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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

BBN's ARPA project in Knowledge Representation for Natural Language Understanding is aimed at developing techniques for rendering computer-based assistance to a decision maker who is attempting to understand and react to a complex, evolving situation. This report summarizes our research in knowledge representation and natural language over the length of the contract. In particular, we discuss the development if KL-ONE, NIKL, and KL-TWO, the advances in RUS and the PSI-KLONE systems, and our work in understanding discourse and speaker's intentions. Keywords include:

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BBN's ARPA project in Knowledge Representation for Natural Language Understanding has developed techniques for rendering computer-based assistance to a decision maker who is attempting to understand and react to a complex, evolving system or situation. The decision maker's access to the situation is mediated by an intelligent graphics display system which is controlled largely through natural language input. A typical and motivating instance is that of a military commander in a command and control context, either of strategic situation assessment or of tactical crisis management. In such situations, the commander requires a flexible and easily controllable system capable of manipulating large amounts of data and, most importantly, of presenting information in a variety of forms suited to the user's expressed or inferable needs and capacities.

A display system of the kind envisaged would have the capacity to present information in tabular, graphical, textual, and cartographic forms. The user of such a system must be able to monitor, add, change and delete information and, independently, to create and alter the various representational forms. Moreover, for the system to be truly flexible and adaptive, it must maintain models of the domain and situation being represented, of the representational systems at its disposal, and of the user's conceptions of these domains, situations, and systems of representation. For this last purpose, the system must also be able to construct models of its interactions with the user.

On the basis of these different kinds and sources of information, the system must produce intelligible and appropriate displays in response to high-level descriptions and commands. That is, the commander can usually be expected to request a presentation of certain aspects of the situation or system being monitored in terms appropriate to the domain itself and not in terms of display forms. Even when the request, explicit or implicit, is expressed in terms of display forms, the specification will typically be at a level of abstraction appropriate to the commander's purpose - not to those of a graphics system designer or programmer. The system must be able to accept a description of the information to be represented together with an abstract specification of a display-type and then it must intelligently determine the details required actually to produce an effective display. Finally, given information about the user's knowledge of the situation being monitored and his particular concerns with respect to it, the system must, in some cases, be able to infer what kind of display a user might want to see, produce it, and monitor the user's response to its initiatives.

The crucial requirements for a medium of communication with such a system are robustness, flexibility, the ability to express specifications while abstracting from details of various kinds, and the ability to express conceptualizations of both the presented domain and the modes of display in ways that match a user's conceptualization. By far the most natural form of access to and control over such a system for most users will be through the use of natural language input. Hence, a major focus of our research has been the design of a system powerful enough to represent the content of natural language utterances together with facts about the user's beliefs and goals as these are communicated in the user's interactions with the system. Such a representational formalism must also express, in usable form, information about the domain or situation being monitored and the nature of the display system itself.

Our research has been concentrated in four basic areas: knowledge representation, planning, parallel algorithms and architectures and natural language understanding. Below is a summary of research in each area.

Knowledge Representation

The development of knowledge representation tools is a major accomplishment of our research group. We have extended and revised the KL-ONE knowledge representation system to a new system KL-TWO.[1] It incorporates:

1. A taxonomic knowledge representation system of the KL-ONE variety called NIKL (for a new implementation of KL-ONE), a cleaner and more efficient version of our earlier KL-ONE (see [9]).

2. A propositional reasoning system called PENNI based on RUP, a TMS originally designed by McAllester [6] and reimplemented in INTERLISP (see [9]). This system allows a user to represent and reason about assertions concerning individuals.

3. An interface between these two systems that allows taxonomic descriptions to be applied to individuals and allow knowledge to flow between PENNI and NIKL.

KL-TWO represents our first implementation of a hybrid system, that is, a system built from several components, each of which provides an expressive, natural

[1] In a previous report we used the term NIKL to refer to the new version of KL-ONE and to the whole system that interfaces assertions with the new KL-ONE implementation. KL-TWO is the current name for the whole system.

representation, and a special-purpose reasoning engine for efficient control of inference; each reasoner is then interfaced to the others. Hybrid systems include constructs that allow a user to capture important intuitions about the structure of a domain and also offer the user more control over the reasoning process than previously possible. In KL-TWO, we have joined a reasoner for taxonomic hierarchies of knowledge with one for propositional logic. Our recent experience in designing and implementing an interface between these two reasoners is reported in Chapter 2, [11].

Our experience with NIKL over the past year has led us to develop a programming environment for working with NIKL taxonomies. This environment makes it possible to build, edit, and install new and changed hierarchies and makes use of several Interlisp debugging features for NIKL. The programming environment, developed by D. Stallard, is reported on in Chapter 3, [11].

Over the life of this contract, we have made our knowledge representation research available to the community both through system releases and through invited workshops in 1980 (reported in Chapter 2 of [8]) and in 1981 (reported in [7]).

For representing and reasoning bout time, we have designed and implemented a system called the Time Machine. It offers a logic for time intervals and time points. It finds the transitive closure of all possible relationships among known intervals and stores them in an efficient manner. The Time Machine includes a truth revision facility for reasoning about changes in one's knowledge of time. The Time Machine is described in Chapter 6, [12].

We have also developed a formal theory of knowledge and belief that allows an agent to reason about his or her own beliefs and reasoning and about the knowledge needed to perform actions. This research is discussed in Section 6 of [9].

Explorations in Planning

Planning has become a focus of our research efforts largely through our natural language research on discourse, where it is necessary to come to an understanding of the speaker's plans and to develop a plan for responding to the speaker's intentions. We have recently begun to formalize some research on planning for use in our group. Work by A. Haas [11] presents a theory of planning involving time and agents that addresses some of the problems that have limited the plans a planner can design.

Parallel Algorithms and Architectures

We have designed and implemented a syntactic-semantic cascade between the RUS parser and the semantic interpreter using KL-ONE and NIKL. The system cascades the action of the parser and the semantic interpreter so that each component uses knowledge from the other in its processing. This cascade relies on an algorithm for incremental description refinement that permits in parallel searches for partially parsed phrases. This work is reported in Chapter 4, of [8]. We have also explored algorithms for situation recognition and a marker passing engine. We designed and implemented a marker passing version of the classifier of KL-ONE for use on highly parallel machines This work is reported in Chapter 6 of [8].

Natural Language Understanding

Our natural language research has made several significant advances. We have built and extended the RUS and PSI-KLONE system (see Chapter 4, [3]; Chapter 4, [8] and [1], [2]) to include the lexical acquisition module to aid users in adding lexical information without knowledge of the implementation (see [9]) and in adding semantic rules (see Section 5 in [11]). An important aspect of lexical acquisition is the changes to the lexicon we have made for subcategorization of verbs. BBN Report No. 5684 [5] presents an explanation of subcategorization of verbs that motivated the restructuring of the dictionary.

We have continued to develop the RUS parsing system (see [12]). We have improved its efficiency and its interaction with semantics so that most sentences are processed without any backup. We have, over this contract, created and extended the RUS grammar to a large number of rules, and we have developed a large dictionary of more than 5000 words, for use with the lexical acquisition module. We have made a version of RUS that is transportable to a variety of decision-support systems (see [9]).

Since language understanding also requires understanding what the meaning of a utterance tells the hearer about the world, we have explored several issues in discourse understanding. See Chapter 3, [8] for a discussion of the goals for a natural language system and scenarios for its use. We have developed several systems that recognize speakers' intentions (see Chapters 5 and 6 in [3], and Chapter 5 in [8]). Building on that work, we have implemented a plan parser for recognizing speakers' plans and explored its relation to other discourse behavior. This work is reported in Chapter 6 in [11]. We have explored the general requirements on building a natural language system with graphics (see [10]).

Understanding descriptions plays a significant part in discourse and natural language as a whole, and we have investigated it in two ways: a general framework for understanding the first use of descriptions in discourse (see Section 9 in [9]), and a theory and implementation of (extensional) referential descriptions to objects in the hearer's view (See Section 10 in [9], and Chapter 7 in [11]). We hope to extend the general framework for descriptions in future research.

The theory and implementation of extensional reference encompasses a model of reference that differs significantly from previous approaches. In this theory a reference process doesn't simply succeed or fail. Rather the process takes into account ways the speaker may have miscommunicated about the object of interest, and it relaxes aspects of the description until a referent is found. By viewing communication between speaker and hearer as a process that may include description errors, Goodman has taxonomized many kinds of miscommunication in discourse other than those involving reference (see the forthcoming BBN Report [4]). We expect to expand our research in miscommunication and discourse to include a model of some of these discourse errors.

For a list of papers published and presentations given during this contract, see the annual reports for each contract year:

1978: BBN Report No. 3963
1979: BBN Report No. 4274
1980: BBN Report No. 4513
1981: BBN Report No. 4785
1982: BBN Report No. 5188
1983: BBN Report No. 5421
1984: BBN Report No. 5694

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