RESEARCH ON NATURAL-LANGUAGE PROCESSING AT SRI

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CONTENTS

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A. Overview

Research on natural-language processing at SRI spans a broad spectrum of activity. Two of our major current efforts are a pair of research projects under the sponsorship of the Defense Advanced Research Projects Agency. The TEAM project is intended to provide natural-language access to large databases via systems that are easily adaptable to a wide range of new application domains. The KLAUS project is a longer-range effort to address basic research problems in natural-language semantics, commonsense reasoning, and the pragmatics of natural-language communication. These two projects share a common core-language-processing system called DIALOGIC.

DIALOGIC also plays an important role in two other projects: research on providing natural-language access to text (funded by the National Library of Medicine), and research on the development of formal grammars (sponsored by National Science Foundation). An additional project on medical applications, MEDINQUIRY (sponsored by the National Cancer Institute), uses a semantic/pragmatic grammar as the basis for a natural-language interface to medical data. We are also conducting research on natural-language generation (sponsored by the National Science Foundation) and are engaged in two small pilot projects concerned with information management and lexicology.

A brief description of each of these projects follows. The principal investigators--whose names are underlined--may be contacted for further information about the projects. Because DIALOGIC is a core component of several systems, it is described separately.

B. DIALOGIC

Barbara Grosz, Norman Haas, Jerry Hobbs, Paul Martin, Robert Moore, Jane Robinson, Stanley Rosenschein

The DIALOGIC system translates English sentences into representations of their literal meaning in the context of an utterance. These representations, which we call "logical forms," are intended to constitute a purely formal language that is as close as possible to the structure of natural-language, while providing the semantic compositionality necessary for meaning-dependent computational processing. The system is divided into the following modules: (1) the DIAGRAM grammar; (2) a set of semantic translators; (3) a set of basic semantic functions; (4) a scoping algorithm (for quantifiers and sentence operators); (5) a set of basic pragmatic functions. These are all coordinated by the DIAMOND executive system, which provides the grammar definition facility as well as the control for parsing English sentences and translating them into logical-form expressions.

1. DIAGRAM

DIAGRAM is a general grammar of English, expressed in the form of an augmented phrase-structure grammar with rule procedures that allow phrases to inherit attributes from their constituents and to acquire attributes from the larger phrases in which they are constituents. These attributes are used to impose context-sensitive constraints upon the acceptance of an analysis of an utterance. DIAGRAM produces an "annotated parse tree" that is then passed to the other components of the DIALOGIC system. The grammar currently includes rules for all common sentence types, complex auxiliaries and modals, complex noun phrases, nominalized sentences, all the common quantifiers, relative clauses, verbs with sentential complements, comparative and measure expressions, and subordinate clauses and other adverbial modifiers. It does not include rules for conjunctions. A detailed description of

DIAGRAM is contained in (Robinson, 1980).

2. Translators

Each rule in DIAGRAM has an associated semantic translator. The translator specifies how the various constituents of a phrase are to be combined to form an interpretation of the whole phrase. It states the predicate-argument structures that correspond to the grammatical construction or, more generally, the operator-operand structures. Following the syntactic analysis of an utterance, a sequence of translators is invoked to build the logical form that corresponds to a literal interpretation of the utterance in context. In addition, the translators determine the syntactic constraints on and preferences for coreference and noncoreference of noun phrases, especially pronouns (Hobbs, 1976). To insulate changes in the grammar from changes in logical form, the construction of the latter is isolated from the translator procedures by calls on basic semantic functions (Konolige, 1979).

3. Basic Semantic Functions

The actual construction of a logical form is done by the basic semantic functions in two phases: (1) logical form fragments are attached to the parse tree by the basic semantic functions; (2) the final logical form is assembled from these by the scoping algorithm. (Moore, 1981b, contains an initial specification of the particular forms being constructed.) The fragments of logical form are assigned only to certain nodes in the parse tree. These fragments encode that portion of the interpretation of an utterance that can be determined from its component structure (essentially the predicate-argument structure). The basic semantic functions also leave markers on the parse tree to indicate such things as the type of quantifier or determiner associated with a noun phrase. These markers are used by the scoping algorithm to determine the final logical form for the utterance. (Note that the logical-form fragments and markers left by the basic semantic functions may be viewed as further annotations to the parse tree.)

4. Scoping of Quantifiers and Other Sentential Operators

The scoping algorithm is designed to collect the logical-form fragments from the parse tree and produce the possible scopings of quantifiers and other scoped operators. The scoping algorithm used in DIALOGIC (adapted from that in Hendrix, 1978) produces all the scopings that do not violate the hard rules of English scoping, and then ranks them according to a score computed by a set of specialist critics. Each critic is a function that produces a score for some aspect of the conflicting rules of quantification in English; e.g., the left-right scope critic lowers the score of scopings that involve permuting the left-outermost default ordering of quantifiers. All critics receive equal weight in the present implementation, but the design of the system does allow for differential weighting.

5. Basic Pragmatic Functions

Basic pragmatic functions are intended to fulfill several roles in DIALOGIC, all concerned with certain kinds of indeterminacies in logical form whose resolution requires pragmatic information. The three primary uses of basic pragmatic functions in the current system are (1) to provide a context-specific interpretation of certain terms that have only vague meanings in themselves (e.g., prepositions like "of" and "in," and inherently vague verbs like "have"); (2) to determine the specific relationship underlying any given noun-noun combination; and, (3) to identify the referents of pronouns. In the near future we expect to have pragmatic functions that will handle a limited range of metonymy (e.g., the use of "blondes" to mean "people with blonde hair"). Only a small core of pragmatic functions is currently implemented.

C. KLAUS

Doug Appelt, Barbara Grosz, Norman Haas, Jerry Hobbs, Paul Martin, Robert Moore, Jane Robinson, Stanley Rosenschein, Stuart Shieber, Mark Stickel, David Warren

The KLAUS project addresses a number of fundamental problems in commonsense reasoning and natural-language communication. The experimental vehicle for this research is an evolving system designed to interpret assertions and questions expressed in natural language, and to answer the questions by means of logical inferences drawn from the content of the assertions (hence the name KLAUS: Knowledge Learning and Using System). An initial version of the system, NANOKLAUS, implemented using a pragmatic/semantic grammar is described in (Haas and Hendrix, 1980); MICROKLAUS, a new version of the system based on DIALOGIC, is now under development. The research issues we are currently examining in the project are described below.

1. Semantics of Natural Language

It is often assumed in computational linguistics that the major problem of semantics is to decode the mapping between the syntactic constituents of a sentence and the arguments of the predicate expressed by the main verb of the sentence. This presupposes that all sentences have a simple predicate-argument structure, with the predicate and arguments explicitly represented in the sentence. There are many concepts expressible in natural language, however, that do not fit easily into this framework. In this area we are studying some of the problems posed by the following:

* Time and space
* Events, actions, and processes
* Nonstandard quantifiers
* Propositional attitudes and modalities
* Comparatives and superlatives
* Collective entities (plurals)
* Substances (mass terms)
* Semantic content of speech acts other than assertions

We are trying to devise adequate logical forms for English sentences involving these concepts and to formalize the translation of English sentences into these logical forms. Our initial efforts are described in (Moore, 1981b).

2. Commonsense Reasoning

Commonsense reasoning enters into the KLAUS research program in at least two different ways. First, the KLAUS system is intended to answer questions by drawing logical inferences from what it has been told. Second, it is widely recognized that the interpretion of an utterance often requires the ability to draw inferences from world knowledge. These kinds of reasoning pose two major problems for the KLAUS deduction system: it must be able to reason about the full range of concepts that the language system handles; it must be efficient enough to permit real-time response to natural-language inputs.

In regard to the first problem, since the only logical formalism for which automatic deduction is relatively well understood is first-order logic, we are searching both for extensions of the techniques of first-order logic to more expressive systems and for ways of reformulating other systems as first-order theories. In addition, we are working on axiomatizations of core domains of commonsense knowledge, so that, for example, it will be possible for a user to tell KLAUS about airline schedules without first explaining to it what space and time are.

In regard to the second problem, we have identified five areas to explore in making deduction systems more efficient: (1) identification and elimination of redundant search paths in standard deductive algorithms; (2) inclusion of explicit control information in axioms; (3) choosing between logically equivalent axiomatizations on the basis of their computational properties; (4) use of taxonomic information in indexing first-order-logic knowledge bases; (5) use of more sophisticated data structures to minimize the generation of new list structure to represent the intermediate steps of an inference chain.

3. Pragmatics of Natural-Language Communication

Research in this area is concerned with developing techniques that will enable computer systems to participate in ongoing dialogues with users. The DIALOGIC system produces only literal interpretations of utterances and has only limited capabilities for taking into account the context in which a particular utterance occurs. The problems we are currently investigating fall into three areas: (1) the interpretation of expressions that refer to objects and events; (2) the generation of natural-language utterances; (3) speaker/hearer models and intended meaning.

In our work on referring expressions, we are trying to develop formalisms for dialogue models and to specify the interactions between the construction of the model for a particular dialogue and the interpretation of the referring expressions that occur in that dialogue. Our research on generation is an extension of previous work described separately below. Our research on speaker/hearer models provides support for investigation of the other two problem areas. In particular, we are concerned with specifying the role in interpretation of what dialogue participants believe individually and mutually, and with identifying the different purposes an utterance may serve in context (Grosz, 1979).

D. TEAM

Doug Appelt, Armar Archbold, Barbara Grosz, Jerry Hobbs,
Paul Martin, Robert Moore, Jane Robinson, Daniel Sagalowicz
Mark Stickel, David Warren

The goal of TEAM project is to develop techniques that will enable either database administrators or ordinary users to adapt a natural-language processing system to provide access to new databases. A demonstration-of-concept version of such a system, TED, was implemented using a semantic/pragmatic grammar (Hendrix and Lewis, 1981). An initial version of a TEAM system based on DIALOGIC has been developed and is now being modified and extended. The TEAM system has three major components: (1) an acquisition component; (2) the DIALOGIC language system; (3) a data access component.

1. Acquisition Component

The acquisition component or TEAM is responsible for interacting with users to obtain the information necessary for providing a natural-language interface to a particular (new) database. The acquisition dialogue extracts information about the structure of the database and about the language that may be used to refer to the stored data. The user participating in this dialogue must be knowledgeable about database structure, but not about natural-language processing. Research on this component is concerned with techniques for obtaining the information about language needed for natural-language processing from users who are not computational linguists.

The acquisition component incorporates a flexible control strategy, a set of question forms to be instantiated, and a set of updating procedures. The control strategy and question forms combine to determine the form of any particular acquisition dialogue. At the end of the dialogue, a set of question/response pairs is passed to the updating procedures, which then use them to modify the lexicon and conceptual schema used by DIALOGIC, as well as the database schema used by the data access component. (The conceptual schema encodes information about the entities in the domain of the database and the relationships that can hold among them.)

2. DIALOGIC in TEAM

DIALOGIC is used by TEAM to translate English queries and commands into a (database-independent) formal language (or "logical form") that is the input for the data access component of the system. The demands of transportability made by TEAM have affected all the components of DIALOGIC. The most important effects were on the design of the conceptual schema and the logical form into which DIALOGIC translates an English sentence. The conceptual schema is used by the basic semantic functions and basic pragmatic functions. Its design has to take into account the need to acquire the information it encodes systematically (and therefore automatically). The design of the logical form also has to provide for its construction from the kind of information that could be added to the lexicon and conceptual schema as the result of an acquisition dialogue with a user.

We are currently investigating a number of extensions of DIALOGIC that are essential for truly transportable and fluent natural-language access to databases. These include the capability to interpret expressions involving mass terms, aggregates, quantified commands, and time expressions.

3. Data Access Component

The data access component of TEAM is designed to translate from the logical forms produced by the DIALOGIC component into the query language of a database management system. A principal research issue for the TEAM project has been the design of the database schema needed for translating logical-form expressions into database queries. In addition to supporting translation, the database schema has to support acquisition; i.e., it must be possible to obtain the information it encodes in a straightforward and systematic fashion.

The main problem to be overcome in the data access component is to reconcile the difference between the view of the information in the domain of the database provided by the database structure, on the one hand, and that provided by natural-language expressions referring to this information on the other. Basically, database access is in terms of files, records and fields, while natural-language expressions (and hence, their logical forms) refer to the same information in terms of entities and relationships in the world.

E. Natural Language Access to Medical Text

Robert Amsler, Jerry Hobbs, Donald Walker

Increasing amounts of medical information in text form are becoming available for computer search and retrieval. However, the existing keyword-based procedures for locating a particular passage in a document are both awkward to use and grossly indiscriminate. To enable more efficient access by physicians and other health professionals, we are developing capabilities that allow a person to search a body of text more effectively by means of natural-language dialogues.

The initial document for our research is a textbook containing current knowledge about hepatitis, the Hepatitis Knowledge Base being developed at the National Library of Medicine. We are encoding (presently by hand) a "text structure" for the document that consists of logical representations summarizing the information content of individual passages in combination with linkages showing the hierarchical relationships among the passages. The logical representations are expressed in a formal language in which canonical predicates are used.

The text access system (Walker and Hobbs, 1981) has two major components, DIALOGIC and DIANA. The DIALOGIC system translates English requests into the logical representations just described. Many extensions of DIALOGIC's grammar have been motivated by the need to deal with the extended text and medical language that must be accommodated by the text access system.

DIANA (for discourse analysis) is an inference component that seeks to solve discourse problems posed by the dialogue, including the problem of finding the relevant passages to retrieve. It does so by drawing inferences selectively from a knowledge base containing knowledge about hepatitis as well as other world and lexical knowledge (Hobbs 1980). The following specific discourse problems are being explored:

determining the congruence between predicates and their arguments (an operation called "predicate interpretation"), which subsumes the checking of selectional constraints, the expansion of metonymic expressions, and the interpretation of some metaphors (Hobbs 1981); interpreting compound nominals; resolving anaphoric expressions and syntactic ambiguities; establishing the coherence relation that each sentence bears to the preceding discourse; matching the request with the logical representation of the textbook.

DIANA attempts to solve all of these problems conjointly, in a three-pass effort. In the first pass, the discourse problems are recognized and expressed in terms of goals for the inference processes of the second pass. In the second pass, the knowledge base is searched for chains of inference that solve these problems, and, when they are found, a plausible partial interpretation is constructed and merged with others that are consistent with it. In the third pass, the best plausible interpretation--that is, the one that solves most problems the most economically--is chosen and instantiated.

Future work on the text access system will include enhancing the capabilities of DIANA and augmenting its knowledge of the hepatitis domain. In addition, we intend to develop a text modification system that will allow passages reflecting new medical research results to be integrated into the formal structure already established for the current text. It will be a system for the interactive modification of preexisting summaries of passages and, as such, will constitute a feasible first step toward the automatic generation of summaries.

F. Natural Language Generation

Douglas Appelt, Barbara Grosz

Our research on natural-language generation is a continuation of recent work on the planning of natural-language utterances sponsored by the Office of Naval Research. The theory (Appelt, 1981) is based on defining a hierarchy of linguistic actions that can be used by a planner called KAMP (Knowledge And Modalities Planner) to construct plans involving multiple agents in which communication actions are necessary. To devise plans involving illocutionary acts, KAMP uses a formalism based on Moore's possible-world-semantics approach to reasoning about knowledge and action (Moore, 1980). The abstractly specified illocutionary acts are further refined into English sentences by the planner, which takes advantage of the ability to perform multiple actions simultaneously in an utterance and coordinates the linguistic actions with their physical counterparts. This approach makes it possible to integrate the process of "deciding what to say" with that of "deciding how to say it". A speaker's intention to refer to an object can involve the planning of physical actions such as pointing, which can cause domain-level actions to be planned--which in turn can influence what is said.

Future work in this area will be directed toward increasing the linguistic coverage of the system to include a wider variety of syntactic structures, as well as extending the planning component to cover the planning of extended discourse by formally defining and planning discourse level actions, such as topic-shifting.

G. Computational Aspects of the Use of Metarules in Formal Grammars

Kurt Konolige, Jane Robinson

We are investigating the use of metarules to construct formal grammars of English. Metarules operate on grammar rules to produce new rules. They capture the linguistic generalizations that have heretofore been expressed by using transformational rules to restructure phrase markers. Since the effects of metarules can be computed before the grammar is used to analyze input, the computational efficiency of a phrase structure grammar can be preserved.

Theoretical motivations for the use of metarules have been advanced by several linguists in recent years. Our formalism for expressing metarules differs significantly from those previously devised in that they apply to rules of an augmented phrase-structure grammar (APSG) that annotate phrases with arbitrary feature sets. APSGs have been written and tested at SRI for a large subset of English, and their computational viability has been demonstrated in DIAGRAM, the grammar used in DIALOGIC (Robinson, 1980). Because of the increased structural complexity of APSGs over PSGs without annotations, new techniques for applying metarules to rules have been developed. The formalism has been implemented and preliminary tests have been conducted (Konolige, 1979).

Future work will be directed towards producing extensive grammars, varying the metarules and the basic rules to which they initially apply, and observing the effects on system performance. A major goal of our investigation is to determine whether metarules interact to produce a manageable number of rules, suitably constrained to give correct analyses to well-formed inputs while rejecting ill-formed ones.

H. MEDINQUIRY

Robert Amsler, Donald Walker

The MEDINQUIRY project (which is being conducted cooperatively with researchers at the University of California, San Francisco, the University of Pennsylvania, and the National Library of Medicine) is concerned with providing natural-language access to clinical databases. The MEDINQUIRY system (Epstein and Walker, 1978; Epstein, 1980), which is based on LIFER (Hendrix, 1977), is designed to support both clinical research and patient management by physicians engaged in the prognosis of chronic diseases. The current database, which is being created at SRI, will store information on over 150 attributes from approximately 1500 records of patients with malignant melanoma.

MEDINQUIRY enables the physician to enter requests in English that retrieve specified data for particular patients or for groups of patients satisfying certain characteristics, to perform a variety of calculations, to browse through the database, to receive assistance in identifying and exploring relationships among patient attributes, and to relate information in the database to prognosis and outcome. The grammatical rules for analyzing these requests were developed on the basis of a comprehensive review of the literature on melanoma, an analysis of the database, and discussions with melanoma experts. Studying how physicians use the system can provide insights into the process of medical decision making, as well as suggesting extensions to the system.

Our primary medical objectives include investigating the natural history of melanoma, studying differences between patient populations, and developing individual risk-prediction methods. To validate hypotheses that have been formulated through MEDINQUIRY, statistical tests can be applied to the appropriate data using the BMDP Biomedical Computer Programs. Future work on MEDINQUIRY will increase its linguistic and conceptual coverage, particularly for time-related phenomena, as well as its biostatistical capabilities. A subset of the melanoma database is accessible through the INGRES relational database management system, and some comparative studies of the two access methods are being conducted.

I. POLYTEXT

Robert Amsler, Donald Walker

The projects on natural-language access to clinical databases and medical text may be viewed as part of a broader program of research on the organization and use of information (Walker, 1981a,b) that is being carried out cooperatively with Hans Karlgren at the Kval Institute for Information Science in Stockholm. Our major focus is on understanding how people, working as scientists and professionals on problems in their respective areas of expertise, actually use information to solve those problems. The strategy we are pursuing entails constructing computer-based systems in which the users can access different kinds of information through dialogue interactions in ordinary conversational language. By observing how these systems are used we expect to be able to determine what modifications are required to make them increasingly more valuable.

An initial system, called Polytext, is now being developed

(Karlgren and Walker, 1980). It will accumulate users' experiences within its database, and will also make it possible to evaluate alternative algorithms and strategies for processing textual data. A user's request for information is refined through natural-language dialogue with the system; a response includes pointers to relevant items in the primary database and to the results of previous requests that appear related. The central feature of the system is the notion of "messaging": all data elements in the system are considered to be messages; so are the alternative representations of the content of each data element, the requests addressed to the system, the evaluations of the relevance of each request to the data retrieved, and other communications among users. Structural features of each such message (in particular, a topic/comment relation patterned after contemporary linguistic usage) provide the basis for linking it appropriately to other messages.

J. Computational Lexicology

Robert Amsler

Computational lexicology (Amsler and White, 1979) is concerned with the use of computers in analyzing machine-readable texts of man-made dictionaries--both to identify their structure (Amsler 1981) and to help specify the content and organization of the lexicon for use by other natural-language processing programs. We are working with several machine-readable dictionaries (Longman Dictionary of Contemporary English and Merriam-Webster's Seventh Collegiate and New Pocket Dictionaries) and a variety of textual data (the Brown University Corpus and word frequency data, American Heritage Word Frequency Data, the RADC hyphenation lexicon, and the National Library of Medicine Hepatitis Knowledge Base). These are being compared and combined to derive databases of linguistic information for other research applications and to develop basic understanding of phenomena in lexical science.

Specific areas of application are automatic derivation of computational-linguistic features from dictionary entries; automatic selection of subject domain vocabulary from dictionary subject codes; the use of dictionary definition texts in automatic lexical disambiguation; and the development of usable "tangled" hierarchies of word senses from dictionary definition texts for use in management of lexical data, content analysis, and information retrieval.

Topics of research interest include development of a theory of definitions that encompasses both dictionary definitions and the linguistics of defining in text, as well as empirically-based theoretical studies in such areas as semantic property inheritance and semantic domain structure.

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