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RESEARCH IN PROGRESS

The Advanced Computational Methods Center, University of Georgia

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Abstract

The Advanced Computational Methods Center (ACMC), established at the University of Georgia in 1984, supports several research projects in artificial intelligence. The primary goal of AI research at ACMC is the design and installation of a logic-programming environment with advanced natural language processing and knowledge-acquisition capabilities on the university's highly parallel CYBERPLUS system from Control Data Corporation. This article briefly describes current research projects in artificial intelligence at ACMC.

A Nonmonotonic Inference Engine

People are often forced by circumstances to make judgments based on incomplete information. These circumstances do not disappear when we augment our native reasoning ability with the use of knowledge bases and automated reasoning systems. It is therefore extremely important that our systems be able to assist us in this kind of reasoning. Frequently, the best conclusion that can be drawn from an incomplete set of facts about a situation are different from the best conclusion that can be drawn from a complete or nearly complete superset of the same facts. The set of conclusions we draw as our information increases does not simply change in one direction or monotonically by getting larger; it can also shrink as our previous best conclusions are rejected on the basis of new information.

A system of nonmonotonic reasoning based on the PROLOG programming language is under development at ACMC. Called PROWIS for PROgramming WIth Subjunctives, this system implements features of recently developed logics for subjunctive conditionals (Nute, 1980a; Harper, Stalnaker, and Pearce, 1981; and Nute, 1984). Rules in this system include not only the usual monotonic rules of standard PROLOGs but also both weak and strong nonmonotonic rules. These correspond roughly to the "might" conditionals and the subjunctive or counterfactual conditionals of conditional logic. Besides nonmonotonicity, the system implements a restricted system of chaining for strong nonmonotonic rules.

Another PROLOG extension under development called N-PROWIS implements features of intuitionist logic. N-PROWIS is the result of integrating PROWIS with another program called N-PROLOG (Gabbay & Reyle, 1984). The central feature of N-PROLOG is the ability to evaluate conditional goals. The natural method for doing this results in a treatment of the monotonic rules of PROLOG which is much closer to intuitionist logic than to classical logic. Evaluation of strong nonmonotonic rules or subjunctive conditionals as goals is also implemented in N-PROWIS. With the evaluation of conditional goals, it becomes possible to incorporate conditionals into the bodies of rules in the system.

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Discourse Analysis

Research into natural language processing at ACMC focuses on problems in the analysis of discourse. This work is motivated by two recently developed techniques: conversational score and discourse representation theory.

The term *conversational score* denotes a collection of parameters that help to determine the acceptability of an utterance. Speakers accommodate each others utterances by tacitly agreeing on those parameters as a conversation proceeds. For example, when a speaker attributes the vague predicate "large" to a dog of a certain size, members of the audience might accommodate the speaker by tacitly agreeing to apply the term "large" in this conversation to dogs of at least this size. Once established, these parameters restrict later utterances in the same conversation. For example, our original speaker could not say later with impunity that another dog, larger than our original subject, was *not* large. The notion of conversational score applies to a wide range of linguistic phenomena, including presupposition, salience, and criteria for evaluating conditional utterances (Lewis, 1979; Nute, 1980b).

The second theoretical tool upon which our research in discourse analysis is based, discourse representation theory (DRT), provides techniques for constructing partial formal models of the meaning of a piece of discourse. The theory is motivated by strong evidence that it is often impossible to fully represent the meaning of an utterance in isolation. The minimum meaningful unit of language is, thus, a piece of discourse rather than a single sentence. As additional sentences are uttered within a piece of discourse, the discourse grows together with the discourse representation structure (DRS) assigned to it by the theory. Sentence meanings become functions from DRS to DRS. This theory has been particularly useful in the analysis of anaphora and tense (Kamp, 1981).

A DRS might be represented computationally as a small database. The truth of a DRS relative to a model depends on the possibility of embedding the DRS in that model. Computationally, the truth of a DRS database relative to a larger database will depend on the possibility of embedding the smaller database in the larger. When a piece of discourse is intended to inform a computing system, the task is to update the system's database in ways that allow the DRS database for the piece of discourse to be embedded in the system database. The theory lends itself readily to computational linguistics (Guenthner, 1983a, b; Kolb, 1985).

Further investigation is required into the possibilities for representing the kinds of intensionality involved in conditional logic within DRT. Conversational score and DRT are viewed as complementary approaches to the analysis of natural language, but further work is required to integrate these two theories.

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Estimation of Chemical Parameters from Molecular Structure

The Environmental Protection Agency (EPA) has developed sophisticated pollutant fate models for predicting the consequences of introducing substances of known physical and chemical properties into various bodies of water. For these models to provide the greatest benefit to the agency, it must be possible for a user with limited background in chemistry to apply the model to compounds whose physical and chemical properties have not been reliably measured. A highly trained chemist can estimate these properties on the basis of molecular structure with a degree of accuracy suitable for the kinds of results the pollutant fate models are intended to provide. What is needed is a system that can perform this task of estimating physical and chemical parameters from molecular structure with reasonable accuracy.

In cooperation with the EPA, ACMC is developing a system for estimating chemical parameters for hydrolysis and ultraviolet (UV) light absorption from molecular structure. These two processes were selected for initial investigation because they are considered to be reasonably well understood; there is extensive data that can be used for calibration; and they represent extremes in the kind of results to be produced: a discrete rate constant in the case of hydrolysis and a continuous spectrum in the case of UV light absorption. The final system will consist of a module that can build a canonical representation of molecular structure from names, line drawings, and so on; a module that can identify contributing and perturbative substructures using the canonical representation produced by the first module; and a module that can estimate rate constants and UV light absorption spectra from the information provided by the second module. ACMC is responsible for designing the second or middle module of this system and for integrating it with the other two modules. It is expected that the nonmonotonic inference engine PROWIS will be used extensively in this project.

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The CYBER Cooperative Logic Programming System (CYCLOPS)

The CYBERPLUS system at the University of Georgia is the first such system to be delivered to a university research center. The system consists of a CYBER 845 serving as host to three high-performance processors (HPPs) connected in a two-way loop and sharing common memory. One of the HPPs is equipped with a floating-point accelerator. Each HPP incorporates 15 functional units performing different arithmetic, logical, control, and I/O functions. These units are connected with each other through a 16 × 18 cross bus. Thus, the system exhibits parallelism at two different levels, within and between the individual processors. In this initial configuration, the system has a theoretical performance limit of nearly 600 million floating-point operations each second. The system can be expanded to include 4 loops of HPPs with 16 HPPs in each loop. The University of Georgia is developing plans to expand its system to 10 HPPs in the near future.

A primary goal of ACMC is to develop and install a cooperative logic-programming system (CYCLOPS) on the CYBERPLUS. This system would incorporate the nonmonotonic inference engine PROWIS and would implement features developed in the investigation of conversational scorekeeping and DRT. CYCLOPS will be a development system for creating large knowledge bases that will then be ported to smaller machines for delivery. An essential feature of CYCLOPS will be its natural language capability and its use of the nonmonotonic inference engine to interact with the user in the task of knowledge acquisition.

A difficulty in constructing large systems of rules for use in expert systems is the constant threat that a new rule might interact with existing rules in the system to produce unexpected or undesirable results. For example, we might add the rule "If a patient with high blood pressure spends less time working at his stressful occupation, his blood pressure will improve" to a system that already contains the rule "If someone is fired, he no longer works." In particular cases, the new system will chain these two rules and behave as if it contained the following rule: "If a patient with high blood pressure is fired, his blood pressure will improve." Anticipating these results is a major task for the knowledge engineer. Once they have been discovered, the knowledge engineer must rewrite rules in the system to avoid the bad consequence. We call this the *chaining problem.* The situation is different with PROWIS because PROWIS's nonmonotonic rules do not chain except in special circumstances. Problems can still arise through chaining a monotonic with a nonmonotonic rule, but in these cases the problem can be corrected by adding a new rule that defeats the inference, with no rewriting of existing rules required. However, restricted chaining poses a new problem. In many cases, we want our nonmonotonic rules to chain. CYCLOPS will identify likely places for such chaining and interact with the knowledge engineer to determine whether to allow chaining in specific instances.

CYCLOPS will also identify situations in which the system can draw no conclusion because of competing nonmonotonic rules with unrelated antecedent conditions and situations in which different kinds of inconsistencies and incoherencies could arise in a PROWIS rule set. Once these problems have been identified, CYCLOPS will interact with the knowledge engineer to correct the problem. Thus, CYCLOPS will share some of the most burdensome aspects of knowledge base construction with the knowledge engineer. This sophisticated interaction in the construction of the database will require the computational power of the highly parallel CYBERPLUS, but knowledge bases constructed using the system will be portable to smaller machines.

Another obvious goal of the CYCLOPS project is the exploitation of the parallelism of the CYBERPLUS. Initial plans are to use one processor to serve as a loop and solution checker for the other processors (Covington, 1985; Nute, 1985). Novel approaches to the elimination of loops in PROLOG programs are implemented in a PROLOG interpreter written by Stearns for the IBM PC. By altering the PROLOG inference engine itself, Stearns's interpreter avoids several of the most common ways the system can enter a loop.

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References

Covington, M (1985) Eliminating unwanted loops in PROLOG *ACM Sigplan Notices* 20(8):32-37

Gabbay, D M & Reyle, U (1984) N-PROLOG: An extension of PROLOG with hypothetical implications *The Journal of Logic Programming* 1:319-355

Guenthner, F. (1983a) Discourse representation theory and PROLOG IBM Research Report, International Business Machines Corporation

Guenthner, F (1983b) Discourse representation theory and databases IBM Research Report, International Business Machines Corporation

Harper, W L., Stalnaker, R , & Pearce, G *Eds* (1981) *Ifs: conditionals, belief, decision, chance, and time* Dordrecht, Netherlands: D Reidel Publishing Company

Kamp, H. (1981) A theory of truth and semantic representation. In J A G Groenendijk, T M V Janssen, and M B. J Stokhof (Eds), Formal methods in the study of language Mathematical Center Tract 135, University of Amsterdam

Kolb, H -P (1985) Aspekte der implementation der diskursrepraesentations theorie MA Thesis, Research Center for Natural Language Systems (FNS), University of Tuebingen

Lewis, D (1979) Scorekeeping in a language game. *Journal of Philosophical Logic* 8:339-359

Nute, D (1980a) *Topics in conditional logic* Dordrecht, Netherlands: D Riedel Publishing Company

Nute, D (1980b) Conversational scorekeeping and conditionals. *Journal of Philosophical Logic* 9:153-166

Nute, D (1984) Nonmonotonic reasoning and conditionals ACMC Research Report 01-0002, Advanced Computational Methods Center, University of Georgia

Nute, D (1985) A programming solution to certain problems with loops in PROLOG *ACM Sigplan Notices* 20(8):32-37.