, are inconsistent. Of course, the inconsistency of

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statements 11 through 13 does not simply follow from the connected SA-images representing the state of affairs described by statements 11 through 13. For this we need an additional component, a logical component.

That a process corresponding to the connection of SA-images actually occurs in the human brain is most obvious whenever a hearer encounters a sentence which - in isolation - is semantically anomalous or possibly even contradictory. Thus, sentences 16 and 17:

16) Haensel broke off a part of the roof and ate it.

17) This boy is a girl.

which are not semantically well-formed, i.e. whose DSA-images are not "well-formed", make sense in their proper context. Sentence 16 occurs in Grimm's fairytale Haensel und Gretel, sentence 17 in numerous stories in which a girl, in order to be near her lover, a soldier, disguises herself and joins the army. Her true identity is eventually discovered. In the case of sentence 16, the system has stored the fact that the witch's house consists of cake and candy, i.e. that the house and its parts are edible. Thus, the SA-image of sentence 16 is compatible with the established fact structure, the current connected SA-images, though the DSA-image of sentence 16 violates at least one of the rules of the system's meaning rule component. In the case of sentence 17, which is contradictory and thus logically false, the system establishes

that one of the predications a and b with the argument x_j (the disguised girl) in the SA-image of sentence 17

a) x_j is a boy and b) x_j is a girl

is not consistent with the current SA-image pertaining to x_j . The system, depending on outside information, either rejects predication (a) as false, or predication (b), or both.

We shall now introduce the last necessary component of device K. So far, we have tacitly assumed that an SA-description describes an SA that occurs or exists outside of K. An SA-description may, of course, also describe SA's inside of K, as, for example, components, meaning rules, states, SA-descriptions, DSA-images, and SA-images. We shall classify two devices J and K, with the same properties mentioned so far and identical internal configurations, according to the way they process or react to the following statements:

17) Did Mary sell a car?

18) What did Mary sell?

19) Mary sold a car.

20) "Mary sold a car" is a sentence.

21) "Mary sold a car" is not a sentence.

Device J processes the sentences 17 through 21, storing for each sentence the SA-description, and the associated DSA-images and SA-images. Its only in-built reaction is that either sentence 20 or sentence 21 or both be deleted from

the memory, since they are inconsistent. K reacts in the following way: (we shall use "SA:x" for "the SA described by the SA-description of SA x"): When K has established the DSA-image of SA:17, it searches through its memory. If an SA-image identical (except for the representation of negation) to the SA-image the device J would produce when processing sentence 19 has been stored or can be deduced from existing SA-images by means of meaning rules and logical rules, K prints out "no" if at least one negation occurs in the SA; "yes", if no negation occurs. If no such SA-image is found, K prints out the stereotype answer: "The question cannot be answered, insufficient information." For sentence 18: Again, recognizing that an answer is expected, searching through its memory and finding a representation of "Mary sold her house on the 20th of July, 1969. She got \$25,000 from Henry for it.", K prints out: "Mary sold a house to Henry for \$25,000 on July 20, 1969." K then continues processing statement 19 in the way J processes it. We shall call device J a somewhat sophisticated language data processor; we shall call K a model of comprehension or a device with rudimentary artificial intelligence.

A slightly more intelligent version of K, having generated the DSA-images of SA 20 (or SA 21), will analyze the DSA-images $x \xrightarrow{15}$ (and $x \xrightarrow{\neg 15}$) by means of an operation rule; ($\xrightarrow{15}$ represents the predicator "sentence"). This operation rule, a subroutine called by $\xrightarrow{15}$ (or $\xrightarrow{\neg 15}$),

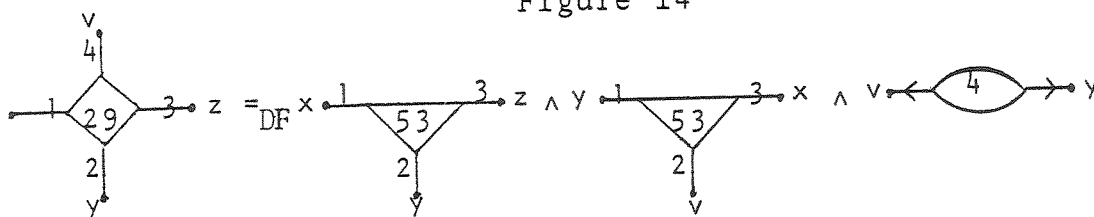
establishes that the SA-description is true (false) if x is generatable by the syntactic component; if x is not generatable, that the SA-description is false (true). The corresponding SA-images and DSA-images will be deleted.

This "awareness" component of K , if modified slightly in the way indicated below, would also make device K a restricted speech production device. The modifications necessary would be:

- K may print out a sequence of SA-descriptions t_1, t_2, \dots, t_n ;
- each t_i ($1 \leq i \leq n$) is a partial, incomplete representation of the underlying SA-image;
- for each t_i, t_{i+1} ($1 \leq i < n$): the SA-image of t_i is connected with the SA-image of t_{i+1} ;
- the conjunction of all SA-descriptions t_i ($1 \leq i \leq n$) is an exhaustive description of the underlying SA-image.¹⁹

By means of the semantic component and the definitions in the meaning rule component given in the following figure, K can produce the sequence of sentences below.

Figure 14



where 29 represents "sell"; 53, "give"; 4, "is a compensation for"; the caret stands for logical and.²⁰

- 22) A woman sold a house. A man gave her money for it.
- 23) A house was sold. The owner, a woman, got some money for it. The present owner is a man.
- 24) A woman sold something. It was a house. Somebody, a man, gave her some money. The money is the compensation for the house. etc.

In addition to the necessary components already mentioned, the device may contain several others, as e.g. a component which associates a stylistic interpretation with an SA-description t , or a component which corrects printing errors.²¹

Let us recapitulate the major properties of the comprehension device. It is able to store and reproduce SA-descriptions. By means of a syntactic component, it can associate with each processed SA-description t all and only the syntactic descriptions of t . By means of a semantic component, it can associate with an SA-description t all and only the DSA-images of t . It can further associate all and only the SA-images of t with SA-description t by means of a discourse structure component. The association component of K performs the connection of SA-images pertaining to the same SA.

In addition, the device contains a meaning rule component, a logical component, and an "awareness" component. A more elaborate description of such a model of comprehension for purposes of Information Retrieval can be found in our report "Normalization of Natural Language for Information Retrieval".

Let us now represent the terms introduced above by their linguistic equivalences. An SA-description is a sentence in natural language. The syntactic description of an SA-description is the description of the surface structure of a sentence in natural language. An atomic DSA-image represents the meaning of a sentence in isolation. An atomic SA-image represents the meaning of a sentence in context. Molecular images may correspond to "semantic readings". We are not aware of an established linguistic term which corresponds to the set of connected SA-descriptions in the current state T_q of the device; it represents the current knowledge of facts of the device. The term "state of affairs" finally corresponds to the terms "referent", "significatum", "denotatum".²²

We shall call a sentence t synonymous with a sentence u if t and u have the same SA-image or meaning.²³ In particular we shall call sentence t a paraphrase of sentence u if t is synonymous with u , and t and u are sentences of the same language. We shall call sentence t a translation of sentence u , if t and u are synonymous, and t and u do not belong to the same language.

The purpose of these explanations was to provide the basis for a discussion of the components of a translation device and, in particular, of the question which of the components of a comprehension device should be part of such a translation device.

3. Desirable Properties of a Translation Device

It is sometimes argued that in translation, at least in MT, it is not necessary to understand the meaning of a text as long as the target language equivalents for the words and syntactic structures of the source language can be correctly established or - in our formulation - as long as molecular or atomic expressions and syntactic structures of the source language can be mapped into the corresponding equimolecular or atomic expressions and structures of the target language.

We shall investigate, by means of the following German examples and their English translations, the extent to which this claim is justifiable by showing some of the problems that a mechanical translation device T will encounter and will have to solve. We shall try to indicate which of the components of device T will be involved in handling a particular problem, and, specifically, which components of device K must be part of T. (We do not restrict our attention to the translation of scientific texts. Statements on the greater ease with which such material may be mechanically translated seem to express to a greater extent opinions rather than careful investigations;²⁴ we also assume that MT device T will be able to translate scientific texts if it can translate "normal text", provided that the necessary vocabulary and their equivalences have been incorporated into T.)

first requirement that an MT device should meet is to be able to derive the semantic reading R of t from a surface sentence t. In particular, an MT device should be able to handle syntactic problems represented by the following German examples. (In each of these examples, the correct English translation will be preceded by a literal translation.)

1. *Die Geschichte faengt mit einer Explosion an.*
The history catches with an explosion at.
History begins with an explosion.
2. *Er liess ihr Bescheid sagen, dass ...*
He let her notice say that ...
He sent word to her that ...
3. *Ich habe ihm aber Bescheid gesagt.*
I have him but notice said.
I gave him a piece of my mind.
4. *Die Sonne geht im Osten auf und im Westen unter.*
The sun goes in the east up and in the west down.
The sun rises in the east and sets in the west.
5. *Fritz ist nach Spanien, seine Frau nach Italien und ihre Tochter nach Griechenland gereist.*
Fritz is to Spain, his wife to Italy, and their daughter to Greece traveled.
Fritz traveled to Spain, his wife to Italy, and their daughter to Greece.

It may be obvious from these examples that the system will need the capability to deal with discontinuous elements as in sentence 1; it will have to be able to assign a syntactic description and semantic interpretation to such combinations of lexical items within a particular sentence, independent

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of the syntactic description and semantic interpretation of the individual items in the dictionary. The same capabilities are required for examples 2 and 3, which represent phrasal and idiomatic expressions. In particular, the system will need the capability of dealing with combinations of lexical items with internal variable slots. The items filling such slots may either not be translated at all, as in examples 6 and 7; or be translated, as in the idioms in examples 9 and 11.

(Such items are underlined in the following examples.)

6. Die Entwicklung nahm ihren Anfang mit ...
The development began with ...
7. Der Aufstand nahm seinen Anfang mit ...
The revolution began with ...
8. Er schoss einen Bock.
He shot a buck.
He made a mistake.²⁵
9. Er schoss einen gewaltigen Bock.
He shot a tremendous buck.
He made a tremendous mistake.
10. Den Entschluss fassen, etwas zu tun.
To seize the decision to do something.
To decide to do something.
11. Den festen Entschluss fassen, etwas zu tun.
To seize the firm decision to do something.
To decide definitely to do something.

(We observe in sentences 6 and 7 that the gender of the German possessive pronoun, which has no equivalent in the English translation, is dependent on the gender of the subject.)

The system must also be able to assign a semantic function to the constituents of sentences dependent on the meaning of those constituents and not necessarily on their syntactic function (cf. examples 12 through 16). Thus, the adverbs underlined in the German examples 12 through 14 have to be interpreted as semantic predicates or at least have to be mappable into predicates, given in broken underlines, of the output language; the German dative objects in sentences 15 and 16 appear as English possessives:

12. Er studiert gern Physik.
He likes to study physics.
13. Er studierte lieber Physik.
He preferred to study physics.
14. Er sprach weiter.
He continued to talk.
15. Er kam ihr zu Hilfe.
He came to her aid.
16. Sie brachte es ihm zur Kenntnis.
She called it to his attention.

(We may note in examples 12 through 14 that the tense of the original German predicate is associated with the English predicate which itself is a translation of the German adverb.)

With respect to the languages German and English, the system should also be able to translate the German article in cases of inalienable property as the English possessive:

17. Er kreuzte die Arme.
He crossed his arms.

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LEHMANN/STACHOWITZ

RADC-TR-71-295, Volume II
Final Technical Report
December 1971



FEASIBILITY STUDY ON FULLY AUTOMATIC HIGH QUALITY TRANSLATION

University of Texas

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

FEASIBILITY STUDY ON FULLY AUTOMATIC HIGH QUALITY TRANSLATION

Dr. Winifred P. Lehmann
Dr. Rolf Stachowitz

University of Texas

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18. Er legte ihr die Hand auf die Schulter.
He put his hand on her shoulder.

We further expect from a translation device that it not only associate a correct semantic reading with a sentence but rather that it provide the correct semantic reading. That is, it should be able to assign to a sentence *t* all its semantic readings in the case that *t* is ambiguous and should further be able to select from those readings the one which is correct in the textual environment.

19. Die Maenner hatten die Frauen ermordet. Wir nahmen sie drei Tage spaeter gefangen.
The men had murdered the women. We caught them three days later.
20. Die Frauen waren von den Maennern ermordet worden. Wir nahmen sie drei Tage spaeter gefangen.
The women had been murdered by the men. We caught them three days later.
21. Die Maenner hatten die Frauen ermordet. Wir beerdigten sie drei Tage spaeter.
The men had murdered the women. We buried them three days later.
22. Die Frauen waren von den Maennern ermordet worden. Wir beerdigten sie drei Tage spaeter.
The women had been murdered by the men. We buried them three days later.

The problem in examples 19 through 22 is the recognition of the proper referent of the pronoun "sie" in the second sentence of each example. We maintain that none of the

four two-sentence combinations are ambiguous. "sie" in examples 19 and 20 uniquely refers to the men; in examples 21 and 22, it uniquely refers to the women. Since both men and women can be captured as well as buried, there is no clue in the semantic reading of the words "men" and "women" which permits the correct association of the proper referent for the subsequent pronoun. Thus, "wir nahmen sie drei Tage spaeter gefangen" in examples 19 and 20, and "wir beerdigten sie drei Tage spaeter" in examples 21 and 22 should be either ambiguous or vague. We can explain the non-ambiguity and non-vagueness of the sentences by the fact that a meaning rule "for all Y: if X kills Y, then Y is dead", is used when the SA-image of the first sentence of each sentence pair is constructed; i.e. that an SA-image is generated in which the argument "women" receives the predication "dead". Assuming that the verb "gefangen nehmen" requires for semantic wellformedness a human object that is alive and "beerdigen", an animate object which is not alive, we can easily explain the establishment of the proper referent. The reader should not be misled by the fact that the English translations of the problematic German sentences display the same ambiguity in isolation. That access to the established SA-image is necessary will be obvious when we translate the sentences into Italian, where the selection of the pronoun *le* or *li* referring to the women and the men, respectively, has to be made.

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The problems that have to be dealt with in examples 19 through 22 are, however, not restricted to such apparently constructed examples, which are possibly rare in actual texts, in particular in scientific texts. It is necessary to point out that this problem, in a different appearance, comes up fairly frequently in possibly every text. In the sentences 23 and 24 the predicate *liess ... frei* is translated correctly as *set ... free* in the environment animate (physical) object, and as *left ... blank* in the environment inanimate object, respectively.

23. *Er liess Sylvia schliesslich frei.*
He finally set Sylvia free.

24. *Er liess schliesslich die Zeile frei.*
He finally left the line blank.

However, in German and many other languages semantic features of nouns are neutralized when the nouns are pronominalized. Thus, the German sentences 23 and 24 both become sentence 25 under object pronominalization, which, consequently, is ambiguous in isolation.

25. *Er liess sie schliesslich frei.*

The sequences 26 and 27, each of which contains sentence 25, correctly show different translations for 25.

26. *Mark konnte Sylvias Qualen nicht laenger ertragen.*
Er liess sie schliesslich frei.
Mark couldn't bear Sylvia's ordeal any longer.
He finally set her free.

27. Mark wusste nicht, wie er die letzte Zeile ausfüllen sollte. Er liess sie schliesslich frei. Mark didn't know how to fill in the last line. He finally left it blank.

It follows that for the proper translation of such German sentences, we need to be able to recover the disambiguating semantic features from the contextual information which has been lost due to the pronominalization of the disambiguating German nouns.

It may be interesting to point out that of the 36 selection restrictions associated with the eight verbs in the appendix of my paper "Lexical Features in Translation and Paraphrasing: An Experiment", 13 entries cannot be translated properly if the stated semantic feature for subject or object is neutralized due to pronominalization. This surprisingly high percentage might become even larger if we take into account that the semantic features listed in that paper sometimes are not sufficient for correct interpretation or translation, and additional, more refined semantic features might be required. (Cf., for example, the entry *erhalten*.)²⁶

Attempts to solve such problems by assigning to the various translation equivalents a probability, possibly based on criteria of frequency of occurrence, we regard as being unsatisfactory. Assume that an item with two different translations is translated as X in 60% of all the cases and as Y in 40% of the cases. To base translation on their

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assigned probability will mean that on an average in 100 occurrences of the item we will obtain 40 wrong interpretations and translations. This, moreover, is independent of whether we use the translation X and Y or the translation X alone. In the case that some MT system needs to select translations on considerations of probability, we would regard the restriction of the translation to just the item X as more practical since the user could be warned that X contains a certain margin of error: namely, that it may mean Y in 40% of the cases, whereas, if translations X and Y were used, the user would have to learn that X may mean Y in 40% of the cases and Y may mean X in 60% of the cases.

28. WIE GEHT ES IHNEN? *Mir geht es gut.*

How are you_{sg}? I am fine.

29. WIE GEHT ES IHNEN? *Uns geht es gut.*

How are you_{pl}? We are fine.

30. WIE GEHT ES IHNEN? *Ihnen geht es gut.*

How are they? They are fine.

Examples 28 through 30, moreover, show that translation of individual sentences based on the information contained in the immediately preceding context is not always possible.

The disambiguating information may be provided in sentences which follow the ambiguous sentence. The argument that these examples could be translated correctly if they were not given in the frequent key punch representation which loses the distinction between majuscule and miniscule holds only for English.

28., 29. *Wie geht es Ihnen?*

How are you?

30. *Wie geht es ihnen?*

How are they?

For translation into other languages, as for example Spanish, we still need to be able to access the responses.

(28.) *Wie geht es Ihnen? Mir geht es gut.*

Cómo está Ud? Estoy bien.

(29.) *Wie geht es Ihnen? Uns geht es gut.*

Cómo están Uds? Estamos bien.

It may sometimes not be necessary for device T to have access to the environment in the cases where the ambiguities of the input sentences can be mapped into a corresponding output ambiguity, as examples 19 through 22, 28, and 29, or sentence 31 show:

31. *Johann beobachtete den Mann mit dem Teleskop.*

John watched the man with the telescope.

The capabilities of translation device T would certainly increase if it contained a component which mapped input ambiguity into corresponding output ambiguity, if possible.

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Whereas this capability may only be desirable, the corresponding capability to carry over input uniqueness into corresponding output uniqueness is certainly necessary. That output non-ambiguity does not simply follow from input non-ambiguity may be shown by means of sequence 32, where brackets indicate that any, but only one, of the pronouns in the brackets may be used; the subscript of a pronoun indicates that it refers to the word with the same subscript occurring in the preceding text.

32. Diese Maschine₁ hat einen Atommotor₂. Gestern ist
 eines $\begin{bmatrix} \text{ihrer}_1 \\ \text{seiner}_2 \end{bmatrix}$ Raeder₃zerbrochen. Wir werden
 $\begin{bmatrix} \text{sie}_1 \\ \text{ihn}_2 \\ \text{es}_3 \end{bmatrix}$ zurueckschicken und Ersatz verlangen.

A translation which preserves the pronominalization would result in the following sequence:

32a. This machine₁ has a nuclear engine₂. Yesterday
 one of its_{1,2} wheels₃ broke. We will send it_{1,2,3}
 back and demand a replacement.

As we can see, this translation introduces ambiguities which do not occur in the German counterpart. The correct translation should be:

32b. This machine₁ has a nuclear engine₂. Yesterday
 one of the $\left[\begin{matrix} \text{machine's}_1 \\ \text{engine's}_2 \end{matrix} \right]$ wheels₃ broke.
 We will send the $\left[\begin{matrix} \text{machine}_1 \\ \text{engine}_2 \\ \text{wheel}_3 \end{matrix} \right]$ back and demand
 a replacement.

We finally expect from a good translation device that the syntactic structure of translation u of some input sentence t be isomorphic with or similar to the syntactic structure of t ; we also expect that the stylistic evaluation of subgraphs of the structure of t be identical with the stylistic evaluation of the corresponding graphs of the translation u of t . Both statements, of course, are to be understood with the proviso that such corresponding, similar structures or stylistic evaluations occur in both languages.

So far, none of the examples mentioned have provided us with counterevidence to the claim that translation is possible by mapping molecular lexical items into equivalent molecular items. How shall translation device T react if it meets a molecular expression in one language which has no corresponding equivalent equimolecular expression in the target language, as predicted by adherents of the Humboldt-Cassirer-hypothesis, also called Sapir-Whorf-hypothesis?

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Two solutions are possible: T may contain a dictionary in which two or more molecular expressions of the target language are given as the equivalent of the molecular expressions in the source language or - to quote Professor Bar-Hillel - by permitting the system to "tell a story". The first way is normally selected in dictionary entries, though very often not very successfully, as translations like that of the German entry *jemandem etwas absehen* illustrate. Wildhagen gives the translation equivalent *learn something by looking at a person*, Langenscheidt, *learn something from a person*.²⁷ According to these translations, the German sentence *Er hat seiner Mutter das Schoenschreiben abgesehen* would be translated as *He learned calligraphy by looking at his mother* (Wildhagen) or *He learned calligraphy from his mother* (Langenscheidt), whereas the exact translation should be *He learned calligraphy by watching his mother do it*. The first dictionary translation does not express the fact that there is a causal relation between someone's learning some action or behavior and his watching someone do it. The second translation does not indicate the fact that this someone is performing the action or displaying the behavior. A better translation would consequently have been: *to learn doing x by watching someone do x*, and/or: *to learn to be x by watching somebody be x*. Assume now that a translation for term q cannot be provided because the dictionary - due to lack of any translation equivalent - does not contain a translation for q. (We do not

know of such occurrences.) In this case, System T needs to be equipped with the capability for describing the SA-image representing term *q*. This, however, can be simulated by permitting System T to have access to its meaning rule component, where it can read off the definition for the term in question. This, again, means that the user of the MT system can update the bilingual dictionary by providing as a translation the equivalents of the terms used in the definiens of the definition of *q*.

Real problems will arise only if a state of affairs is described in the source language which simply cannot be described by any language-means in the target language. In this case, both human and mechanical translation would be impossible. We doubt that this will happen, in particular, in scientific texts.²⁸

We finally investigate whether "self-awareness" is required for translation device T. This may be discussed by means of an example which was given by Roman Jakobson during one of the conferences pertaining to the Study. In Polish as in other Slavic languages the equivalent of "I" is normally omitted, but stated in emphasis. In one of them (Czech, if I recall properly), the opposite is the case. A translation of a Polish text: *Whenever he spoke of himself, he used the word 'I'.* into Czech should read: *Whenever he spoke of himself, he omitted the word 'I'.* (Note that the translation of Polish *I am speaking* into Czech *(I) am speaking* (where underlining

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indicates occurrence of the pronoun in the surface; enclosure in parentheses, absence in the surface) is not beyond the capabilities of the device; this could be handled by the semantic or, possibly, the stylistic component.) Clearly, the correct translation of such examples requires that the system contain the ability to interpret statements about itself or part of itself and associate those statements with the corresponding parts of that system. The system would thus have to be able to 'think' about itself or some of its parts. This capability, artificial intelligence, we do not regard as necessary for an MT system for some time to come.

The gravest argument against the possibility of mechanical translation has been the claim that knowledge of the world and even knowledge of the subject matter is required for the translation of a text. This argument, reformulated for our device T, reads: There are sentences whose ambiguity cannot be resolved by access to the immediate preceding or following textual environment. Sentences 33 and 34 may represent such ambiguities:

33. *Fred and John had beaten Mary and Jane so brutally that we had to take them to a penal camp.*
34. *Fred and John had beaten Mary and Jane so brutally that we had to take them to a hospital.*

It seems obvious that we understand these sentences correctly, i.e. that we can determine the proper referent for *them* (necessary, e.g., for their proper translation into Spanish

os and las) because we have stored knowledge about certain typical "sequences of states of affairs". The fact that we understand these sentences in isolation does not mean, however, that MT device T must have the same capability. Very often the preceding and/or following context may contain - for us redundantly - information which permits the disambiguation of such sentences. Consider for example as a continuation of sentences 33 and 34, respectively:

33a. *After three weeks Fred and John were released from the camp.*

34a. *After three weeks Mary and Jane were released from the hospital.*

Consider even the "counterevidence" given in the following sentences 33b and 34b:

33b. *There they were safe from Fred and John.*

34b. *There they posed no more danger to Mary and Jane.*

As we can see, our knowledge about typical sequences of states of affairs permits us to draw conclusions with some, normally high, probability but not with absolute certainty. (This probability may be 100% when the relation between states of affairs is a cause-effect relationship.)

A difficulty of a different nature is represented by the fact that certain terms have a different translation dependent on the particular subject area they pertain to.

35. *John had always wanted to become a conductor.
(bus, orchestra)*

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But again, we might expect continuations like:

35a. *He attended every performance of the local orchestra and watched the conductor with admiration.*

or:

35b. *As often as he could, he rode in a bus and watched the conductor with admiration.*

We do not intend to belittle these difficulties confronting successful mechanical translation. On the other hand, we believe it is fair to point out that no research has been performed to find out the extent to which the preceding or following context provides the information necessary for the proper disambiguation for such sentences. We do, however, believe that sentences do not occur in isolation, at least not in material presented for translating, and that the required factual knowledge may be replaceable by access to the information contained in the contextual environment. If difficulties should arise because the device, instead of printing out all readings in such cases, prints out just one with a warning signal, we may still rely on the powers of the reader to interpret statements pertaining to a subject area he is well acquainted with.

Let us now recapitulate the properties that we expect MT device T to have:

a) It must be able to assign to a source language sentence *t* all its syntactic descriptions and all its semantic readings. This might be done without a genuine semantic component provided that the "semantic function" of the arguments, i.e.

their location on the numbered lines in representations as in Figure 12, page 21, can be computed from the syntactic structure and the information associated with the lexical items occurring in that structure; this, we are inclined to believe, is possible. (Cf. also Fillmore's arguments in "The Case for Case".) T will, however, have to contain a transformational component which permits at least permutations and deletion recovery (for the source language), and permutations and deletions (for the target language).

b) It must be able to map the lexical items and the semantic relations expressed in t into the equivalent equimolecular lexical items and semantic relations of the target language sentence t'. This requires either a translation component: Source language \rightarrow Target language, or an interpretation component: Natural language \leftrightarrow Interlingua, for each of the languages involved in the translation process.

c) It must be able to derive at least one sentence t' with its syntactic description from the semantic reading of t'. The syntactic structure of t' will have to correspond to the syntactic environment required by the lexical items in t'. This again - for each language involved - requires an extensive dictionary with sufficient syntactic and semo-syntactic information for every entry.

d) T must further be able to disambiguate sentence t based on the contextual information preceding and/or following t.

This definitely requires aa) the association component of K, bb) the capability not to be restricted to sentence-by-sentence translation, and cc) a lexicon in which terms with different meanings in particular areas of provenience - which are not disambiguable by means of semantic features - are equipped with area of provenience information (remember *conductor* in example 35, page 45). Device T, of course, needs the capability for exploiting such area of provenience features.

e) T must have access to the definitions of a meaning rule component. This requirement can be replaced and, for the time being, should be replaced by updating the source-target language dictionary by providing a combined translation in the target language of the terms of the definitions of the "difficult" item in the source language; this combination can be treated as one lexical item, possibly with internal variable slots (cf. examples 6 and 7 in this chapter).

In addition, the following properties are desirable:

f) It should be able to provide a translation t' for sentence t whose syntactic description is identical or similar to the syntactic description of t . This requirement means that the system must be able to associate with some semantic representation R all target language sentences (with meaning R') with their syntactic description. In uni-directional translation, this requirement may be limited to only those structures which

are isomorphic or similar to structures occurring in the input language.

g) It should be able to provide a translation t' for sentence t whose stylistic evaluation is identical or similar to the stylistic evaluation of t . This means T should have a stylistic component which can possibly be simulated by stylistic features associated with lexical and syntactic structures.

h) T should be able to associate a translation t' with a sentence t in such a way that, if t is ambiguous in some specified fashion, t' is ambiguous in the same fashion. This desired property of MT system T , complementary to requirement d, is really a makeshift solution, proposed because of the current but, hopefully, passing inaccessibility of the information provided by the context to mechanical devices.

i) Finally, T should be able to produce a non-ambiguous translation t' for a non-ambiguous sentence t .

As we see, an MT device should incorporate a greater part of the components of a comprehension device and some additional components pertaining to the output in a foreign language to provide syntactically similar and stylistic translations. We are not able to say whether a translation device needs to have access to a long-term memory or an "encyclopedic knowledge" component. Examples which clearly show this necessity for a comprehension device or an information-retrieval system may

not be relevant for an MT system.

We conclude that translation by mapping semantic relations between molecular or atomic expressions of the target language into equivalent equimolecular expressions (or combinations of expressions), under preservation of the semantic relations, is possible. Such translation can, in general, be performed on the level of semantic readings (DSA-images). Access to the short-span memory, the association component of K, to select the proper reading in cases of ambiguity, will be necessary. The extent to which access to the association component cannot be avoided, or to which this necessity can be replaced by relying on the intellectual capabilities of the reader of the translation has not been investigated, so far.

We shall discuss in the subsequent chapter which of the better known, current linguistic theories account for the requirements that we expect from such an MT device or, at least, the extent to which they account for them.

4. The Capabilities of Current Competence Models or The Properties of a Realizable Mechanical Translation Device

In the preceding chapter we gradually developed the properties of a hypothetical MT device T, based, in part, upon the linguistic problems occurring in translation which T must be capable of solving, and, in part, on certain esthetic expectations. These require that T carry across into the target language the message to be translated, in a way closely corresponding to the structure and the evaluation associated with the message in the source language. In this way, we increased the capabilities of MT device T until it approximated to some extent the capabilities of a human translator.

In this chapter we want to determine the extent to which these hypothesized capabilities are actually realizable within the framework of the current better known grammatical models. The models we have in mind are: a) the various realizations of transformational grammar, as the "standard" model; the "extended standard" transformational grammar; and the "universal base hypothesis", the transformational grammar with a generative semantic base component, b) the case grammar of Fillmore, and c) the dependency grammar, which in several variations is prevalent in European and Soviet approaches to MT.

All of these models have been defined, explicitly or implicitly, by their proponents or adherents as competence models, i.e. abstract devices which enumerate an infinite list of individual

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or non-coherent sentences. Competence models are regarded as components of performance models which account for such human capabilities as the production and understanding of sentences in actual speech situations or simulations of them, i.e. the production and understanding of coherent sentences.

These limitations of the capabilities of a competence model limit the capabilities of our MT device T. The main requirements which cannot be met in current competence models are:

requirement d (page 47), the disambiguation of sentences based on the information given in the context;

requirement c, the derivation of sentences from their semantic representations;

requirement e, the production of translations for source sentence - target sentence pairs whose semantic representations contain equivalent combinations of items with different internal molecularity, by means of a meaning rule component;

requirement g, the production of translations which have the same stylistic interpretation as the corresponding source language sentences.

It seems that the "universal base hypothesis" grammar is theoretically able to account for requirement c, the derivation of sentences from their semantic representation, provided there are efficient production (and recognition) algorithms.

This is due to the fact that the deep structure they propose, common to all languages, represents the meaning of the sentences transformationally derivable from

those deep structures by means of the rules of the transformational components of the individual languages. Since, however, this model has only been scarcely described - by means of a few examples restricted to English - we arrive at the conclusion that none of the requirements stated above can be met by the current competence models.

We are thus confronted with the choice either of attempting to simulate or construct a component of a performance model which permits us to meet requirement d and possibly c (we assume we can dispense with requirement g without considerable loss to the quality of the translation) or of lowering our requirements for MT device T to make it compatible with the current capabilities of the existing competence models. The latter possibility is the one normally taken by proponents of MT and automatic information retrieval. For MT it means that the original definition of translation as an association of source language sentence t , with the meaning $R(t)$, into the corresponding target language sentence t' , with the same meaning, i.e. as a mapping of meaning into meaning, is changed to a definition of translation as an association of the lexical items in t and the syntactic structures which interpret them with the corresponding lexical items in t' and the corresponding syntactic structures interpreting them in the same fashion.

Clearly, the powers of the hypothetical MT device T have been considerably reduced: not all paraphrases can be accounted

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for. In addition, the restricted device cannot account for verbal phrases and idiomatic expressions if they do not have a literal correspondence in the other language.

(To my knowledge, Gruber's proposals have not been incorporated into transformational grammars or any other of the mentioned grammars.)²⁹ From a practical point of view, however, we can assume, based on experience in translating actual texts, that this restriction may still provide generally satisfactory translations, especially for languages whose syntactic structures are similar.

What are now the theoretical requirements for such a translation process? We need to be able to associate with a source language sentence t a syntactic representation, preferably the deep phrase marker; we need to map this representation into the corresponding deep phrase marker of the target language, and we need to derive from that deep phrase marker, by means of transformation rules, the corresponding surface sentence t' .

Though the algorithms which perform such recognition, mapping and production have been described and have been in existence for several years,³⁰ no machine translation system has been produced. This is due to two facts: the lack of comprehensive grammatical descriptions for any language and the lack of a component which is part of all four competence models: A lexical component in which for each lexical item two types of information are listed:

- a) its own syntactic and semo-syntactic properties, and
- b) the syntactic and semo-syntactic properties of the environment in which it may occur.

Confronted with this gap, we again have two choices: to lower the requirements for an MT system even further by allowing a lexical component which does not contain such features, or to construct such a lexical component, a difficult, tedious, and time-consuming task.

The first choice, in spite of the intermediate development of transformational recognizers would lead to systems which perform only slightly better, as experience has shown, than the ones criticized in the ALPAC report.³¹

Thus, really only the second choice is open for a designer of an MT device: he has to rely on a complete lexical description of the languages that he is dealing with; he has to construct his own featurized lexicon or hope that somebody else may have produced one from which he may be able to profit.

This decision is independent of whether he is happy with the capabilities of the current competence models or whether he wants to simulate additional capabilities of a performance model by permitting access to the contextual environment, i.e. whether he wants to perform research in discourse analysis.

What sort of approximations to the additional capabilities of device T can we expect from a restricted hypothetical MT device T' which performs mechanical translation based on a lexicon with features and a grammatical description of the languages involved in the translation process?

(We do not share Petrick's opinion about the length required and the extent of difficulties involved in the construction of comprehensive grammars; we believe that his pessimism is based on the fact that he considers the difficulties primarily from the point of view of transformational grammars.)³²

Those additional requirements are:

requirement f (page 48), syntactic similarity of source and target sentence structure or at least preservation of the relative order of the lexical equivalents;

furthermore,

requirement h, the carrying across of lexical and/or syntactic source sentence ambiguity; and

requirement i, the carrying across of source sentence non-ambiguity.

The first requirement might be met by establishing additional correspondences between the relevant reverse (source language) transformations and the order in which they apply with the corresponding forward (target language) transformations (in opposite order). We have no opinion on how these correspondences should be established. The checking of the coincidence of the relative order of the corresponding lexical

items may be easily incorporable into T' and may thus serve as a means to select one translation from a set of transformationally related translations.

The second requirement would mean that from the translations, i.e. the sets of surface sentences:

$$A_1 = \{t'_{1,1}, t'_{1,2} \dots t'_{1,m}\}$$

$$A_2 = \{t'_{2,1}, t'_{2,2} \dots t'_{2,k}\}$$

$$\vdots$$

$$A_n = \{t'_{n,1}, t'_{n,2} \dots t'_{n,j}\}$$

the one occurring in each or in the greatest number of the sets A_1 through A_n would have to be selected (where source sentence t has the deep phrase-markers $DM_1, DM_2, \dots DM_n$). Clearly, such a procedure would not be practical.

The third requirement would mean that T' would have to generate all sentences generatable from the mapped deep structure, analyze each of the generated surface sentences again by means of the input component of the target language and select one of those sentences which have only one deep phrase structure representation.

We thus also relinquish requirement h and the first part of requirement f. (The abandonment of the second part of requirement f, preceding page, would possibly impose too heavy a burden on the powers of the reader to interpret correctly.)

Within the capabilities of the current competence models translation by means of MT device T' can thus be represented as a sequence of three processes:

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- 1) recognition of the deep phrase-marker(s) of source language sentence t ,
- 2) mapping of the deep phrase-marker(s) of t into the deep phrase-marker(s) of t' ,
- 3) production of some target language sentence t' from (each of) the phrase-marker(s) of t' .

We assume that such translations may be satisfactory, especially if performed between related languages. In view of the problems which will confront such a translation procedure (cf. Chapter 3), we regard MT device T' as an intermediary solution. We personally feel that the model which should be strived for is MT device T . In the following chapter we shall describe an approximation to such a device T , the Linguistics Research System.

5. The Linguistics Research System

"Everything in nature, in the unorganic world as well as in the organic world, happens according to rules, though we do not always know these rules ...

The use of our capabilities also occurs according to certain rules which we follow, at first unconsciously, until gradually, through attempts and continuous usage of our capabilities, we obtain a knowledge of them, even acquire such a fluent usage of them that it takes much effort to imagine them in the abstract. Thus, e.g. the general grammar is the form of a language as such. But one does speak without knowing the grammar, one has indeed a grammar, and speaks according to rules, but one is not conscious of them.

Like all our capabilities, our reasoning is subjected in its actions to rules which we can investigate." (Translated from the first through third paragraphs of Kant's Introduction to his Logik.³³

The purpose of the Linguistics Research System (LRS), which is currently being constructed at the Linguistics Research Center of The University of Texas at Austin, is to provide a description and an explanation of human linguistic capabilities by performing recognition and production of sentences in natural language, mechanical translation, and information retrieval. LRS is a system of components which can be connected like

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building blocks to form larger configurations. Each component consists of a set of algorithms and instructions which are executed by the algorithms; they modify the general operations of the algorithms in a prescribed way. Such instructions are linguistic rules, dictionary rules, syntactic rules, interpretation rules; transformation rules, meaning rules, mapping rules, connection rules, and others.

In its basic configuration LRS is a grammatical model for the recognition and production of synonymous sentences in natural language with identical or different deep structures. By deep structures we mean the stage of a sentence derivation in standard transformational grammar when all base component rules, constituent and feature re-writing rules, have applied but before lexical insertions have been performed.

The purpose of this model is to associate with each sentence in a natural language all its canonical form (KF) representations. A sentence which has one semantic reading has one canonical form, a sentence which has n semantic readings has n canonical forms. Two sentences t and u which have one semantic reading in common have one canonical form in common. Two sentences t and u of the same language which have one canonical form k in common are called paraphrases in the reading k . Two sentences t and u of different languages which have the canonical form k in common are called translations of one another in the reading k .

LRS has the power of an interpretative semantic model in that it assigns the same KF reading to synonymous sentences with different deep structures. It has the power of a generative semantic model in that, given a particular KF reading k , it permits the generation of all sentences with different deep structures with that reading k .

A canonical form consists of a sequence of connected canonical form expressions (KF expressions). The language of canonical forms K has the following properties:

a) Each KF expression is a primitive element of K ; (it has - for the user - one and only one (atomic) semantic interpretation); if a surface terminal k has n different senses or meanings, then n different KF expressions or connected KF expressions represent the different senses of k .

b) No two different (connected) KF expressions p and q are synonymous. If two surface terminals have one sense in common, then that reading is represented by the same (connected) KF expression.

Numerous statements have been made in history as to whether such a canonical language can be constructed. Counterarguments have mainly been given during the last few decades by proponents of the Humboldt-Cassirer hypothesis. Assuming that the "world views" of different natural languages are indeed different, a universal language can hardly be more than the logical sum of the different world views, which,

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however, should not be a reason to abandon this notion.

However, compare Catford: *A Linguistic Theory of Translation. An Essay in Applied Linguistics*, and Hjelmslev: *Prolegomena to a Theory of Language*.³⁴

Due to the lack of a theory of semantics applicable to the mechanical recognition and production of sentences in natural language and because of the immense difficulties involved in the construction of canonical forms, LRS represents the meaning of sentences by means of normal forms.

The normal forms of a language are distinct from canonical forms of a language in that the lexical primitives of normal forms may be both atomic and molecular with respect to the canonical forms, for example, *bachelor*, *unmarried man*, *unmarried human adult male*. When information retrieval or translation from any language into any language is attempted, the normal form representations will either have to be replaced by canonical form representations or, more economically, the meaning rule component will have to be expanded to permit the construction of the particular required canonical form when logical conclusions have to be found, or when different languages partition the "world" differently. Cf. Latin *patruus* (father's brother) and *avunculus* (mother's brother).

The process of associating with a surface sentence *t* all the normal forms of *t* is performed in three steps. To each step there corresponds a component:

The surface component, the standard component, and the normal form component.

ne grammar, the surface grammar, the standard grammar, and the normal form grammar, is associated with each component. The non-terminal and terminal vocabulary symbols of each grammar are complex symbols (except for the terminal symbols of the surface grammar). Each complex symbol consists of a category symbol and zero or more subscript or feature symbols; each subscript may have zero or more values.

The grammar rules used during the recognition and production of sentences, both performed as a bottom-to-top direct substitution analysis, are generated by the processing algorithms by means of instructions represented as context-free rule schemata. A constituent in the consequent of a rule schema matches every analyzed (WS) complex symbol from which it is not distinct, i.e. it may match a whole complex WS symbol or a part of a complex WS symbol. A rule schema is successfully applied if each of the positive and negative conditions for each constituent in the rule schema is fulfilled by the matched complex WS symbol, and if all the required relations between two or more constituents stated in the rule schema hold between the corresponding complex WS symbols. If a rule schema is successfully applied, a new WS constituent is constructed according to the instructions stated in the antecedent of the rule schema.

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The conditions that may be stated for individual constituents in a rule consequent are:

- a) A particular category symbol may not or must contain a particular subscript or combinations of subscripts.
- b) A particular category symbol may not or must contain a particular value or combinations of values.
- c) Operations between subscripts of different constituents may not or must be successful. These operations, the set-theoretical operations Intersection, Sum and Difference, are performed with the values of the specified subscripts.

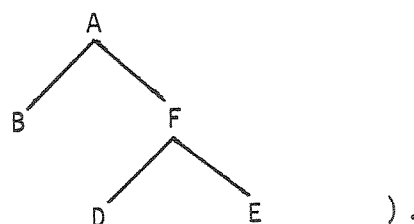
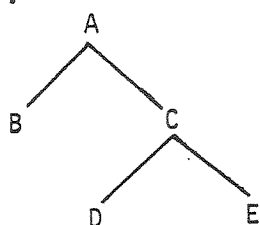
Each rule schema of each grammar consists of a syntactic part and an optional transformational part. For surface and standard grammar the syntactic part of each rule schema consists of context-free rewrite rules. The transformational part contains only transformations whose structural description is satisfied by a string of symbols interpreted by the constituents of the rule schema consequent. The transformations possible in surface and standard grammar are permutations, deletions, and insertions. The transformations are "feature-sensitive"; in particular, it is possible to lexicalize features of a particular constituent and to "featurize" terminal or non-terminal constituents. Thus, words like *up* which form a lexical unit with some verbs, as e.g. *look something up*, are assigned as a feature to the head of the verbal construction, resulting in *look something*.

+up

The rules of the normal form component differ from surface and standard rules in two respects:

- a) They apply to connected graphs;
- b) They are not rewrite rules.

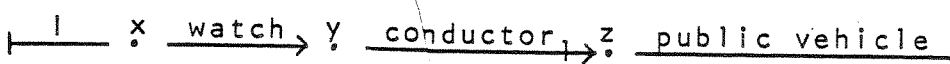
An NF rule applies to all graphs, terminal, non-terminal, or combinations of them, whose nodes, labeled by complex symbols, are non-distinct from the complex symbols in the consequent of the NF rule. The antecedent of the NF rule assigns to all graphs to which it applies a particular semantic reading, an NF expression, represented by that antecedent. Since NF expressions apply to graphs whose nodes are labeled by complex symbols, it is possible to assign a particular NF reading to a terminal k with a particular part of speech interpretation and with a particular selection restriction. At the same time, all graphs $t_1, t_2 \dots t_n$ interpreted by the same NF expression k are substitutable for one another, regardless of whether the root and end nodes of t_i are identical or different from those of t_j ($1 \leq i, j \leq n; i \neq j$). (It is theoretically possible that t_i and t_j have identical root and end nodes and still be different, cf.



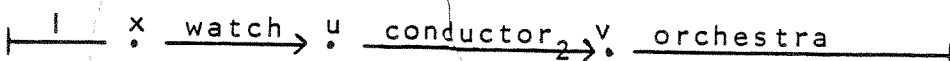
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The normal forms of an ambiguous sentence t may be connected by means of "or" links, resulting in one connected normal form. Assume that the normal form of each of the following sentences is represented by the associated graph.

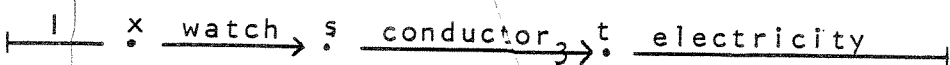
I watched a public vehicle conductor.



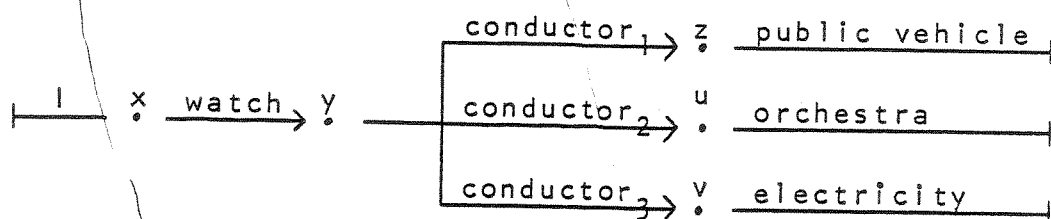
I watched an orchestra conductor.



I watched an electric conductor.



Then *I watched a conductor* can be represented as:



An "or" link is represented by a line which meets or intersects a labeled line at a right angle. (These graphs are simulated, simplified representations of the actual normal forms. For the actual normal form representations of such sentences cf. p. below.)

It is the function of the surface component to assign to each surface sentence all its syntactic readings according to the surface grammar; ambiguous lexical items which have the same part-of-speech interpretation are represented as one "conflated" lexical item in a surface reading. After surface analysis all readings which are not dominated by the initial symbol S are deleted; then all transformation instructions contained in the remaining rules are executed. They associate with each of these readings a tentative standard string. Tentative standard strings consist of complex standard terminal symbols; these may be confluations of surface terminals and their (possibly disambiguated) dictionary interpretation, and dummy symbols which are introduced by the transformations of the surface rules which applied. Dummy symbols represent grammatical morphemes and elided lexical items. Elements which were discontinuous in the surface are contiguous in the tentative standard strings.

These strings are then analyzed by the standard grammar which assigns them a standard description and also filters out all those strings which are not well-formed according to the standard grammar.

The readings of the remaining standard strings are then analyzed by the NF grammar which assigns NF expressions to individual standard subtrees or combinations of them.

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It is not necessary that the roots of the graphs interpreted by the same NF expression are labeled by the same category symbol. It is thus possible to define adjectives and nouns, e.g. *sun* - *solar*, *spectrum* - *spectral*, as synonymous in one reading by assigning each member of such pairs the same NF expression. The same holds for adjectives and verbs, e.g. *bright* - *to shine* or nouns and verbs, e.g. *destruction* - *destroy*, etc. It is also possible to define synonymy relations between lexical units and idiomatic expressions like *die* - *kick the bucket* or lexical units and phrasal expressions like *strike* - *give a blow* - *receive a blow* or *kill oneself* - *commit suicide*, etc. In the latter examples the actual synonymy relation is established between the verb *strike* and the noun *blow*, or between the verb *kill* with the feature reflexive and the noun *suicide*. The verbs *give*, *receive* and *commit* are introduced as empty verbal place holders; in addition, *receive* is defined as the logical converse of *give*, permitting such paraphrases as *Mary hit John*, *Mary gave John a blow*, *John received a blow from Mary*. It is also possible to define synonymy relationships between lexical pieces which have an internal variable slot without affecting their transformational possibilities.

To be paraphrases of one another, it is not necessary for two sentences *t* and *u* that each lexical piece in *t* be synonymous with some lexical piece in *u* and vice versa;

this may be realized from such generatable paraphrases as
All men are not virtuous - No man is virtuous, etc. or
He overlooked this - He did not take this into account,
 etc. or *A precedes B - B follows A*, etc. or *A is larger than*
B - B is smaller than A, *B is not as large as A*, etc.

How LRS assigns such paraphrases the same NF reading can
 be found in Lehmann - Stachowitz, 1970, Vol. II, pp. T217-268.

During production, the recognition process is reversed.
 Each NF expression *k* is replaced by all the standard rule
 schemata interpreted by *k*. The standard grammar rules thus
 obtained and only those are used for the generation of
 standard strings in a regular bottom-to-top recognition process.
 The combinations of all graphs which are connected with a root
 labeled by the symbol *S* represent the legitimate standard
 readings; all others are filtered out.

The terminal standard strings obtained from each well-formed
 standard reading are then analyzed by the rearrangement
 grammar of the language which

- a) arranges the standard terminals in surface word order,
- b) deletes the standard dummy symbols, and
- c) re-introduces lexical pieces which are deleted after
 surface analysis.

In addition, the rearrangement grammar filters out all strings
 which are not well-formed according to its rules.

This basic component of LRS just described is based on the following linguistic assumptions:

- 1) that grammatical relations can be more easily and correctly stated for standard strings;
- 2) that surface information is necessary for correct semantic interpretation;
- 3) that synonymous sentences can be reduced to the same "universal" representation.

This component is part of the Linguistics Research System for Mechanical Translation and the Linguistics Research System for Information Retrieval.

In the remainder of this chapter, we will cursorily describe those components of LRS which are essential for performing mechanical translation of sentences in natural language.

More detailed information can be found in our forthcoming report Lehmann - Stachowitz, 1971a, and in Lehmann - Stachowitz, 1970, Vol. II. The components of LRS pertaining to an information retrieval system are described in Lehmann - Stachowitz, 1971b.

Based on the problems represented in the examples of Chapter 3, we assume that high quality translation has to be based on the following kinds of information; these are:

- textual information,
- co-textual information, (and possibly also)
- contextual information.

These terms correspond to the usage of Catford (op. cit.).

Contextual information is that type of information which can be derived from the speech situation, the belief systems and world knowledge of speaker and hearer. Terms also used to denote this type of information are: "Pragmatics", "pragmatic information", "socio-psychological information". Co-textual information refers to the speech acts that precede and follow an utterance. In case of a written utterance, co-textual information is represented by the written utterances which precede and follow the given utterance. Textual information is that information available from an utterance or a written utterance itself when contextual and co-textual information are ignored.

Translation based on all three types of information we regard at present as being beyond the requirements for an MT system; the situation may change, though, once intensive research in discourse structure shows the necessity for it.

The LRS translation system performs translation based on textual information derived from the basic input component and on co-textual information contained in the immediate environment of a sentence derived by means of an approximation of the short-span memory mentioned on page 20, Chapter 2.

We have observed that LRS is capable of producing various paraphrases. This capability, though desirable for Information Retrieval purposes, may not always be desirable when performing translation, even if the connections of sentences with the

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preceding and following textual environment are properly preserved. Thus, we would prefer to translate *A geht B voraus* as *A precedes B* rather than as *B follows A*, or *Alle Menschen sind tugendhaft* as *All men are virtuous*, rather than *No man is not virtuous*, or *A verkauft B* as *A sells B* rather than *B is sold by A*.

This capability is obtained by means of the fact that NF-expressions are represented as complex symbols containing essential and accidental features. Essential features pertain to properties of an interlingua, accidental features to the properties of a particular language represented by lexical pieces and syntactic structures. Thus, the various graphs in Figure 12 which we repeat below as Figure 16, are all representations of the NF-expression 29.

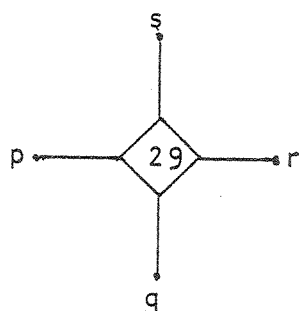


Figure 15

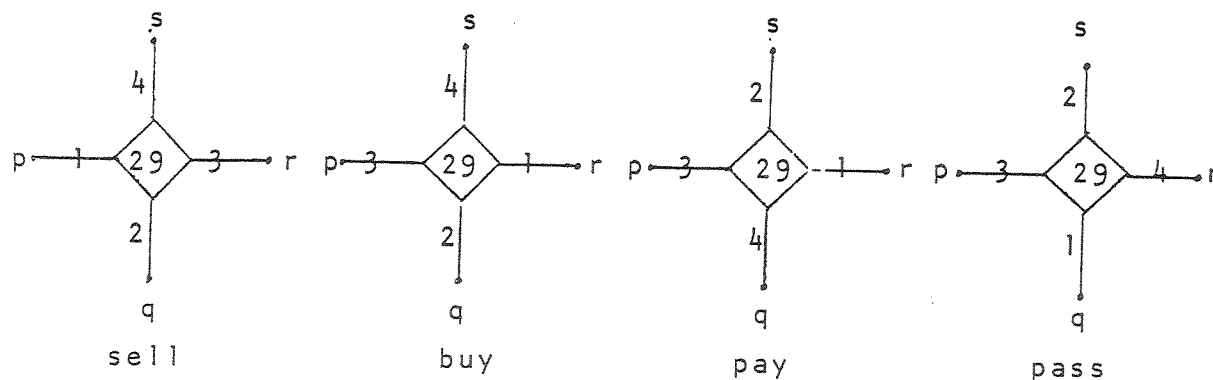
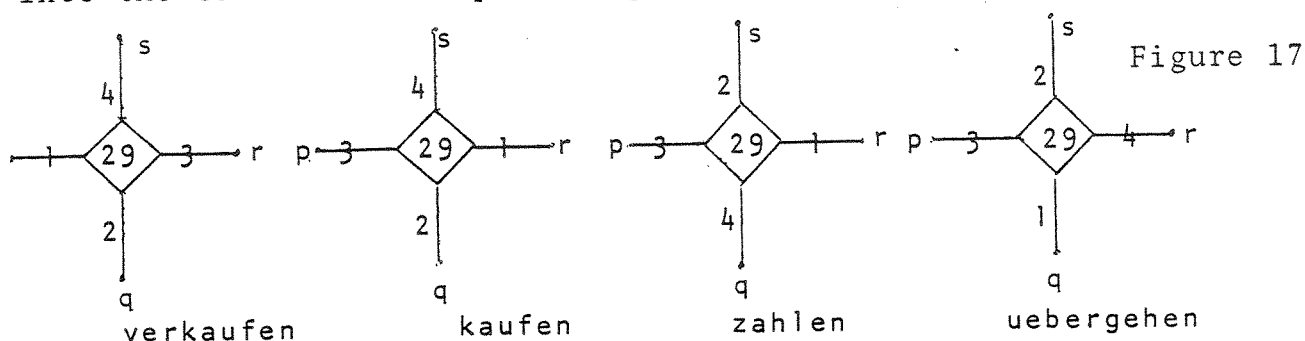


Figure 16

The numbers in Figure 16 represent accidental features. They permit a more precise translation as, for example, from or into the German counterparts represented as:



Similarly, syntactic information like active sentence, passive sentence, can be added by means of accidental features to the NF expressions which interpret these structures. (If an NF expression cannot be mapped into an identical (i.e. including accidental features) NF expression of the target language, all NF expressions in that normal form are mapped by means of only the essential features).³⁵

Machine translation is performed by means of the following components:

- 1) the basic recognition component, which derives the normal form of surface sentence t , or the normal forms of t if t is ambiguous;
- 2) the DSA-image component, which represents the normal form of t as a DSA-image (cf. Figure 11, page 20);
- 3) the connection component, which interprets the established DSA-image of t , connects it with the SA-images of the sentences that preceded t , and disambiguates, if possible, the normal form of t ;

4) the mapping component, which maps the normal form K of t into the normal form K' of the target language;

5) the production component, which produces, by means of the grammars of the target language, a translation t' of t.

Let us represent this translation process by means of the sequence of sentences 38 through 40:

38. *Im Museum sahen wir einen Leiter.*

39. *Den Leiter schaute sich eine alte Dame an.*

40. *Sie zerbrach ihn.*

The corresponding English translation of the individual sentences in the sequence is:

38a. *In the museum we saw a leader [or: conductor (animate), conductress, head, chief, executive, manager, manageress, president, director, directrice, superintendent, principal, conductor (inanimate)].*³⁶

39a. *An old lady looked at the leader [or: conductor (animate), conductress, head, chief, executive, manager, manageress, president, director, directrice, superintendent, principal, conductor (inanimate)].*

40a. *She (it) broke him (it).*

Let us assume that the German sentence 38 of this sequence has already been analyzed and resulted in the following SA-image:

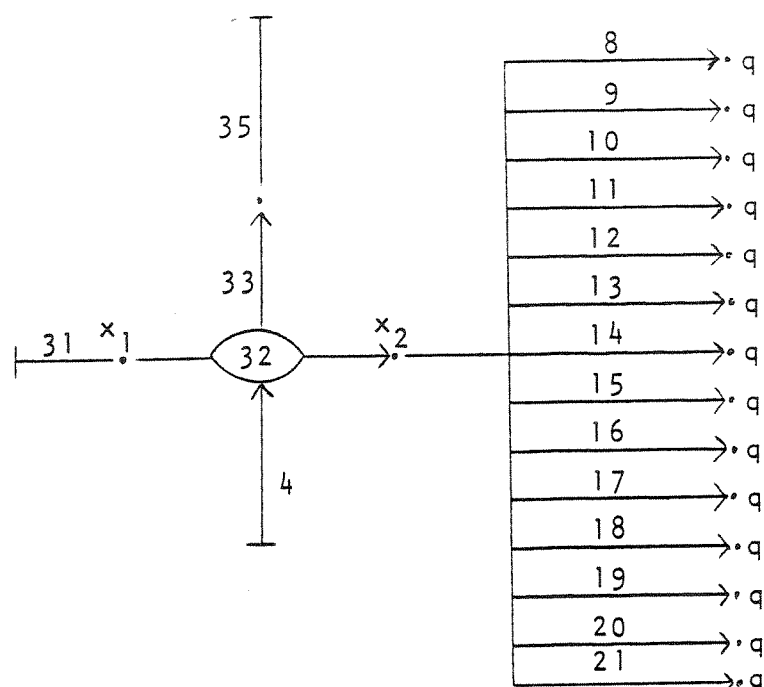


Figure 18.

The digits on the relation and property lines represent molecular expressions. 31 may stand for "we"; 32 for "see"; 33 for "inside of"; 35 for "museum"; 4 for "past"; 8 for "leader"; 9 for "conductor (animate)"; 10 for "conductress"; 11 for "head"; 12 for "chief"; 13 for "executive"; 14 for "manager"; 15 for "manageress"; 16 for "president"; 17 for "director"; 18 for "directrice"; 19 for "superintendent"; 20 for "principal"; 21 for "conductor (inanimate)".

The input component, when processing sentence 39, assigns to this sentence a surface description which we represent, in a simplified manner, in the following graph (for a detailed description of a surface analysis cf. A. Stachowitz "Es liegt eine Anzahl von Elementen vor"):

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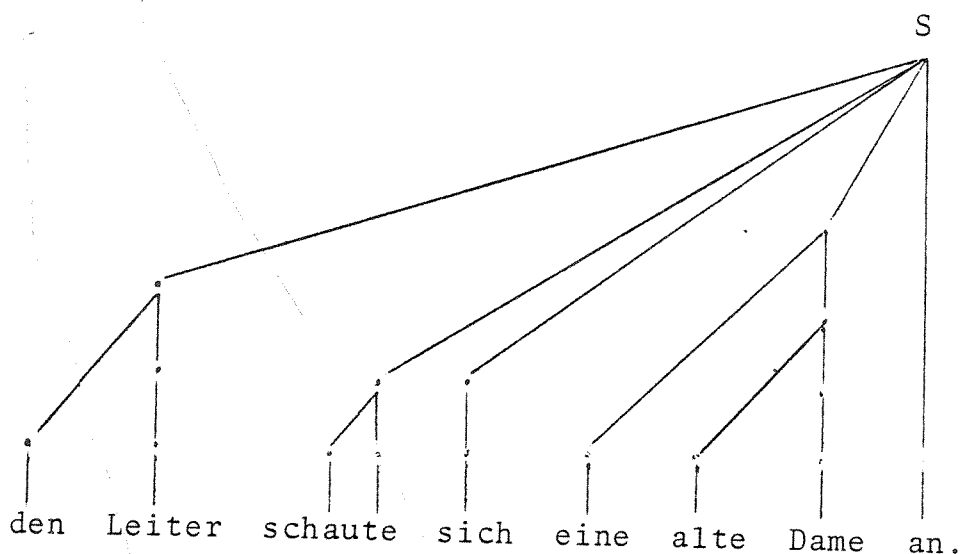


Figure 19

The semo-syntactic information associated with the rule which interprets the word *schaufen* given in Figure 20 is exploited by the transformation instructions associated with the rule which rewrites the symbol S.

C V	<i>schau</i>
+ PR(0'1'2'...)	
+ TS(:': 'AN'...)	
+ SS(:': '2'...)	
+ CG(:': 'D.A'...)	
+ TO(:': 'R.PO,AB'...)	
+ SO(:': '0.3'...)	

Figure 20

This rule represents all (prefix-) verb combinations which contain the verb *schaufen*. The symbol C identifies the category symbol VERB; subscripts are identified by a "+": PR stands for "prefix", TS for "type of subject required", SS for "deep order of subject", CG for "case government", TO for "type of object required", SO for "order assigned to objects". The expressions within parentheses are values; 2 stands for the prefix "an". AN for "animate", D for

"dative", A for "accusative", R for "reflexive", PO for "physical object", AB for "abstract". The "." indicates that the verb takes two objects; a "," represents logical or;³⁷ the digits in SS and SO represent the order assigned to the subject and the objects. (The verb always has the order 1, the deep subject order 2, etc.) The value 0 expresses the fact that the reflexive object in the dative is to be deleted. (This deletion is only performed for genuine reflexive verbs.) The apostrophes represent columns in the "feature matrix" of the verb.

By means of this information and the transformation instructions associated with the nodes in the sentence, the following standard string is derived.

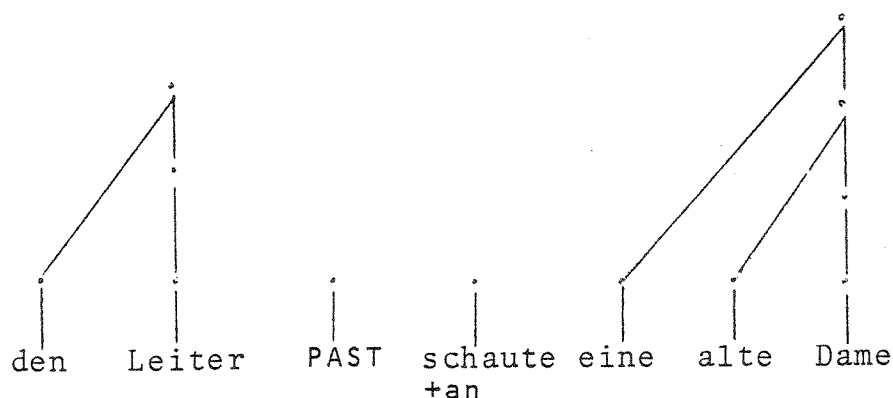


Figure 21

After applying the standard rules, the following structure is derived:

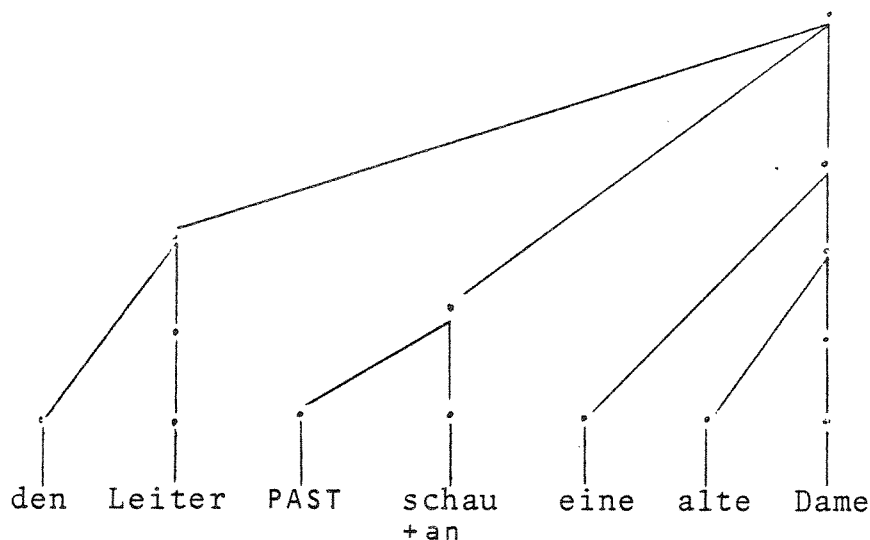


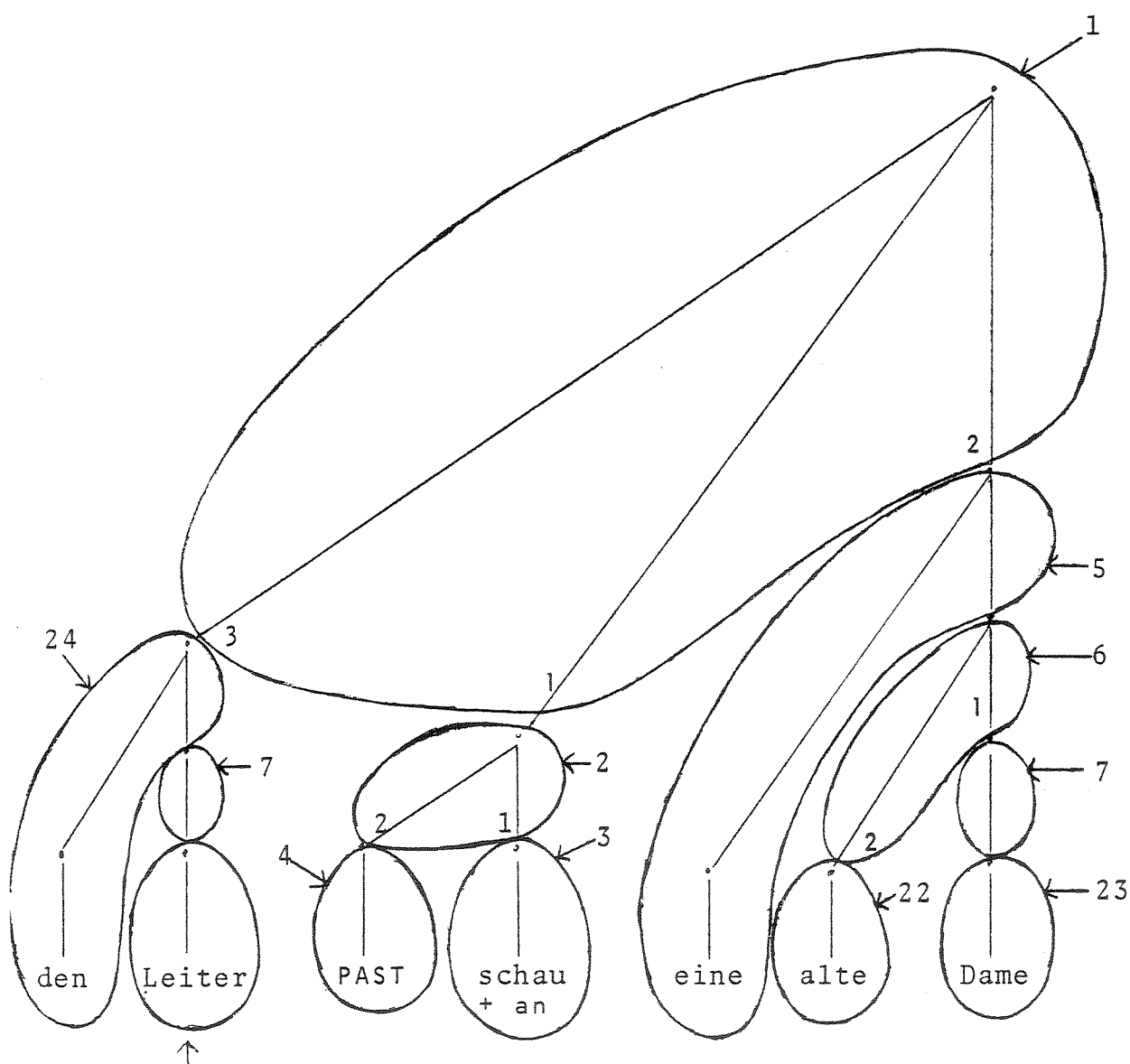
Figure 22

To this structure, the rules of the normal form grammar apply, which derive the following normal form:

$$\begin{aligned}
 & \overset{1}{R(p,q)}_3 \times \overset{2}{Time}_2 \times \overset{3}{\text{observe}}_0 \times \overset{4}{\text{Past}}_0 \times \overset{5}{\text{Argument}}_1 \times \overset{6}{\text{AND}}_2 \times \\
 & \overset{7}{\text{Number(SG)}}_1 \times \overset{23}{\text{Lady}}_0 \times \overset{22}{\text{Old}}_0 \times \overset{24}{\text{Argument}}_1 \times \overset{7}{\text{Number(SG)}}_1 \times \{ \\
 & \overset{8}{\text{leader}}_0, \overset{9}{\text{music-conductor-male}}_0, \overset{10}{\text{music-conductor-female}}_0, \\
 & \overset{11}{\text{head-person}}_0, \overset{12}{\text{chief-person}}_0, \overset{13}{\text{executive-person}}_0, \\
 & \overset{14}{\text{manager-male}}_0, \overset{15}{\text{manager-female}}_0, \overset{16}{\text{president}}_0, \overset{17}{\text{director-male}}_0, \\
 & \overset{18}{\text{director-female}}_0, \overset{19}{\text{superintendent}}_0, \overset{20}{\text{school-principal}}_0, \\
 & \overset{21}{\text{electric-conductor}}_0 \}.
 \end{aligned}$$

Figure 23

The items in script represent atomic or molecular NF expressions. The information given in light face print represents instructions for the DSA component; subscripts represent the degree of the normal form expression, which preserves information about the original standard constituency; the numbers above an NF expression refer to the connected sub-graph in the following figure, which has been interpreted by that NF expression.



8,9,10,11,12,13,
14,15,16,17,18,
19,20,21

Figure 24

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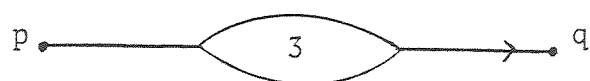
Note that the NF expressions represented by the digits 24 and 5 each interpret a sequence of connected standard trees.

The normal form of a sentence is processed by the DSA-image construction component, which ignores all items which are not of degree 0, or which do not have an operator statement (indicated by light-face print), or which do not have an identifier (indicated by a "+"). For each non-ignored NF expression, the DSA-image component has an instruction:

- a) every unary degree 0 symbol is represented as .
- b) n-ary degree 0 symbols are represented as lenses or arrows³⁸ (binary), triangles (ternary), diamonds (quaternary);
- c) other normal form expressions have special instructions which have to be looked up in a set of operation statements. These representations are connected with objects represented by nodes according to wellformedness conditions computable from the degrees of the non-ignored NF expressions.

Let us now discuss the construction of the DSA-image of sentence 39 from its normal form representation. The first instruction, represented in NF expression 3, constructs a lens with the end nodes p and q and calls the lens by the name of the NF expression given in the DSA-image component. (We shall assume that this representation is the numerical representation above the NF expression in Figure 23.)

The first instruction results in the following graph:



Instruction 4 states: Assign the predication "past" to the last predication. NF expression 5 states: Replace one of the variable node names in the existing graph by name x_i (the order of replacement is dependent on the inherent order of the arguments of the predicator. It is reflected by the alphabetical sequence of the letters in the graph.) Expression 6 states: Attach two "and-branches" to the node with which it can be connected through the degree conditions³⁹; NF expressions 23 and 22 call these branches LADY and OLD. We have so far obtained the following DSA-image:

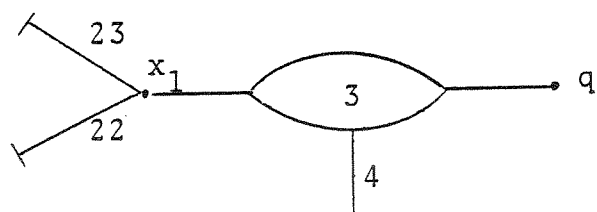


Figure 25

Expression 24 states "change the next variable name to a_i ". Thus, q is changed to a_i . To this node, lines representing the NF expressions 8 through 21 are attached by "or" links, resulting in the graph:

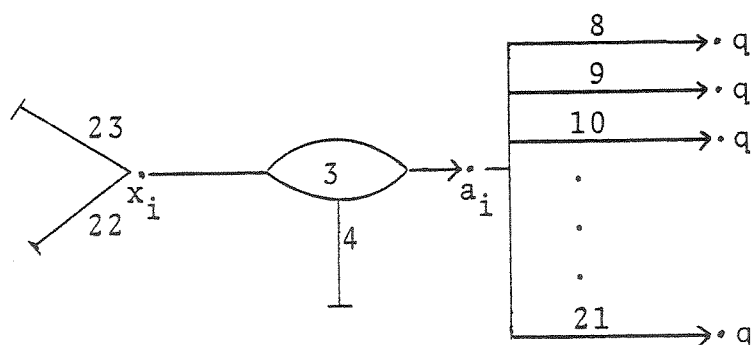


Figure 26

The output of the DSA component is processed by the connection component whose purpose is to replace, if possible, the names of the nodes in the DSA-image by the names of the nodes in the already established SA-image.

The connection component has the following instructions:

For each node in the DSA-image which is named x_i it generates a numerical subscript which has not yet occurred in the SA-images, i.e. it assigns a numerical subscript which is larger by 1 than the last that was previously assigned. For each node named by a_i it performs a search through its short-span SA-image and tries to replace the name a_i of that node by the name of one of the nodes in its SA-image, based on the predication associated with the node a_i .⁴⁰ (We see that only node x_2 in Figure 18, page 75, fulfills this condition.)⁴¹ When all nodes in the DSA-image have been assigned their proper names represented in Figure 27, this image is connected with the established connected SA-image, resulting in Figure 28. Duplications of predications upon objects are not repeated.

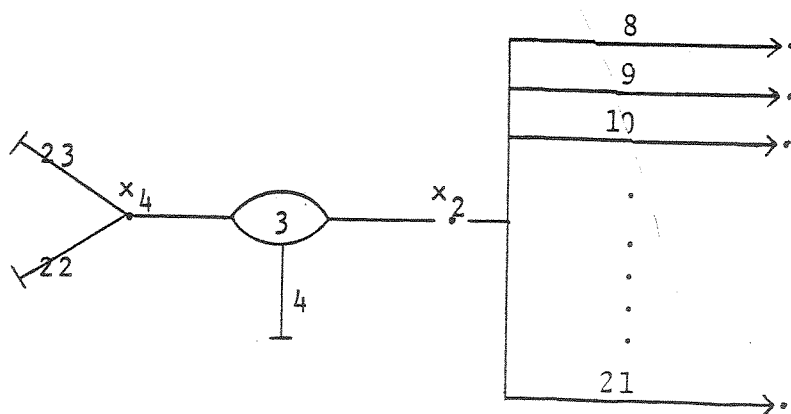


Figure 27

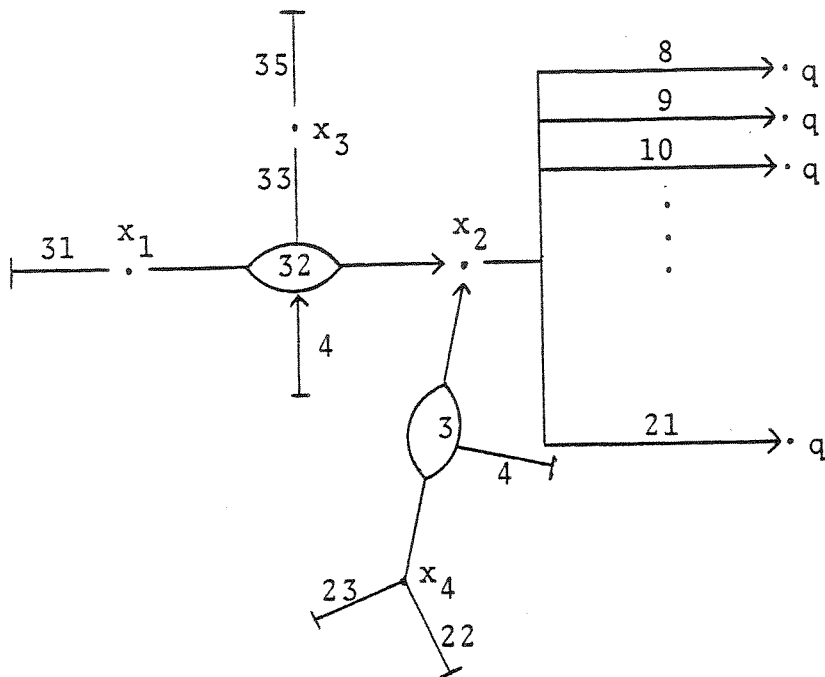


Figure 28

The processing of the sentence *Sie zerbrach ihn* results in the following DSA-image:

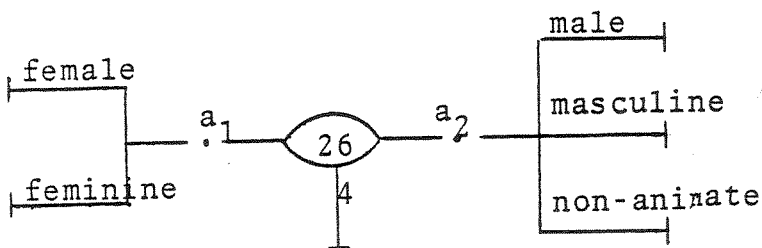


Figure 29

where the expressions above the property lines, connected by "or"-links, state the syntactic or semantic features of a_1 and a_2 , respectively. (These are obtained from the pronouns *sie* and *ihn*, respectively.) Thus, the name " a_1 " represents the pronoun *sie*, which can refer to a female or

feminine object. " a_2 " represents the pronoun *ihn*, which can refer to a male object, a non-animate object or an object of gender masculine.

The connection component tries to establish the referent for nodes a_1 and a_2 , beginning with its most recent SA-image. a_1 could refer to x_4 or to x_2 since all of its predications meet at least one condition of a_1 . a_2 , however, can only refer to x_2 . Consequently, the SA-image for this sentence results in Figure 30.

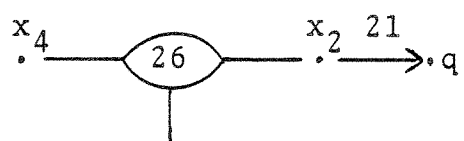


Figure 30

Its connection with the already established SA-image results in Figure 31 in which all the ambiguities represented by the "or" links associated with x_2 have disappeared.

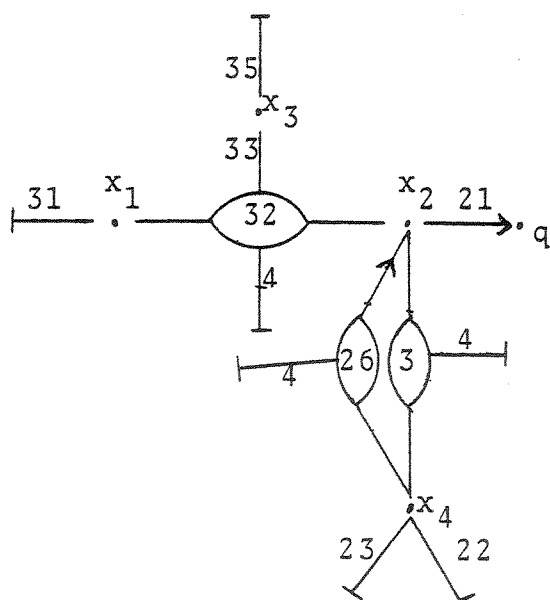


Figure 31

The first and second sentences are disambiguated by comparing their DSA-images against the established SA-image. The disambiguation of DSA-images results in a removal of the ambiguous NF interpretations for the term *Leiter*.

The resulting normal form of sentence 39 is then mapped into the identical normal form of the output language, and the graphs associated with each output NF expression are retrieved. One of these graphs is the NF rule

```
V LOOKAT    R 39
$ A(2)      + OB(at)
$ B(3)
```

where the values "2" and "3" represent accidental features carried over from German. This rule results in the retrieval of the standard rule (a subset of the surface rule):

```
R 39  V V      look
      + PX(0)
      + TY(AN)
      + SS(2)
      + OB(at)
      + TO(PO,AB)
      + SO(3)
```

The standard sub-graphs associated with each normal form expression are analyzed by the standard grammar of the output language, resulting in

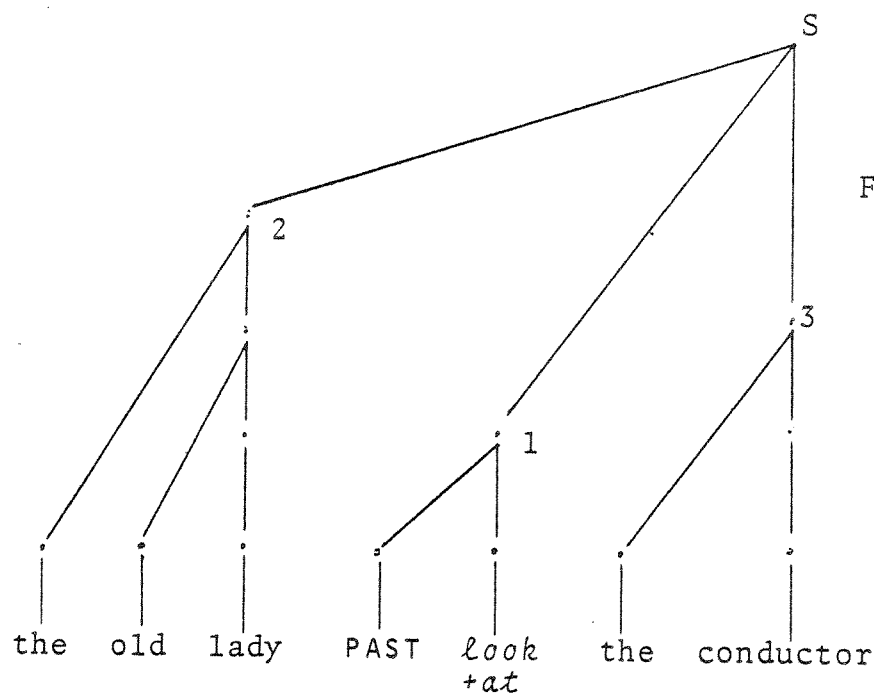


Figure 32

The rearrangement grammar featurizes the dummy symbol PAST and lexicalizes the feature *at*, resulting in the surface string

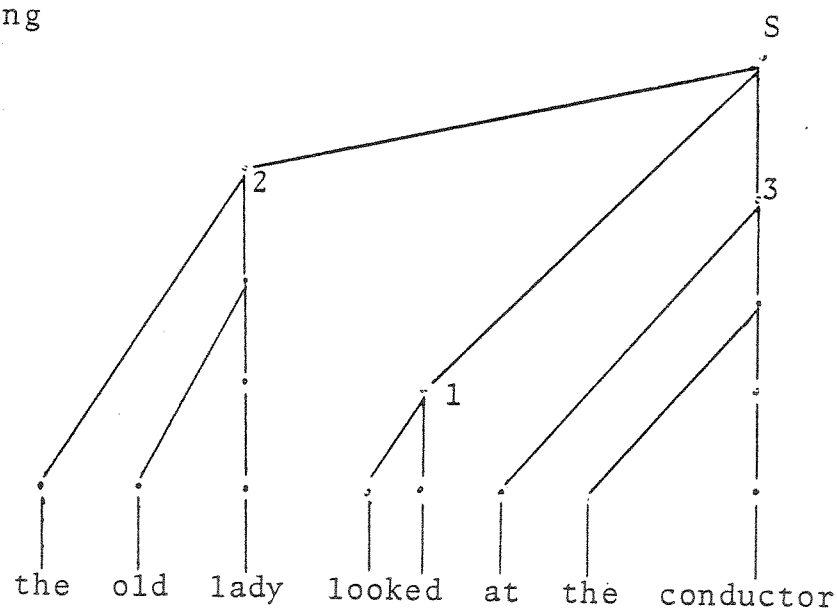


Figure 33

We performed this translation by actually using the memory of the designed LRS information retrieval system. We assume that in translation a short-term memory will be

sufficient. DSA-images then only need to be constructed for the immediate environment of an ambiguous sentence. It may even be possible to restrict the construction of such DSA-images to the unary predications of the objects occurring in the environment. This decision, of course, is dependent on the results of research in discourse analysis. (In MT, it is not necessary to establish every referent of an expression as it is for information retrieval; it is only necessary to establish those referents which help to disambiguate a particular sentence.)

That the system has the power to carry input ambiguity across can be observed from the fact that the English terminal *conductor* will be retrieved twice as an equivalent item for *Leiter*, once through *conductor-music-male*, and once through *conductor-inanimate*. It is fairly simple to compute output terminals which have several meanings in common with an input terminal (cf. Lehmann-Stachowitz, 1970). However, this will only be necessary if the context does not provide any disambiguating information.

The construction of ambiguous syntactic structures also has to be performed by means of SA-images. Assume that the sentence "John watched a man with a telescope" is represented by the SA-image:

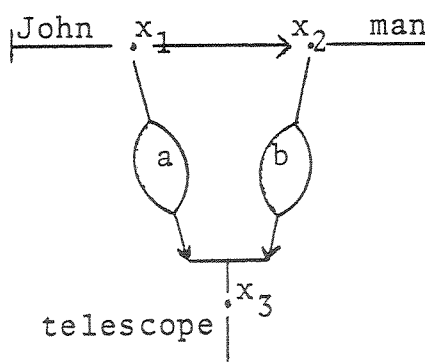


Figure 34⁴²

where a stands for "use", b stands for "have". In order to map this ambiguity across, the system would have to be provided with the knowledge that the structure

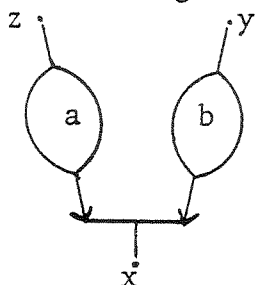


Figure 35

can be mapped as "with x" and the objects naming the nodes have to occur in the surface order z, y, x where x has to follow y directly. Such capabilities are those of a speech production device which are currently not regarded as being necessary for MT.

The capabilities of LRS are based on the following factors:

- a) its subscript grammar with the feature-sensitive transformations;
- b) its normal form component;
- c) its DSA-image and connection component; and most important,
- d) its lexicon.

The subscript grammar permits us to express in a rule relations like agreement and government, which correspond to the intuition of a human speaker. We can express grammatical categories as

- a) lexical categories: noun, verb; b) syntactic categories: NP, predicate;
- c) generic grammatical categories: number, tense, case;
- d) specific grammatical categories: singular

plural; present, past; nominative, accusative; etc.⁴³

We can also express semantic categories like human, animate abstract, etc.; stylistic categories like colloquial, vulgar, learned; and lexical categories like morpheme and allomorph. The subscript grammar permits us to express in a natural manner such concepts as gender (with the values masculine, feminine, and neuter) instead of representing it as a bundle of unordered binary features as in

[+masculine]	[-masculine]	[-masculine]
[-feminine]	[+feminine]	[-feminine]

where the combination

[+masculine]
[+feminine]

has to be excluded by means of an ad-hoc segment-structure rule.

By means of the subscript grammar rules we can formulate redundancy statements, conflate ambiguous trees into one tree; we can also update the lexicon by adding additional necessary semantic features to it without having to make corresponding changes in the syntactic rules interpreting them.

The transformational component permits the disambiguation of lexical items by means of "jump operations" within a disambiguating syntactic or semo-syntactic environment. It permits us to add stylistic interpretation to syntactic structures if certain conditions stated as features of the constituents are fulfilled.

The normal form component assigns an NF expression to (connected) syntactic subtrees, and to lexical subtrees with a specific set of semantic features within a specific semo-syntactic environment. It is also able to assign a semantic interpretation to verbal phrases and idiomatic expressions with or without internal variable slots and to map these NF expressions into the corresponding NF expressions of the output language without affecting their transformational properties (cf. the following graphs)

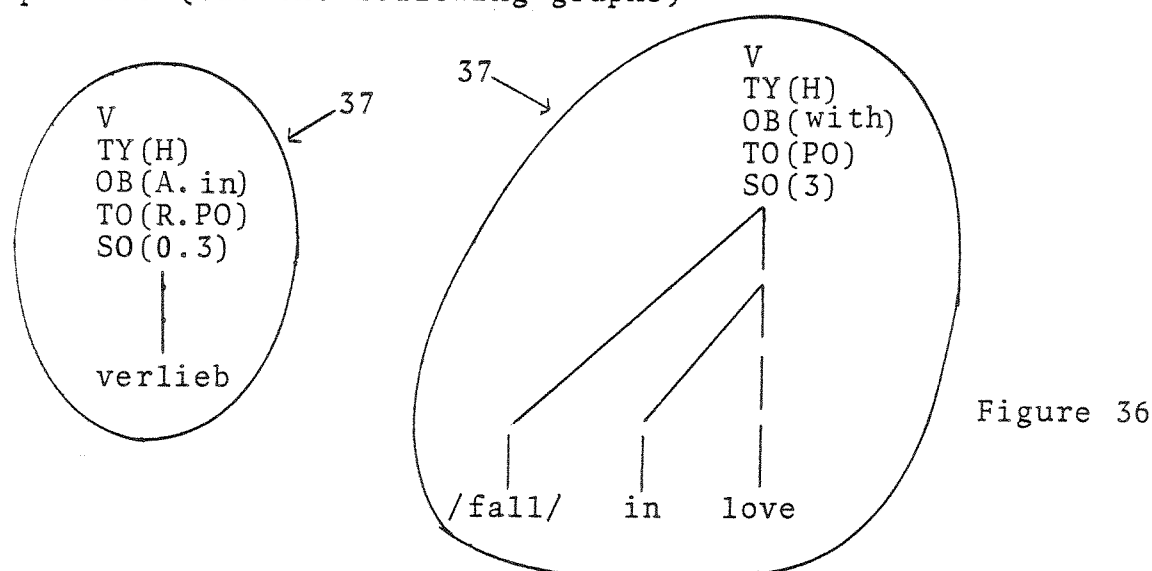


Figure 36

where /fall/ represents the morpheme *fall* (the actual allomorph is generated during the rearrangement stage).

NF rules are currently the only rules of the meaning rule component of LRS; we are planning to extend this component to include definition and inference rules, as for example

N KILL	→	N DEAD
§ P		§ Q
§ Q		

which represents: "If P kills Q, then Q is dead."

The DSA-image component and connection component permit the disambiguation of an ambiguous sentence by means of its co-textual environment.

All the capabilities of the components mentioned would be ineffective if it were not for the lexicon which has to a large extent already been constructed at the Linguistics Research Center. The LRS dictionaries contain stems, inflectional affixes (and, for German, two types of derivational affixes: separable and inseparable prefixes) which are concatenated by means of the surface word grammar rules.

These dictionaries are currently being updated by establishing for each stem

- a) its syntactic and semo-syntactic properties,
- b) the syntactic and semo-syntactic properties of the environment in which the item may occur with a particular meaning.⁴⁴

Polysemic terms are thus represented as one term. The system of rules

R 3	C N	*page	:	surface rule
	+ TY(H,IN)			
	:			
	N HOTELBOY	R 3	:	NF rules
		§ TY(H)		
	N BOOKPAGE	R 3		
		§ TY(IN)		

expresses the polysemy of the noun *page*. The transformations of the surface component have the effect that *page* is

interpreted as *HOTELBOY* or *BOOKPAGE*, or both, in environments as *The page slept* or *The page tore* or *He touched the page*, respectively.

Lexicographic work at LRC (cf. the appendix, for details) has already resulted in word lists containing

a) 10,000 German verbs and 10,000 English verbs, both classified with respect to their object complements;⁴⁵ about 2,000 entries of the latter have been classified with respect to subject and adverbial complements. Similar work on the German verbs is in progress.

b) 33,000 German nouns (letters A through K) with about 70,000 English correspondences; the first 7,000 of these German nouns have been classified according to the scheme shown in the appendix;

c) 6,000 German and English verbal phrases (verb-noun phrase and verb-prepositional phrase combinations), classified as to subject, object, and adverbial complement. Work on adjectives and adverbs is beginning.

Future additional lexicographic work at the Center will be directed towards the establishment of a minimal set of additional semantic features in order to disambiguate verbs which have particular meanings in particular lexical environments, "distinguishers" in the sense of Katz-Fodor.

In view of such combinations as:

<u>abhaengen von</u>	<u>depend on</u>
<u>abhaengig von</u>	<u>dependent on</u>
<u>Abhaengigkeit von</u>	<u>dependency on</u>

we also plan to reduce the size of the surface dictionary (projected number for German = 80,000 entries, for English = 100,000 entries) by removing productive derivations and compounds from the dictionaries. This will be performed by adding derivational affixes to the surface dictionary and word formation rules to the surface word grammar. In order to facilitate the design of the necessary word formation rules for German and English, programs are presently being constructed to analyze and display in concordance format the analysis of each of the individual entries in the current surface dictionaries by means of the whole surface dictionary (to which all derivational affixes of the language have been previously added).⁴⁶

The listed components, in particular the complete lexical component, give LRS to a great extent the power of the hypothetical translation device T (pages 46 through 49).

LRS can meet the requirements a through g:

- a) derivation of semantic reading R for sentence t;
- b) mapping of semantic reading R into semantic reading R';
- c) derivation of sentence t' from semantic reading R';
- d) disambiguation of t in context;
- e) access to a meaning rule component;
- f) generation of syntactic structure of t' which

resembles the syntactic structure of t;

- g) generation of t' with a stylistic interpretation corresponding to the stylistic interpretation of t.

Though LRS permits the carrying over of lexical ambiguities (requirement h), we feel that this will not be necessary because of the ability to disambiguate in context.

Requirement i): carrying across of non-ambiguity of t into corresponding non-ambiguity of t' , can presently only be obtained by re-analyzing standard string t' . This we do not regard as practical. Carrying over of non-ambiguity could be guaranteed by adding diacritics to t' which simulate the labeled bracketing of t' . However, this may not be very convenient for the reader.

Apart from its applicability to machine translation and information retrieval, we assume that LRS also provides reasonable explanations for a number of not easily explainable linguistic phenomena, as for example the occurrence of the underlined *the*'s in the sequence

41. One of Rembrandt's pictures was sold yesterday.
42. The seller was very happy with the price.
43. The buyer is probably an American.

If we represent the sentence 41 by the graph

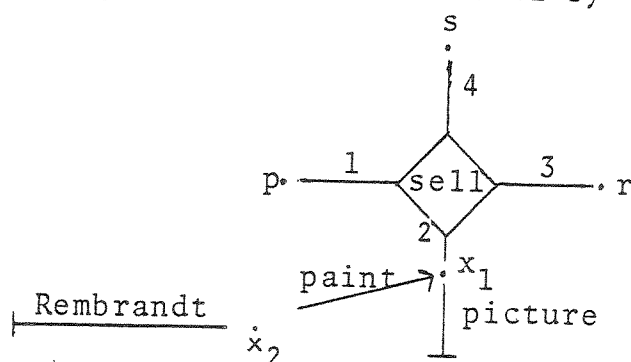


Figure 37

we can explain the occurrence of the definite articles in the sentences 42 and 43 by the fact that the object they

refer to (p, r and s) have been implied though not specified in sentence 41.

We can also reasonably explain the following "paraphrases" of sentences:

A and B kissed. A and B kissed one another. A and B gave kisses to one another. A and B exchanged kisses.

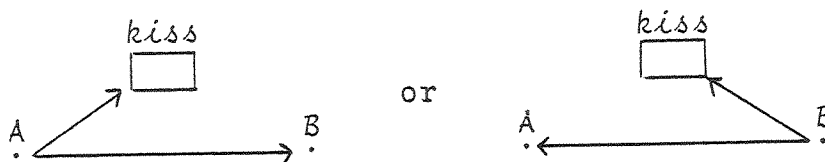
which have complete or partial correspondences in a number of languages such as French, Latin, Serbian, Hebrew, German. Let us represent *A and B kissed* by $A \cdot \xleftrightarrow{\text{kiss}} \cdot B$ (which can also be read as:

A and B kissed one another: A . $\xleftrightarrow[\text{kiss}]{\text{kiss}}$. B).

The nominalization of *kiss* results in the following diagram



In order to establish a relation between the three objects, a diagram like



is necessary. These graphs permit the interpretation *A gives a kiss to B* or *B gives a kiss to A*.

Since the kiss that B gives to A is identical with the kiss A gives to B, we need to extend the graph to

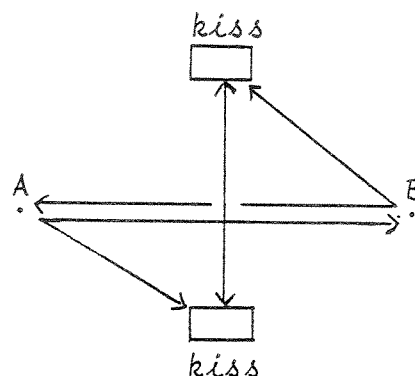


Figure 38

The resulting diagram, as we may observe, is similar to the diagram for "sell" in Figure 7 (page 15), where one of the conditions for the equivalence of the given objects, namely money, has been removed. This exactly describes the actions involved in an exchange of objects thus permitting the interpretations: *A gives a kiss to B and (simultaneously) B gives a kiss to A or A and B gave kisses to one another or A and B exchanged kisses (or: a kiss).*

LRS, as we observe, is a complex configuration of components, actually more complex than described in this paper. This complexity, of course, is due to the complexity of the processes occurring during speech recognition and speech production. The question, however, that naturally arises is: How efficiently, i.e. how inexpensively, can mechanical translation be performed with LRS? We will try to answer that question in the next and final chapter.

6. Progress in Hardware Development and the Future of Machine Translation

The criteria according to which the feasibility of machine translation is normally evaluated are: quality, speed, and cost. In this chapter we do not want to deal with the first of these criteria: our demands on the quality of MT output have been stated and the quality of such output can really not be evaluated before the output exists. We also want to ignore speed, since speed is a factor which is normally used in favor of machine translation. As to cost, we want to restrict ourselves to costs arising from computer processing and exclude those costs which might arise through pre-editing and post-editing (though not in LRS, which is conceived as a fully automatic MT system) and key-punching of a text.

Cost of computer time is dependent on mainly two factors: the actual use of central processing time and the use of input-output time. That the central processor can work with immense speed is generally known; it is less known to the non-specialist that input-output operations are by many orders of magnitude slower than the speed of the central processor and that the central processor must stop with its computations for a particular program until the input-output operations for that program are completed.

Machine translation is a process which requires almost constant input-output operations. We can visualize the

performance of a computer during machine translation by imagining a human being A who reads a text according to the following conditions: A has available different kinds of information;

a) a dictionary consisting of a number of separate booklets, which contains all paradigmatic, syntactic, and semo-syntactic information pertaining to a word,

b) a grammar which also consists of several separate individual volumes,

c) a dictionary of word definitions or meanings consisting of even more separate volumes than the paradigmatic dictionary,

d) a semantic grammar in several volumes which contains the interpretation rules necessary for the computation of the meaning of a text from the lexical items and syntactic relations.

A has to read the text word by word. He may only continue with the next text word if he has found the word that he is currently looking at in one of the parts of the paradigmatic dictionary. Actually, it must be in that part of the dictionary which he is holding in his hand. If the word occurs in that volume, he may proceed to the next word. If not, he has to put this volume down and pick up another volume and check whether the word occurs in it. By means of an efficient search procedure he repeats this process until he finds the volume which contains the word. He then looks up the word and writes down its part of speech interpretation. Then he proceeds with the next word. To speed up his per-

formance, A keeps the volume which he is currently "processing" in his hand as long as possible because it might be the case that the next word that he reads also occurs in that part. In reality, to decrease the number of volumes of the dictionary, A is not reading whole words but constituents of words.⁴⁷ When A has looked up and written down all the paradigmatic information associated with each word constituent, he begins processing the text again, beginning with the first word, this time consulting his grammar books. The procedure is repeated in a similar fashion. Then A starts using his dictionary for semantic analysis, and so on.

The picking up of individual volumes and putting them down again represent the input-output operations of a computer whose central memory is simply not large enough to hold several volumes of a dictionary, or even the whole grammar, since the memory must also hold the programming instructions and the results of the computations.

The advantage of the LRS subscript grammar G is that it represents an abbreviated edition of a multi-volume grammar G'. (Some of the subscript rules represent hundreds, a few even thousands of former context-free rules with simple symbols.) The information in grammar G permits the computer to compute the information contained in Grammar G' and only that information actually needed for the analysis of the particular text sequence currently being processed. And we recall that a computer can compute with extremely high speeds.

In spite of the advantages of the subscript grammar, we observe that the problems pertaining to the recognition of the dictionary items are not alleviated by means of such a grammar since the number of dictionary entries is a given number which cannot be changed. (The conflation of dictionary items, possible with a subscript grammar, still does not change the number of entries.) Fortunately, a development in computer hardware is in the offing which will have decisive effects on machine translation and other research areas which are forced to deal with large data bases: the holographic memory. (Cf. Peter L. Briggs: "Holographic Memories Could Make Others Obsolete", Part IV of "The Great Memory Debate" in Computerworld, August 26, 1970, page 44.)

"Researchers now working with holographic memories claim that one holographic memory the size of an average office desk will have the capacity of all on-line storage in use in the Western world." and that "The desk-size holographic unit, with several 100 trillion bits of storage, would exceed the capacity of all of the disks, drums, and core memory now in use ..."

(Holographic memory) "will offer users multitrillion character storage at ... prices probably less than one-thousandth of (the current price) for large-capacity disk storage."

The information in such memories can be accessed with the speed of light; "access times below 20 nano-seconds/per character or/word or/whatever (will be) feasible within five years. It is possible that such memories may be sufficiently faster than (the processing speed of) the best central processors, that they

can efficiently serve several large CPUs ... or several thousand terminals at once." ... "Users have indicated that they really don't have any idea what impact unlimited memory might have on their DP" (data processing) "applications and system designs, but they all agree that the whole way of using a computer ought to change when the storage of data is no longer a factor, and when the access speeds are as fast as the central processor, itself."⁴⁸

The conclusions for MT are obvious. The speed and, consequently, the cost of machine translation can be considerably reduced because all the dictionaries, syntactic rules, semantic rules, etc., even the processing programs can be stored in a part of a holographic memory. The problems which remain in the production of workable holographic memories, namely to make them erasable, are no real problems for an established MT system since it will be able to operate with a read-only memory. Changes and additions to the grammars which will be necessary because of neologisms that are introduced into a language can always be stored on disk and be read into the central memory before translation is performed.

In our opinion the real importance of such memories lies not so much in the increased speed with which data processing can be performed, but in the completely new methods of processing data and solving problems that such memories will permit.

The various models of human performance that have been constructed in the social sciences: sociology, economy, etc., normally reflect

in some way the way we are accustomed to talk about a subject matter. In linguistics we are accustomed to talk about sounds, morphemes, words, syntax, semantics, and even about context and pragmatics. Linguistic models, however abstract, in some way reflect this way of our talking about language. Thus, we have hierarchical phonological, syntactic and semantic "levels" in some models, and phonological, syntactic and semantic "components" in others. The effect of each component or level is twofold:

- a) it assigns to the data an interpretation according to its instructions, and
- b) it eliminates those interpretations which were well-formed according to the instructions of previous components but which are not well-formed according to its own.

Holographic memories may change our way of constructing models which is based on 19th century investigations and considerations (John Stuart Mill); according to those we assume one, or a few variables for the analysis of a complex phenomenon and keep all other factors invariant. The fact that we speak of several levels or components of "language", like phonetics, phonemics, morphology, lexicon, syntax, semantics, pragmatics, etc., has not been imposed on us because of the nature of language but because it is easier for us to treat individual phenomena by ignoring certain others, especially if those others are very complex and really not quite understood. With the capabilities of computers expanded in such a way, we can

finally begin to re-introduce the total approaches (ganzheitliche Methoden) by mentioning the conditions for all the variables that we know.

Now, what does that mean for machine translation? Since the projected access time of such memories, about 20 nano-seconds, is shorter than the time needed for a minimal basic computer operation, it means that such a memory can be read by several computers "simultaneously".

We could thus theoretically construct a machine translation system in which one computer performs dictionary analysis; one, word analysis; one, syntactic analysis, etc.: one computer for each component of the system. The intermediate output of each computer could immediately become input for the next "higher" computer, which again would give its output to the one "above" it, etc. At the same time, each computer could return the results of its own computation to the computer working directly "below" it in the hierarchy. Of course, we are not seriously proposing a system consisting of several computers to perform machine translation, but it is generally known that we can simulate on one computer the performance and capabilities of several computers. We can thus write programs which no longer analyze the data in a hierarchical "horizontal" fashion but in a hierarchical "vertical" fashion, which is the way the human brain operates during the understanding and production of sentences. Nobody would seriously assume that semantic interpretation is

performed over the output of some type of complete syntactic analysis represented by a tree with the root S. If that were so, strings of words like those underlined in the following sequence:

George said: After I had ... As usual he could not finish his sentence because Mary interrupted him.
could not be understood. And that we really understand sentences sequentially is clear from many observations, like the following: During a conversation between two people A and B, B explains some matter to A and hesitates, grasping for some word that eludes him; A provides the missing words and continues the sentence for B.

It is perfectly possible that mechanical translation performed with such "vertical" model will approximate "simultaneous translation"; that, while the system is still processing source language text on the input side, it is already producing target language translations on the output side.

I may be overly optimistic when I say that eventually the cost of machine translation may depend on two factors:


- a) the speed with which the source material to be translated can be read into the computer, and
- b) the speed with which the translation can be printed out by computer.

Holographic memories will provide us with the technical capabilities to construct models which are to a high degree representations of the reality which surrounds and which

affects us. They will provide us with the means to test our hypotheses, and, if necessary, to modify or even reject them. It is our task to be prepared for these possibilities by performing the necessary research, by collecting the necessary data. This task will not be easy; it will also be expensive; but eventually it will be rewarding, not just as an "intellectual exercise" but as a means to understand ourselves, to become an integrated part of a cybernetic society.

FOOTNOTES

- 1 There is no need to deal in this paper with certain claims according to which these disciplines are actually sciences.
- 2 Cf. I.M. Bocheński: Die zeitgenoessischen Denkmethoden, Dalp-Taschenbuecher, Bd. 304; Lehnen Verlag, Muenchen, 1959 (2).
- 3 "Die schematische Durchfuehrung eines vorgegebenen allgemeinen Verfahrens bietet (nach einigen Proben) offenbar einem Mathematiker kein besonderes Interesse. Wir koennen also die bemerkenswerte Tatsache feststellen, dass ein schoepferischer Mathematiker durch die spezifisch mathematische Leistung der Entwicklung einer allgemeinen Methode den durch diese Methode beherrschten Bereich gewissermassen mathematisch entwertet." Hans Hermes: Aufzaehlbarkeit, Entscheidbarkeit, Berechenbarkeit, Springer-Verlag, Berlin, 1961. The translation of this passage provided in the English translation of this book somehow does not reflect the author's statement.
- 4 Charles J. Fillmore: The Case for Case in: Universals in Linguistic Theory (eds.: Emmon Bach and Robert T. Harms), Holt, Rinehart and Winston, Inc., New York, 1968.
- 5 Cf. John Lyons: Introduction to Theoretical Linguistics, Cambridge University Press, Cambridge, 1968.
- 6 Personal communication with Reed Bates and Emmon Bach.
- 7 This principle is most often used in dictionary definitions where the meaning of the term defined is a common subset of the meaning of the words linked by "or" in the definiens.
- 8 Cf. Peters, P. Stanley and Robert W. Ritchie: "A Note on the Universal Base Hypothesis". Journal of Linguistics, Vol. 5, 1969 and "On the Generative Power of Transformational Grammars", to appear in Information Sciences. It is surprising how little impact their results have had on the linguistic community, so far. For the only exception - to my knowledge - cf. Emmon Bach: "Syntax since Aspects" (paper given at the Georgetown Roundtable Conference, March 1971).

- 9 Cf. the publications in the series: Transformation 20
and Discourse Analysis Papers, University of Pennsylvania.
- 10 Performed in spring 1967 and described in Lehmann- 21
Stachowitz, 1970 and Stachowitz, 1971.
- 11 Clearly, commands, requests and questions might be
reformulated as statements, as for example "Someone
orders that S", "Someone requests that S", "Some re-
quests a statement S(x)" such that the variable x is
replaced by a constant, where x represents the
questioned element in a sentence, as in "Where are
you going?" or by an affirmation, negation or modi-
fication of certainty or uncertainty as in "Will he
come?" "Yes". "No". "Maybe". "Possibly". "Maybe not".
etc. We do not have such a reformulation in mind.
We argue in the next paragraph of the text that a
sentence evokes an image of something. This "some- 22
thing" we want to call a state of affairs.
- 12 $j > i$ stands for: The point of time represented by
j is later in time than the point of time represent- 23
ed by i.
- 13 Lines which extend from a node represent predications
joined by logical and. 24
- 14 Clearly, this is a simplified version of the meaning
of "sell"(A,B,C,D). We ask the reader to accept our
definition.
- 15 Line 7, representing the property "physical object",
may be omitted from Figure 10 if we assume a meaning
rule component which contains the meaning rule "For
all x, if x is a car, then x is a physical object".
- 16 The value for n will have to be determined experiment- 25
ally.
- 17 If the equivalence relation between "sell" and "pay",
and "sell" and "pass" is not regarded as appropriate, 26
the sign for equivalence may be replaced by the sign
for inference.
- 18 Ternary relations are represented by a triangle,
binary relations by a cross-section of a lens:  27
- 19 Requirements c and d are possibly too strict to
represent actual speech production.

- 20 We are ignoring in this representation the various time relations as expressed in Figure 7.
- 21 A leaflet handed out by one of the University of Texas at Austin student groups in 1965 contained as the only statement: "Students should have a voice in decisions that effect them".. We assume that the system as well as the reader of this footnote automatically interprets "effect" as "affect"; the system would do this because it becomes "aware" of the absurdity of the statement as it stands, in contrast to the reader, who, normally, only becomes aware of it when the printing error is pointed out. (I owe this example to Professor Norman Martin of the University of Texas at Austin Philosophy Department.)
- 22 To be exact, the terms "referent", etc. only refer to the objects which are "involved" in states of affairs.
- 23 We are using the term "synonymous" as a substitute for the term "equi-iconic", which to define would be a further digression; for this term cf. Lehmann-Stachowitz, 1971b.
- 24 We exclude from this judgment the works of J.A. McConochie Simplicity and Complexity in Scientific Writing: A Computer Study of Engineering Textbooks. Ed.D. dissertation, Columbia University, 1969, and M.L. Gopnik, Linguistic Structures in Scientific Text, Ph.D. dissertation, University of Pennsylvania, 1969; both authors have arrived at results which seem to indicate that the language used in scientific texts is indeed a simpler subset of the regular language.
- 25 A stylistically correct translation would be "He goofed".
- 26 The actual percentage is lower since we considered only eight verbs of 15 verbs occurring in that passage. The text, though originally selected at random, is, of course, too short to count as a representative sample.
- 27 Wildhagen, Karl and Will Héraucourt, English-German German-English Dictionary, Vol. II German-English, Brandstetter Verlag, Wiesbaden, 1953, and Heinz Messinger: Langenscheidts Handwoerterbuch Deutsch-Englisch, Langenscheidt KG, Berlin, 1960 (2).

- 28 Such an assumption would, of course, mean that there are certain human beings which have learned and can express certain things in their language which no speaker of another language can learn and express. We regard this as impossible. 39 40
- 29 Gruber, Jeffrey S., Studies in Lexical Relations, Ph.D. dissertation, M.I.T., Cambridge, September, 1965. 41
- 30 For a comprehensive description, cf. S.R. Petrick, "Syntactic Analysis Requirements of Machine Translation", IBM T.J. Watson Research Center, Yorktown Heights, 1971. 42
- 31 Automatic Language Processing Advisory Committee 1966. Language and Machines: Computers in Translation and Linguistics. Publication 1416. Washington, D.C., National Academy of Sciences, National Research Council. 43
- 32 Petrick (op. cit.) 44
- 33 Immanuel Kants Logik, ein Handbuch zu Vorlesungen in: Immanuel Kant - Werke in zehn Baenden (herausgegeben von Wilhelm Weischedel), Band 5, Wissenschaftliche Buchgesellschaft, Darmstadt, 1968 (pocket book edition of the Kant-Studienausgabe). 45
- 34 Catford, K.C., A Linguistic Theory of Translation -- An Essay in Applied Linguistics, London, Oxford University Press, 1965, published as volume 8 in the series Language and Language Learning, R. Mackin and P.D. Stevens (eds.) and Louis Hjelmslev, Prolegomena to a Theory of Language, Baltimore, 1953. 46
- 35 This is necessary to insure the eventual well-formedness of the standard string. If more than one string should result, those which most closely correspond in their accidental features to those of the input sentence t can be selected.
- 36 We have taken these examples from: Langenscheidt's German-English dictionary, cf. footnote 27.
- 37 The comma has a stronger binding power than the period.
- 38 We use the arrow to refer to a binary relation which is nominalized.

- 39 An "and expression" attaches two lines to a node if it is not in the domain of another "and expression"; one branch, if it is.
- 40 The terms "a" and "the" have really several operation statements associated with them, interpreting such sentences as "A whale is a mammal", "The whale is a mammal", "The United States is a country", and "Whenever John rides a bus, he starts a fight with the conductor".
- 41 The NF expressions contain the semantic features of the interpreted terminals of the language, which permits the disambiguation of the predications upon x_2 .
- 42 We treat proper names as predications for two reasons: They may refer to more than one object; certain semantic features, like human, male, female, are normally associated with proper names, even size, as e.g. "Haenschen" (little John). In our system, the "proper names" of objects are represented by a subscript of x.
- 43 Hockett, Charles F., A Course in Modern Linguistics, The MacMillan Company, New York, 1960.
- 44 Such information includes semantic markers, distinguishers in the Katz-Fodor sense, area of provenience information, and stylistic information.
- 45 The list of English verbs - taken from Hornby, A.S., E.V. Gatenby and H. Wakefield, The Advanced Learner's Dictionary of Current English, Second Edition, Oxford University Press, London, 1963 - will appear as an appendix to Lehmann-Stachowitz, 1971b, the list of German verbs in Lehmann-Stachowitz, 1971a. The lists are alphabetically arranged according to the following criteria:
- a) verbs which are both transitive and intransitive,
 - b) verbs which are only transitive, and
 - c) verbs which are only intransitive.
- Each list is subdivided into two parts: one with one-word entries, the other with entries consisting of more than one word. The lists of English verbs which take prepositional objects, sorted alphabetically according to various criteria, has appeared as an appendix to Lehmann-Stachowitz 1970, vol. II.
- 46 The results will be published as derivational dictionaries of German and English, sorted according to affixes and stems.

- 47 This look-up procedure is actually more efficient than generating a glossary of the text and analyzing each word only once.
- 48 I would like to thank Bary Gold for calling my attention to this article and for discussing some of the technicalities and my conclusions with me.

APPENDIX

Lexicographic Work at the Linguistics Research Center

Lexicographic work at the Center is performed in five stages:

- a) the copying of lexical material from dictionaries, such as Wildhagen, cf. footnote 27, and Hornby, cf. footnote 45. Information pertaining to distinguishers and area of provenience is copied as given in the dictionaries;
- b) the addition of syntactic and semo-syntactic features to the obtained items according to the classification scheme given in the following pages;
- c) the establishment of equivalence relations or inference relations between syntactic and/or semo-syntactic features of all entries or large subsets of entries. (Features that can be predicted from the occurrence of other features need not occur in the dictionary; they can be introduced by means of redundancy rules during actual analysis);
- d) mechanical conversion of the established lists to the LRS dictionary format.
- e) conflation with the current LRS dictionaries which contain for each item a subscript pertaining to paradigmatic information and, in the cases of allomorphs, a subscript with the information on how to generate the

lemma. German nouns contain gender information; all adjectives contain information about their attributive and/or predicative use.

Stages a and b represent the descriptive phase; stage c, the interpretative phase. Lexicographic work on German and English adjectives, adverbs and nouns is in stage a, work on verbs and a subset of nouns in stage b. During stage c, we plan to introduce additional semantic features required because of the distinguishers associated with some lexical items. (Area of provenience information is handled as one of the accidental features of a lexical entry).

The following pages are a copy of the coding instructions for the LRC lexicographers. Note that some semo-syntactic features occur - to facilitate encoding - as syntactic features, cf. the subscript RL under nouns. During the conversion to LRS format, the features will receive their "correct" interpretation.

VERB FEATURES

TY	(VT, VR, VI, VTC, NP, NG* _E)
TS	(<u>HU</u> , <u>AL</u> , <u>PL</u> , <u>IN</u> , <u>AB</u> , <u>PO</u> , <u>AN</u> , BP, MS, CN, CO, NM, UN, QU, MA, <u>E</u> , P)
FS	(NP, IT, TH, MI, FT _E , GR _E , ICL, IMI _E , II* _G)
DS _G	(G, D, A)
OB	(G _G , D _G , A _G , O _E , all PREP's, TH, CL, MI, FT _E , GR _E , ICL, IMI _E , PAPL, II _G , BC, CM, NC, NA, AC, I)
TO	(<u>HU</u> , <u>AL</u> , <u>PL</u> , <u>IN</u> , <u>AB</u> , <u>PO</u> , <u>AN</u> , BP, MS, CN, CO, NM, UN, QU, MA, <u>E</u> , P, <u>R</u> , <u>RCC</u> , <u>IT</u>)
RA	(TIM, PNC, EXT, SIM, PRI, POST, LOC, DIR, ORN, MAN, MOD, CAUS, MSR, DEG, FRQ, PRB)
OA	(DOR)**

Subscript Definitions:

TY	= type of verb
TS	= type of subject; always code one of the underlined values for TS and TO; code values without underline only if subject or object is restricted to that value
FS	= form of subject
DS	= deep subject; mark only if English translation is nominative, e.g. <i>es friert mich</i> ; do not mark <i>es gehoert mir</i>
OB	= form of object; for 2 objects with +, the order is: O + PREP, O + CLS; PREP + PREP reverse order given in dictionary. English: Only one object: NP or refl. is not marked. Adjust G order to E order
TO	= type of object; code TO values even for object clauses and phrases
RA	= requires adverb; e.g. <i>put</i> RA(DIR). He put the book on the table, but *He put the book.
OA	= optional adverb

Value Definitions:

TY	{	VT	= takes at least one object which is not a reflexive pronoun
		VR	= takes at least one object which must be a reflexive pronoun

TY	{	VT, VR = takes at least two objects, one which is reflexive and one which is not a reflexive pronoun
		VI = intransitive
	{	VTC = takes a cognate object only; we define cognate object as the true cognate and all nouns subsumed under that term, e.g. <i>einen Tanz (Walzer, Regentanz) tanzen</i>
		NP = no passive
	{	NG = no progressive
TS	{	HU, AL, etc. as defined for noun features
		E = entia (any noun, PO or AB)
	{	P = plural
FS	{	NP = noun phrase; code only if another FS value is present
		IT = it, es; no TS information is required
	{	TH = that-clause
		MI = marked infinitive
	{	FT = for-to construction
	{	GR = gerund
	{	ICL = interrogative clause
	{	IMI = interrogative pronoun + marked infinitive
	{	II = interrogative pronoun + infinitive
DS	{	G = genitive
		D = dative
	{	A = accusative
OB	{	O = NP object
		Th, MI, etc. as defined above for FS
	{	CL = main clause
		PAPL = past participle
	{	BC = takes <i>be</i> + NP or ADJ (<i>think</i>)
	{	CM = takes optional <i>be</i> + NP or ADJ
	{	NA = takes NP or ADJ complement without <i>be</i>
	{	NC = takes NP complement without <i>be</i> (<i>elect</i>)
	{	AC = takes adjective complement without <i>be</i>
	{	I = infinitive
TO	{	HU, AL, etc. as defined for noun features
		E = entia (any noun, PO or AB)
	{	P = plural
	{	R = reflexive
	{	RCC = reciprocal (<i>aneinander geraten</i>)

RA	{	TIM = time
		PNC = punctual
		EXT = extensional
		SIM = simultaneous with point of reference
		PRI = prior to point of reference
		POST = later than point of reference
		LOC = location
		DIR = direction to
		ORN = direction from
		MAN = manner
		MOD = modality
		CAUS = causality
		MSR = measure
		DEG = degree
FRQ = frequency		
PRB = degree of certainty		
OA	{	DOR = direction or origin, i.e. adverb of directionali

Case ambiguity in German prepositions: 1 = acc., 2 = dat.
Example: AN1, AN2

- * Subscript E: relevant for English verbs only
- Subscript G: relevant for German verbs only

For the descriptors TS and TO, one of the underlined features must be coded for each verb; values without underline can be optionally added.

NOUN FEATURES

TY (HU, AL, PL, IN, AB, AN, PO, MA, BP, MS, CN, CO, NM,
 UN, QU)
 OB (all prepositions)
 TO (HU, AL, etc.)
 TA (ZU, CL, TH, DIR)
 SX (MA, FE)
 RL (WO; WOHIN; WARUM; OB; WIE; ALS)
 DF (VT, VI, A)
 FM (A)

Subscript Definitions:

TY = type of noun
 OB = object
 TO = type of object
 TA = takes attribute
 SX = sex
 RL = relative pronoun
 DF = derived from
 FM = form

Value Definitions:

TY

HU = human
 AL = animal
 PL = plant
 IN = inanimate
 AB = abstract
 AN = animate
 PO = physical object
 MA = machine which can perform human activities
 BP = body part
 MS = mass (homogenous, occurs without article in sg:
 milk, sand)
 CN = count
 CO = collective (components can be counted; can be used
 with *disperse* (group, herd, government))
 NM = proper name
 UN = unit (ADV/QU + ____; e.g. Meter, Jahr)
 QU = quantity (____ + (of) NP; e.g. group, glass, half,
 dozen, %)

In this set, one of the underlined values must be coded for each noun; values without underline are optionally added as appropriate.

TA { ZU = zu-infinitive
 CL = main clause
 TH = that-clause
 DIR = direction (e.g. Flucht nach Italien, zu den Indern)

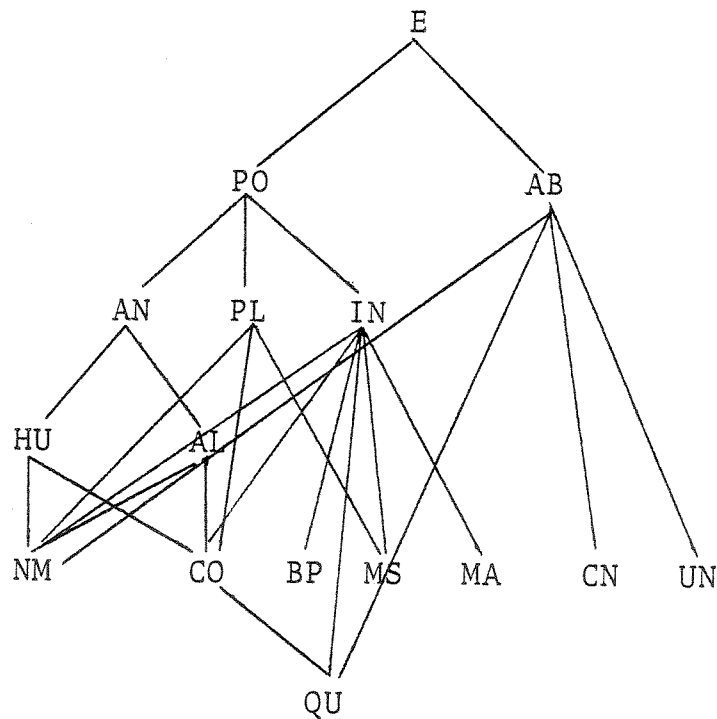
SX { MA = male
 FE = female

DF { VT = transitive verb
 VI = intransitive verb
 A = adjective

FM A = adjective (e.g. "Abtruennige(r) is coded as a noun: ABTRUENNIG TY(HU) FM(A))

Compounds:

BAUM + WOLL + FABRIKANT



TENTATIVE ADVERB FEATURES

TY (TIM, PNC, EXT, SIM, PRI, POST, LOC, DIR, ORN,
MAN, MOD, CAUS, MSR, DEG, FRQ, PRB)
MD (A, AV, V, N, S)

Subscript Definitions:

TY = type of adverb
MD = modifies

Value Definitions:

pe

TY	{	<u>TIM</u>	= time
		<u>PNC</u>	= punctual
		EXT	= extensional
		SIM	= simultaneous with point of reference
		PRI	= prior to point of reference
		POST	= later than point of reference
		<u>LOC</u>	= location
		<u>DIR</u>	= direction to
		<u>ORN</u>	= direction from
		MSN	= manner
		<u>MOD</u>	= modality
		<u>CAUS</u>	= causality
		<u>MSR</u>	= measure
		<u>DEG</u>	= degree
<u>FRQ</u>	= frequency		
<u>PRB</u>	= degree of certainty		

In this set, one of the underlined values must be coded for each adverb; values without underline are optionally added.

MD	{	A	= Adjective
		AV	= Adverb
		V	= Verb
		N	= Noun
		S	= Sentence

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The Current Status of Computer Hardware and Software as it Affects
the Development of High Quality Machine Translation

by

D. Walker

The Mitre Corporation

The developments in computer hardware and software over the past ten years have gone a substantial way toward satisfying the needs specified in the early '60's as prerequisites for effective machine translation programs. In particular, the storage capacities and processing speeds of current computers far exceed some of the stipulated requirements established during that period. Increases in sophistication of programming systems have paralleled hardware developments as evidenced in operating systems like OS for the IBM 360 and 370 series and Tenex for the PDP-10, to name only two. Compiler technology also has advanced markedly during the period, particularly as elaborations of the syntax-directed techniques introduced about ten years ago. Programming languages as well have increased in breadth, flexibility, and power, so that, although assembly language coding certainly still would reduce run-time, it no longer is a cost-effective alternative. As a result it seems reasonable to say that hardware and software considerations no longer constitute major obstacles to machine translation, at least according to strategies that are currently being pursued.

In spite of the conciseness--and, I believe, the essential correctness--of the foregoing summary statement, two observations need to be made before considering the implications I believe can be drawn from it. There are no systems for machine translation that I am aware of which use algorithms designed specifically to take advantage of recent computer capabilities. That is, the strategies currently pursued are those established in the early

1960's. While hardware and software may not be obstacles, it is not clear that they have been used to full advantage. However, looking at the other side of the issue, it also is not clear that new approaches, particularly those motivated by the recent concerns with semantic processing, might not result in specifications for machine architecture or programming that cannot be met by existing equipment and procedures.

Whatever importance is assigned to these observations, it is clear in any case that the problems of mechanical translation at this stage are primarily of two kinds, linguistic and algorithmic. That is, the responsibility for establishing hardware and software requirements depends on the design specifications for a mechanical translation system. And these specifications entail a knowledge of the grammars of the language involved, a strategy for analyzing them, and a procedure for relating the analyses. Until we can resolve these matters satisfactorily, any prescriptions for hardware and software are purely speculative.

In spite of these uncertainties, one class of computer capabilities should be stressed in this context both because of its potential use in the process of mechanical translation and because of the role it may play in grammar development and in the formulation of algorithms for linguistic analysis. I am referring to interactive capabilities that allow for on-line access to the computer. Although it is only recently that such man-machine systems have become cost-effective, it is still worth asking why machine-aided approaches to machine translation were not proposed and pursued in earlier years. Logically, they would seem easier to implement than

would fully automatic approaches. Again, I suspect that the problem here as before is the lack of understanding about grammar, linguistic analysis, and translation algorithms. However, there has been a substantial amount of work now with grammar testers and with systems for handling personal files, work that should be extended into the mechanical translation arena.

Equivalents and Explanations in Bilingual Dictionaries

by

L. Zgusta

Linguistics Research Center
The University of Texas at Austin

and

Department of Linguistics
The University of Illinois

EQUIVALENTS AND EXPLANATIONS IN BILINGUAL DICTIONARIES.¹

L. Zgusta

The task of the bilingual lexicographer is to find such lexical units in the target language as are equivalent to the lexical units of the source language, and to coordinate them. We call "lexical equivalent" a lexical unit of the target language which has the same lexical meaning as the respective lexical unit of the source language. The definitional requirement is that the identity should be absolute: the equivalent should have the same polysemy, the same stylistic value, etc. But such absolute equivalents are rather rare. In the majority of instances, the lexical meaning of the respective lexical unit of the target language corresponds only partly to that of its counterpart in the source language. If we wish to be very precise, we therefore speak about partial equivalents, but normally, we use the term "equivalent" knowing that the majority are partial.

Before starting the search for equivalents, we must compare the structures of the two languages in order to decide which grammatical categories will be considered reciprocal. This is easy in languages which have similar categories of lexical units, or, traditionally, similar parts of speech, e.g. there is no problem in deciding that the French equivalent of an English noun will first be sought among French nouns. But one must not stick to

this principle too strictly. For instance, German *Handarbeit* (subst.) has a good equivalent in English *hand-work* (subst.), but if it is used as a label on wares, the English equivalent is *hand-made*, because the English substantive denotes only the process, not its results. Usually, there are not only such isolated points of trouble, but also discrepancies rooted in the system. It is easy to decide that English substantives and adjectives will be considered equivalent to Czech substantives and adjectives, and to indicate pairs like Czech *nebe* : English *heaven*, Czech *nebeský* (adj.) : English *heavenly*, *celestial*, in a Czech-English dictionary. But there will also be pairs like Cz. *cihla* : Eng. *brick*, Cz. *cihlový* (adj.) : Eng. *brick* (as in a *brick wall*). The second pair of equivalents can be left without comment if the Czech user of the dictionary is supposed to have a fair knowledge of English. If this is not true, the entry of the second pair should contain an indication of how the equivalent is construed, e.g. by giving an example (*brick wall*). The example used here is easy to handle, but the real life of the lexicographer poses more difficult problems of this type. The main thing seems to be to see these discrepancies before one begins the concrete work and to decide on their solution in general, so that the individual instances are treated in a unified way in the whole dictionary.

The equivalent should be a real lexical unit of the target language, which occurs or can occur in real sentences. (We shall see later that this requirement must be limited, but it is valid for the majority of instances.) The usual procedure is for the lexicographer to collect a broad range of typical contexts in the source language in which the respective lexical unit occurs. (It goes without

saying
speaking
but
saying
then
target
equivalent
equivalent
solution
have
coverage
word
dictionary
prepare

G
cons
ference
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only
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so that
the
information
dictionary
German
the

If, on the other hand, the dictionary is intended to help the Chinese user produce German texts, it is necessary to indicate the difference between the two German partial equivalents, so that the user can make the right choice:

xu jia : "heiraten" ("to take in marriage"),
 "sich verheiraten" ("to get married")

(The English words in quotation marks symbolize an indication which would have the form of a gloss or of an explanation, either in German or in Chinese, in a real dictionary.)

A combination of the intentions mentioned requires, then, an entry of a form like

xu jia (von Frauen) : "heiraten" ("to take in marriage"), "sich verheiraten" ("to get married")

Another type of entry can be discussed with the help of the following example: *beinahe, fast* "almost, nearly" can be considered the German equivalent of Chinese *xian xie*. The Chinese contexts are roughly of the type: He nearly stumbled, fell, starved, died, knocked someone down, poisoned someone, etc. Let us, therefore, suppose that a Chinese-German dictionary is prepared which should also have some descriptive power. The entry then would have to contain a gloss stating the applicational restriction, for instance of the following form:

xian xie (bei negativen Ereignissen) "beinahe, fast"

In a Chinese-English dictionary, the entry could have the form

xian xie (referring to negative events) "almost,
nearly"

The applicational restriction could be stated in the form of an example or of some examples; the advantage of this method of presentation is that the information is more immediate, and, additionally, that it is less explicit than the gloss.

Let us now consider the English equivalents. They both have multiple meaning. If we accept Hornby's description of their meaning, we see that *almost* has two senses, viz.: (1) as in *He almost fell* (*almost* is replaceable by *nearly*), (2) as in *Almost no one believed her* (*almost* is not replaceable by *nearly*). The other equivalent, *nearly*, has (according to Hornby again) three senses, viz.: (1) as in *It is nearly 1 o'clock* (replaceable by *almost*), (2) as in *I have \$20, but that will not be nearly enough for my journey* (not replaceable), (3) as in *nearly related* (not replaceable).

If we quote *almost*, *nearly* together as equivalents of the Chinese lexical unit, they disambiguate each other, because every user will assume that only that sense applies which is common to both of them.

On the other hand, if we consider the German equivalents *beinahe*, *fast*, we find that they are as close synonyms as possible, because a difference in their meaning is almost imperceptible. If this is so, we can ask why both of them should be quoted. There are two arguments in favor of citing both. First, the indication of synonyms in the

target language helps the user to find various expressions we can use, if only for stylistic variation. And second, imperceptible as the difference is, there usually is some slight difference between the meaning of even such close synonyms, so that if both are indicated, the information is richer and the user is inspired to imagine yet other possible translations and synonyms. But in any event, even a large dictionary should not indicate too many synonyms of this type, and a small one can omit them.

In sum, we have discussed three types of indication of partial equivalents and synonyms:

(1) *heiraten; sich verheiraten* : a rule (semantic or grammatical) of the target language makes it predictable which of the two will be used;

(2) *almost, nearly* : both can be used, but only in those senses of their multiple meaning which overlap;

(3) *beinahe, fast* : either can be used, and the two taken together make the information somehow richer.

Although there are many borderline cases between these types, it is useful to know them; but it is above all types (2) and (3) which are difficult to distinguish. In type (1), it is preferable to put a semicolon between the two partial equivalents; in types (2) and (3), a comma is generally used.

Another type of problem can be illustrated by the following example. The German equivalent of Chinese *jīn* is *alt* "old". When the lexicographer analyzes the contexts of the source language, he will perceive that they belong roughly to the three following groups: (1) old edition of a book,

an old malady recurs, old society, old ideology, old dwelling, old job; (2) old method, old custom, old dream, old archive; (3) old equipment in industry, old material, old clothes. Unless the dictionary belongs to the smallest type, without any generative power in the target language, it will not be sufficient to state simply *jîn* : *alt*, but it will be felt necessary to give richer indications. It will also be essential to indicate that the German equivalent must not be taken in one of its senses as in *Er ist 10 Jahre alt* "He is ten years old". If the dictionary proceeds, as usual, by the indication of synonyms, one can suppose an entry of approximately the following type:

- jîn* : (1) "alt, früher, ehemalig" (that is, say, "old, former, previous");
 (2) "alt, schon lange bestehend" ("old, existing for a long time");
 (3) "alt, gebraucht, durch langen Gebrauch abgemacht" ("old, worn out by long use").

When we consider these indications, we see that an equivalent like *alt* "old" undoubtedly is a lexical unit which can be immediately inserted into a German sentence, whereas *schon lange bestehend* or *durch langen Gebrauch abgemacht* are somehow felt as non-minimal, as expansions of what the simple *alt* can convey. But these non-minimal expansions have the advantage that they, when we see them in isolation, give more information about the lexical meaning of the source language. Equivalents of the first type are usually called translational equivalents, those of the latter type explanatory or descriptive ones. Naturally there are many equivalents which combine both advantages; for instance *gebraucht* "used" seems to be, in the example given, a good translational equivalent with

great descriptive power.

Very frequently, it is necessary to give a translational equivalent and an explanatory one, or only an explanatory one. For instance, an English-French dictionary can hardly proceed by giving a simple equivalent of English *boyhood*, because there is no really good one. The explanatory equivalent would probably be something like *état de garçon*. But this cannot be inserted into sentences (or translation of sentences) like *In his boyhood, he . . .*. A more translational equivalent like *adolescence* or *jeunesse* is indicated. But these words are not restricted to male children in French, as the English word is. And so the entry would probably have to make a compromise and indicate, say,

boyhood : "adolescence, période de jeunesse"
(d'un garçon)

The explanatory equivalent has the advantage of being very general, because it is situated rather on the notional than on the purely linguistic level. If the user grasps what is indicated, and if he knows French well, he will be able to understand many different English sentences, and he will feel free to adapt his French translations as need be. In various contexts, he may say, "Au temps d'adolescence ...", "Dans sa période de jeunesse ...", "Quand il était jeune garçon ...", but possibly and simply also "Quand il était jeune ...", etc.

The explanatory equivalent works particularly well if the target language is the user's native one, because it makes considerable demands on his knowledge. The advantage of the translational equivalent is that it is purely linguistic and that it offers the user directly an expression that can be

used. But apart from the fact that it frequently conveys less information, the translational equivalent can cause a good deal of trouble to the lexicographer. Let us discuss an example. We said that Chinese *jīn* has a good equivalent in German *alt* "old". The subsequent discussion has shown that the lexicographer will probably feel it necessary to add some further equivalents. This can be pushed too far. For instance, the lexicographer may find Chinese contexts in which the best translation would be "preceding, foregone, past, obsolete"; there will be contexts in which "ancient, antique, archaic" seem to fit well, etc. But to indicate all this would mean that the bilingual dictionary would grow into a synonymic dictionary of the target language. The lexicographer's task is to indicate the most general translational equivalents which have a broad range of application. And so the explanatory equivalent and the translational one are not so much opposed as one would think: they both act as representatives of groups of synonyms and near-synonyms, out of which the user may choose the most suitable one (if he knows them, or if he is able to use a monoglot or a synonymic dictionary of the target language). The difference between the two types is that the translational equivalent is always a possible choice for application in a sentence and sometimes the best one.

But while the lexicographer tries to indicate the best equivalents, he frequently is faced with the fact that he does not find any. For instance, it is hard to find an English equivalent for the Russian preposition *po* in such everyday expressions as Russian *po prībytii ego* "on his arrival", *po ukhode ego* "after he had gone, after his departure", *po okončanii* "as soon as he had finished". Grammatical information must be supplied instead of lexical equivalence, or in combination with it.

The so-called culture-bound words pose another problem, because they frequently have no lexical equivalent in the target language. There are basically three types of solution: (a) The lexicographer may try to create a translational equivalent by borrowing the respective word into the target language, frequently in a phonemically adapted form. (b) He may try to create a translational equivalent by coining a loan-translation, or by coining a new expression in the target language. (c) He may try to find an explanatory equivalent in the target language (with the eventual hope that it may become a translational one, if used frequently in future). If we take examples from a less known language, the three types are:

- (a) Ossetic *alam* : Eng. "alam" (borrowing)
- (b) Oss. *ironvandag* : "Ossetic way" (new coinage by loan-translation)
- (c) Oss. *ziw* : "collective help" (explanatory equivalent)

It is clear that the explanatory equivalent (c) gives the richest information; types (a) and (b) can be chosen only if it is expected that the respective words will have a high frequency in translated texts (where there will be explanatory notes, etc.). But for a real understanding, we need an explanation in all three types, for instance:

- (a) *alam* : "alam" (fruit and candy bound on a twig and carried by mounted participants at a funeral feast)
- (b) *ironvandag* : "Ossetic way" (an ancient Ossetic funeral ritual)
- (c) *ziw* : "collective help" (socially expected help, above all in agricultural work, organized within or by a group of people)

It depends on the lexicographer's decision (and this, in its turn, on the type and purpose of the dictionary), whether his explanations will be minimal (as here, type b), or whether they will verge on the encyclopedic types a, c); but they should have a uniform style through the whole dictionary.

The difference between what we call an explanatory (or descriptive) equivalent and an explanation is that the explanatory equivalent tends to be similar to a translational equivalent. If stabilized and accepted into the language, it can become a lexical unit of the target language. But an explanation tends to be very similar to a lexicographic definition (or is even identical with it) as used in monoglot dictionaries, and usually cannot aspire to becoming a lexical unit. But there is no need, I think, to stress that there are a great number of borderline cases.

And so we see that the bilingual lexicographer works basically with translational equivalents, synonyms, mutually disambiguating synonyms, mutually complementing synonyms, explanatory equivalents, and explanations. All of them have the purpose of informing the user about the meaning of the lexical unit of the source language, of supplying him with lexical units of the target language which can be used in source-language sentences, and of inducing in him a recollection of other suitable, near-synonymic lexical units of the source language even if they are not directly indicated.

A good entry of a bilingual dictionary also needs information usually supplied by illustrative examples (quoted or coined), by glosses, labels and similar means; but a discussion of this type of information would require another paper.

OTNOTE

This article is based on a section of my *Manual of Lexicography* (forthcoming). I wrote that book in cooperation with several colleagues who supplied material and examples from various languages. Full acknowledgment of those examples will be found in the book itself.

The Shape of the Dictionary
For Mechanical Translation Purposes

by
L. Zgusta

Linguistics Research Center
The University of Texas at Austin
and
Department of Linguistics
The University of Illinois

THE SHAPE OF THE DICTIONARY FOR MECHANICAL TRANSLATION PURPOSES.¹

L. Zgusta

A dictionary of the type we have in mind here should contain the lexical units of the source language, selected according to the needs of the type of texts to be translated. Lexical equivalents of the target language should be coordinated with these lexical units in such a way that the choice is as precise and as automatic as possible. Great difficulties are caused in this task not only by the polysemy and homonymy of the lexical units of the source language, but also by the fact that the equivalents usually cannot be coordinated in a one-to-one way. We call "lexical equivalent" a lexical unit of the target language which has the same lexical meaning as the respective lexical unit of the source language; that means the equivalent should have the same polysemy, the same stylistic value, etc., as the lexical unit of the source language. However, this is seldom the case, and, consequently, more than one equivalent is often needed to cover the lexical meaning of the source word. We should, then, make the distinction between absolute equivalents, which comply with the definitional requirement of a one-to-one correlation in lexical meaning, and partial equivalents; but general usage allows us to

¹ Work on this article was performed at the Linguistics Research Center, University of Texas at Austin, Texas, under Rome Air Development Center contract. The paper profited from a discussion of its contents with M. Kay and R. Stachowitz.

peak about equivalents when it is usually the partial
ies we have in mind.

The present article is not primarily concerned with
the problem of (partial) equivalents, their choice, their
actual disambiguation and the delimitation of their appli-
cability in an entry.² This article concentrates on prob-
lems of choice from among more than one (partial) equi-
valent within the entry of a lexical unit of the source
language. The point of view taken here is that, on the
one hand, the more we can rely on simple formal indica-
tions of the source language the better, but that, on the
other hand, such simple formal indications do not always
exist; and that one of the cardinal difficulties with which
we have to cope is that the selection of a suitable (par-
tial) equivalent is to be made by an agent which is by far
less imaginative than the human mind.

Semantic difference in the source language (and, there-
fore, the necessity of a certain selection among the partial
equivalents) is frequently indicated by some difference in
form. The situation is rather simple if the difference of
form is easy to detect. It is easy to change an entry of
the type

German *in* → English *in, into*

into the following shape

German *in + Dat.* → English *in*

in + Acc. → English *into*

² See "Equivalents and Explanations in Bilingual Dictionaries",
to be published in

Since we envisage, for the moment, only basic translational needs, this form of the entry should suffice to guarantee a good selection of the equivalent in sentences like German *in dem Wald gehen* - English *to walk in the wood*, and German *in den Wald gehen* - English *to walk into the wood*, that is, given the ability to recognize which German substantive is governed by *in* and whether it is dative or accusative.

The example just discussed is one of the simplest ones. It can be said that the recognition of semantic difference and the choice of the equivalent entailed by it are not difficult if the semantic difference is indicated by a clear morphological difference.

The formal distinction, however, does not necessarily have to be a morphological one; the main thing is that the distinction should be clear in itself and non-ambiguous. For instance, it should be easy to discern the polysemy of German *handgreiflich*, because in one of its senses, it is used exclusively with the forms of *werden*: *handgreiflich werden* "to use physical force". In its other sense, it is used with *machen*, *sein* and a few other verbs: *handgreiflich machen* "to make available", *handgreiflich sein* "to be available".

Perhaps more complicated is the following type of case. If we simplify the multiple meaning of German *ableiten*, we can construct an entry of the following type:

German *ableiten etwas* → English *to lead away*

ableiten etwas von etwas → *to derive*

s in German *den Strom ableiten* - English *to lead the current away*, German *die Adjektive aus den Substantiven ableiten*, English *to derive adjectives from substantives*.) It would seem that it should not be too difficult to distinguish the two types of reactions quite automatically, and make the choice accordingly. The next example will, however, be more complicated.

The simplest way to construct the entry of German *beraten* seems to be

German <i>beraten jemanden</i>	→ Eng. <i>to advise</i>
<i>beraten etwas</i>	→ <i>to deliberate (upon)</i>
<i>beraten ueber etwas</i>	→ <i>to deliberate (upon)</i>

The last two German reactions are different in their grammatical form, but there is no semantic difference. On the other hand, there is no grammatical difference between the two first reactions, but there is a semantic difference which entails a different choice of English equivalent. The abstract expression of the two reactions in the lexicographic entry *jemanden :: etwas*) is rather simple, and no human user of

a dictionary could have difficulty with it. Still, for the purpose of automatic recognition and choice, the presence of this entry in the dictionary entails the necessity of indicating in the lemma of each substantive whether it belongs to the category "*jemand*" or "*etwas*". This should not be too difficult a task; let us, however, discuss yet another type of situation.

The entry of German *abhalten* can be constructed in the following way:

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German *abhalten* (1) *jemanden von sich* → *to hold off*

(2) *jemanden von etwas* → *to hinder,*
prevent

(3) *etwas* → (a) *to keep out*
 → (b) *to hold*

We see that within one rection, (3), there are two choices (a), (b) which are semantically governed: (a) is chosen if the object (represented by *etwas*) is, e.g., *Wasser, Naesse, Zugluft, Regen*; (b) is chosen if the object is, e.g., *Sitzung, Wahlen, Gericht*, etc.

Another example of this type is German *auslegen*. One of its rections (the most frequent one) is *auslegen etwas*. The respective part of the entry would have to have a form similar to the following one:

auslegen (1) *etwas* (a) [*im Ladenfenster*] → *to display*
 (b) [*Geld*] → *to pay provisionally*
 (c) [*Texte*] → *to interpret*

In a case like this, the really important indication is the one contained in brackets. And as every lexicographer knows, to construct these restrictive (or semantic) glosses (as they are frequently called in lexicographic theory) belongs among the most difficult tasks because it is hard to find the real limits of the restriction. This is, however, a purely lexicographic task which every good lexicographer is accustomed to coping with. It is not without significance that in the compilation of a dictionary of a living language, it is nearly always native informants who are used for this task. But in the

situation envisaged in this article we try to count with an automatic choice from among the equivalents, and this causes much trouble. The reason is that every human user of a dictionary will immediately understand that an indication like [*im Ladenfenster*] is simply an example since goods can be displayed also on stands within a shop or in the market, and so on. Not only that; the human user will also understand that the restrictive gloss [*im Ladenfenster*] is, at the same time, the representative of a certain type of situation, since one can speak about somebody displaying his goods without mentioning where and how, and choice (a) is then entailed. Therefore, this part of the entry could also have the following form:

auslegen (1) *etwas* (a) [*Waren*] → *to display*

This restrictive gloss would have other difficulties of its own. We mention it to show that restrictive glosses have to be chosen from among various possibilities inherent in the facts of language.

In the same way, [*Geld*] is both an example and the representative of a class of synonyms, near-synonyms, and semantically related words (*eine Summe auslegen*). In (c), [*Texte*] would seem to be simply the hierarchically higher notion (*Oberbegriff*) comprising singularia like Bible, Homer, 6th Amendment to the Constitution, etc., or any text(s); but in reality, it must be understood as a representative of other expressions, too. There is no need to go as far as poetical language to have a sentence like *Falls die Datenverarbeitungsmaschine den gestrigen Verkauf von Papieren auf der New Yorker Boerse falsch auslegt, dann . . .*

The difficulty of this problem is obvious. One of the easiest answers would be that we should increase the number of concrete examples quoted in the restrictive glosses. For instance, one could imagine the following form for the entry quoted above:

abhalten (3) *etwas* (a) [*Wasser, Naesse, Fluessigkeiten, Regen, Hagel, Wind, Zugluft*] →
to keep out

The increase in the number of concrete examples in the restrictive glosses would be an enormous gain; but we should count with dozens and perhaps hundreds of them in one gloss. It does not seem to me, however, that the more or less exhaustive enumeration of examples could be a real solution. Let us discuss the following example. That part of the entry of German *verjuengen* which is concerned with technical terminology could have the following form:

verjuengen (1) *etwas* (a) [*Maßstab*] → to reduce
(b) [*in biology*]³ to rejuvenate

The restrictive gloss pertinent to (a) could be expanded by an enumeration of examples. I cannot, however, see that choice (b) could be governed by the indication of concrete examples. First, because the area of objects of rejuvenation, attempted or real, is rather vast; still, one can imagine a restrictive gloss with perhaps hundreds of examples, e.g. [*Gewebe, ...Knochen, ...Zellen, ...Greise, ...Reflexfähigkeit, ...Regenerationsfähigkeit, ...etc.*]. But the second difficulty seems to be more grave. The area of objects of rejuvenation is not only vast; it is always getting more vast, and the very

³ We do not take into consideration that the theory of lexicography usually distinguishes indications of this type from the restrictive (or semantic) glosses. Indications of this type are usually called labels.

purpose of science is to render it more vast. Consequently, one must take into consideration that after we have established our set of examples in the restrictive gloss, there will be biological texts reporting new investigations, discoveries, etc., concerned with new objects not stated among our examples; which would make a correct choice of the equivalent impossible. And since the main purpose of machine translation is to translate recent reports on new discoveries, etc. quickly, we can conclude that the choice of the equivalent cannot be based on an exhaustive enumeration of contextual examples (understood as key words), lest we block our way to the very goal we are trying to reach.

It seems that what is needed is a classification of all entry-words selected for the future dictionary into classes constituted by the restrictive glosses and the semantic criteria contained in them. For instance, since the correct choice of an equivalent in some entries depends on whether the object is a person or not, this category should be indicated in the lemma of each substantival entry-word; since a correct choice in another entry depends on whether the context is a biological one or not, the pertinent indication should be a part of the lemma of the respective entry-words. This should be done with all the restrictive glosses involved in the corpus of entries. It would require further researches, but it seems that the number of different restrictive glosses could be slightly reduced if they had, when possible, the form of hierarchically higher notions (*Oberbegriffe*), or if they indicated terminological areas (such as "biology", "chemistry", etc.). In this way, though the automatic procedure would certainly not command an abstractive ability of its own, it would possess a rich repertory of coherently constructed criteria for the necessary choices,

applicable not to a broader semantic range of texts but at least to a much larger corpus of them than that on which the original investigations were based.

What has been discussed up to now is certainly no panacea.⁴ There will be bases which will resist a generalization. For instance, another rection of German *auslegen* (not mentioned above) is *auslegen* (2) *etwas mit etwas*. In German, contexts characterized by this formal feature are not only clearly differentiated from the contexts of the type *auslegen* (1) *etwas*, but they also form a unified group, with a unified if general meaning. But there is no general equivalent in English, and the choice of the partial ones is governed by the object of the action. Consequently, we have to imagine that this part of the entry could have a form similar to the following one:

auslegen (2) *etwas mit etwas* (a) [Teppiche] → to cover
with (carpets),
to carpet
(b) [Zement] → to line with
(cement)
(c) [Elfenbein] → to inlay,
encrust with
(ivory)

On the other hand, the semantic classification is necessary even in cases where one would not immediately suspect it. We

⁴ The method proposed here has some similarity to the method using so-called "semantic parameters". (Cf., e.g. Ubin, expression of the parameter *Magn* in Russian, in: *Mašinuyj perevod i prikladnaja lingvistika*, 11, 1969, p. 60 ff.; Šaljapina, Ways of expressing semantic parameters in English, *ibid.* p. 106 ff.) The difference, however, is that whereas the search for semantic parameters leads to establishing more or less purely notional frameworks and constructions, the present approach tries to remain as close to really occurring contexts as possible.

have stated above that it is relatively easy to find a solution for those cases in which a difference in meaning is indicated by a difference in form, preferably in morphology. The dictionary can make use of such differences. Sometimes, the morphological distinction alone is sufficient to indicate the difference in meaning. For instance, the series of German forms *die, der, der, die Diaet, die, der, den, die Diaeten* can be seen as a normal paradigm of a feminine substantive. There is, however, the semantic difference that the forms of the singular require the English equivalent "diet, regimen", whereas those of the plural require the equivalent "daily allowances". Such a situation is easy to solve. Probably every lexicographer will take *Diaet* "diet" as *singulare tantum*, and *Diaeten* "daily allowances" as another word, a *plurale tantum*; and such a solution is undoubtedly even more practical for an automatic procedure.

But not all cases are as beautifully clear-cut as this. A morphological difference is sometimes of only partial value. For instance, if we try to find an English equivalent for German *Ort*, in its application as a technical term, we can arrive at the following result:

<i>Ort</i>	(1) [in geography]	→	<i>place</i>
	(2) [in geometry]	→	<i>locus</i>

It is usually maintained that the two are sufficiently differentiated by the fact that *Ort* (1) [geogr.] has the plural *Orte*, whereas *Ort* (2) [geom.] has the plural *Oerter*. This morphological distinction is fully sufficient for the plural; if we had to deal with *pluralia tantum*, this part of the reduced entry could have the form:

<i>Orte</i>	→	<i>places</i>
<i>Oerter</i>	→	<i>loci</i>

Since the singular is not morphologically differentiated, a semantic (that is, contextual) differentiation is necessary.

Cases like this are rather treacherous. Dictionaries are normally built on the principle that the form of the source language in which the entry-word is indicated and to which the equivalent is coordinated (the so-called canonical form) is a representative of the whole paradigm of the entry-word, that is, if the source language happens to be a language with paradigms. Therefore, before the inclusion of a word, with its equivalent(s), into the dictionary, its whole paradigm should be checked, and the more important semantic peculiarities of its single forms should be duly noted.

If polysemy needs semantic differentiation by the context, we can expect that the same will be true of homonymy (overlapping as the two notions are). The situation is basically identical, so there is no need to discuss special examples. There is, however, a special type of situation, in which a homonymous pair or polysemous meanings are differentiated by the form. German *Abrede* generally has the meaning of "understanding, agreement"; but the set expression *in Abrede stellen* means "to disavow, to dispute". This expression being rather frequent, the reduced entry could have a form like:

<i>Abrede</i>	(1)	→ understanding, agreement
	(2)	<i>in Abrede stellen</i> → to disavow, to dispute ⁷

This brings us to a topic which I shall mention only briefly, namely the fact that there are combinations of words which are set, which have a unified meaning, and which even

⁷ This type overlaps with the type of *handgreiflich werden* as discussed above.

function as a lexical unit of a language.⁸ There are many various types of them. A dictionary of the type under consideration here, prepared for coping with texts of a limited range only, will hardly select many colorful idioms such as *Das Hasenpanier ergreifen* "To fly away". But it will have to list frequently occurring set expressions like *in Abrede stellen*, particularly when their meaning is not predictable from that of their individual parts. Also, a dictionary of our type will probably select many technical terms which consist of more than one word. The technical terminology of any science gives many examples of the type *leichte Infanterie*, *schwere Infanterie*, etc. The situation in German is particularly easy, because a large number of such terminological coinages have the form of compound word, cf. *Dampflokomotive* "steam engine". Still, there is no predictable regularity in this, cf.

Sauerkraut "pickled cabbage", but
saure Gurken "pickled cucumber",

so that the lexicographer has to check the whole semantic area carefully. It will also be necessary to have the productive parts of compound words listed in the dictionary as entries of their own if they have a regular effect on the meaning of the whole compound. With real compound words, this is not too frequently the case, but affixes and elements which approach the status of affixes can be treated this way. For instance, German *ur-* → "proto-"; *pseudo-* → English "pseudo-", etc. Such an indication has the big advantage that it is so to say productive: it can take care of newly coined expressions (assuming they are coined regularly), unknown at the moment of the compila-

⁸ On these, see my "Multiword Lexical Units", linguistic studies presented to A. Martinet I, p. 578 ff.

tion of the dictionary.

There are some points which may deserve to be mentioned. Many a dictionary tends to forget that we find multiword lexical units not only among the denotative words. But the inclusion into the dictionary of expressions like German *ab und zu* "from time to time", or German *auf und ab* "up and down" is useful. And again, we will have to put into the dictionary indications of how to discern polysemy. Consider the difference between German *von* (*heute, nun, jetzt, gestern*, etc.) *ab*, English "from (today, now, yesterday, etc.) onwards", and German *vom Bahnhof ab* (*geht die Straße bergab*) "the street begins to go downhill at the station". Therefore, a strongly reduced part of the entry should have the form:

von *ab* (1) [Zeitangaben] → from ... onwards
(2) [Ortsangaben] → at, beyond

A particularly obnoxious type of set expressions are those which allow a certain variation. For instance, German *es* (*tut, schadet, macht*) *nichts* has a good English equivalent in "it does not matter". It would seem that there is no complication in this. Let us, however, consider the following sentences: *Es tut nichts*. "It does not matter". -- *Er tut nichts*. "He is doing nothing". This shows us that a set expression may have parts which allow some variation, but again, it has parts that do not. Therefore, a good dictionary will have to contain indications of the following type:

es (*tut, schadet, macht*) (*nichts, wenig*) →
→ it does not matter.

It can be said that the most difficult problem will be how to guarantee that an automatic device will make the correct choice from among the partial equivalents of the target language. This task is so difficult in itself that we should not make it even more difficult by indicating too many (partial) equivalents of the target language. Let us consider some entries discussed above. An entry of the type

auslegen (2) *etwas mit etwas*

(a) [Teppiche] → "to cover with (carpets),
to carpet"

(c) [Elfenbein] → "to inlay, encrust with
(ivory)"

does not strike us as unusual. The verbs *to inlay* and *to encrust* are synonymous for all practical purposes. Every human user of a dictionary is accustomed to understanding an indication like this, so that he is free to use either one or another synonym.

On the other hand, if we take a part of the entry of *erledigen* discussed above

erledigen (1) *etwas* → *to finish, arrange, settle*

we see that it has the same form, but the difference is in the fact that the English verbs are rather mere near-synonyms than full synonyms. Again, a human user is accustomed to seeing entries of this type in any dictionary. Some dictionaries try to distinguish the synonyms from the near-synonyms by using commas in the first and semicolons in the second case: *to inlay, encrust with*, but *to finish; (to) arrange; (to) settle*. It is, however, extremely difficult to make the distinction in a systematic way, there being

probably more borderline cases than clear-cut ones. And then again, a human user does not need a typographical indication of the distinction so badly: if he is a native speaker of the target language, he knows the distinction anyhow; if he is a speaker of the source language, he may make an error in his choice, but an error which will not be too grave, and with growing knowledge of the target language, he will also acquire the "feeling" for when to use one or another of the near-synonyms.

This is how bilingual dictionaries, particularly the smaller ones, operate: they rely on the abilities and knowledge of the human user. The indications of such dictionaries very frequently have the main purpose of triggering in the human user thinking and imaginative processes which make him recollect words and expressions not immediately indicated in the dictionary.⁹ We cannot rely on all these abilities when we construct a dictionary for mechanical use. Therefore, the rule should be that there should be no unspecified indication of synonyms as partial equivalents: if there is more than one partial equivalent, they should be accompanied by the necessary restrictive glosses which will show which to choose. If both equivalents can really be used unrestrictedly, i.e. if they are fully synonymous, it is possible to indicate only one of them (preferably the more frequently occurring one) or to indicate the possibility of free variation, e.g. for stylistic purposes.

⁹ This statement is focussed particularly on bilingual dictionaries of living languages for general use. Large philological dictionaries of dead languages are of a different type: they frequently contain an enormous mass of quoted contexts with concrete translations and thus make the information given quite factual and concrete. The human user, however, will still tend to go beyond the indications of this dictionary, since, after all, the indications of a dictionary and an adroit translation of a text are always two things.

To prepare a dictionary which will reach this degree of explicitness and accuracy is an extremely difficult task. Moreover, I am afraid that even when all this is done, there will still occur situations in which the automatic device will not be able to make a choice. This may occur, for instance, in any text where the relevant context is not close to the passage which needs disambiguation. It would seem that in such a situation no random choice should be made but both (or all) possible equivalents should be printed in the output with a sign showing their mutual complementarity.

A similar but much worse situation will occur when the automatic device is faced with a neologism, i.e. with a genuinely new expression or with an "old" expression used with a new sense. To discuss this difficulty, however, is quite a different task, because an attempt at the solution of this problem would require an investigation of the regularity of new coinages. For instance, new terminological coinages tend to have a high degree of regularity. In any case, a discussion of these problems must be reserved for another occasion.

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