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RESEARCH IN PROGRESS

# Recent and Current Artificial Intelligence Research in the Department of Computer Science, State University of New York at Buffalo

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**Abstract**

This article contains reports from the various research groups in the SUNY Buffalo Department of Computer Science, Vision Group, and Graduate Group in Cognitive Science It is organized by the different research topics. However, it should be noted that the individual projects might also be organized around the methodologies and tools used in the research, and, of course, many of the projects fall under more than one category.

The Department of Computer Science at the State University of New York (SUNY) at Buffalo, one of the oldest computer science departments in the United States to grant a Ph.D, has been actively engaged in AI research since its establishment in 1965. With half of our full-time faculty members (Shoshana L. Hardt, William J. Rapaport, Stuart C. Shapiro, Sargur N. Srihari, and Deborah Walters), more than 40 graduate students, and several associated faculty members involved in research programs in the various branches of AI, the department is engaged in a variety of applied and theoretical AI research efforts. The different research groups use a variety of AI methodologies and tools in a variety of different fields, including natural language understanding and computational linguistics, expert systems, computer vision and pattern recognition, knowledge representation, reasoning, and cognitive science. The departmental laboratories include VAXes, LISP machines, a SPERRY 7000/40, SUN workstations, a Grinnell GMR 274 graphics system, an Imaging Technologies IP512 image-processing system, and an Adage 3010 graphics system.

## Natural-Language Understanding And Computational Linguistics

Our natural-language understanding projects are focused around representing and reasoning about spatial and temporal information and belief and knowledge reports, as well as a knowledge-engineering approach to natural language.

### Reasoning About the Temporal Structure of Narrative Texts

A major part of what it means to understand a story is to know how the different events and states described in the text relate to one another temporally. Although much of this information is provided simply by the order of presentation within the text, a number of other factors play significant roles in the production of an adequate temporal model. Among these factors are changes in tense, the use of the perfect tense, the distinction between progressive and nonprogressive, time adverbials, world knowledge, and the inherent aspectual properties of different classes of predicates. We also believe it is necessary to use some representation of the present moment within the story, that is, a narrative "now point." This narrative now point is moved forward in time as the story progresses in time, and it functions as the temporal deictic center to which all the events and situations that occur in the story are related. The major focus of our research is on how the various factors mentioned here interact with and affect this narrative now point. The system is being implemented in the SNePS Semantic Network Processing System, (Shapiro, 1979) and is a project of the SNePS Research Group and a part of a research project on deixis in narrative being conducted by the Graduate Group in Cognitive Science. (For further information, see Almeida & Shapiro 1983.)

*Participants:* Michael J. Almeida and Stuart C. Shapiro.

### A Knowledge-Based Approach to Natural Language Understanding

A significant feature of any natural language is that it can serve as its own meta-language. One can use a natural language to talk about the language itself as well as to give instruction in the use and understanding of the language. Because human beings are able to use their natural language to talk about that natural language itself, we have been investigating methods of knowledge representation and natural language understanding that would enable an AI system to do likewise. We have implemented a language-understanding system in the role of an educable cognitive agent whose task domain includes language understanding and whose discourse domain includes knowledge of its own language.

This system has just one (initially primitive) language, which becomes increasingly more sophisticated as the system accepts instruction expressed in its evolving language. Such a system must start with some language facility, and we have strived to make this initial kernel language as small and as independent of theory as possible. With an unbiased kernel language, teacher-users should ideally be able to bootstrap into the language of their choice. The system is implemented in the SNePS Semantic Network Processing System (Shapiro, 1979) and is a project of the SNePS Research Group. (The final report of this project is Neal, 1985; for further information, see Neal, 1981; Shapiro & Neal, 1982; and Neal & Shapiro 1984, 1985, and forthcoming.)

*Participants:* Jeannette G. Neal[1] and Stuart C. Shapiro.

### Logical Foundations for Belief Representation

Our research consists of the design and implementation of a logically and psychologically adequate computer system capable of representing and reasoning about the cognitive attitudes of intelligent agents. The agents include users, other AI systems, and the system itself; the cognitive attitudes include beliefs, knowledge, goals, and desires. The system will be able to represent nested attitudes; it will be sensitive to the intensionality and indexicality of attitudes, in particular, to the phenomenon of quasi-indexicality, a feature at the core of self-referential beliefs; and it will be able to expand and refine its beliefs by interacting with users in ordinary conversational situations. The system is being implemented in the SNePS Semantic Network Processing System (Shapiro, 1979) using an augmented transition network grammar for parsing and generation. This research is a project of the SNePS Research Group and is also part of a research project on deixis in narrative being conducted by the university's Graduate Group in Cognitive Science.

The research is sponsored by a grant from the National Science Foundation and a SUNY Research Foundation Research Development Award. (For further information, see Rapaport & Shapiro, 1984; Rapaport, 1984.)

*Participants:* William J. Rapaport and Janyce M. Wiebe.

### Dynamic Computation of Spatial Reference Frames in Understanding Narrative Text

The actual meaning of a spatial description of an object ("figure") relative to a background ("ground") is determined only when the reference is interpreted in a specific orientational system around the "ground." In the expression, "an unaware boy playing in front of a truck rolling backward down the hill," the real spatial relationship between the boy and the truck hinges on the front-back reference frame set around the truck. In natural languages, spatial references are usually made without explicitly indicating how the reference frame is to be established, and the burden of its determination is left to the hearer's or the reader's inferences. Unlike the case of spoken language where the hearer often need look only at the referent to disambiguate a spatial description, in the case of reading a text the data for computing reference frames is contained solely in the text and the reader's background knowledge.

We are developing heuristics that can be used by a computer "story understander" for dynamically computing the reference frames for spatial descriptions. The system's understanding of a spatial description will be demonstrated by drawing a picture of the situation. For this, we will use the graphic knowledge representation techniques being developed in the project on representation of visual knowledge, described later in this article.

This research is a project of the SNePS Research Group and is also part of a research project on deixis in narrative being conducted by the Graduate Group in Cognitive Science.

*Participants:* Albert Hanyong Yuhan and Stuart C. Shapiro.

## Expert Systems

Research in expert systems includes projects in music, image understanding, message processing, maintenance, and diagnosis.

### An Expert System for Harmonization of Chorales in the Style of J. S. Bach

We are designing an expert system called CHORAL for harmonizing four-voice chorales in the style of Johann

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Sebastian Bach. Using the Bach Chorales as the high standard, as well as traditional music treatises and personal intuitions, we have found approximately 270 rules, expressed in a form of first-order predicate calculus, for describing the musical knowledge to harmonize a given chorale melody. Our rules represent knowledge from multiple viewpoints of the chorale, such as the chord skeleton, individual melodic lines, and Schenkerian voice leading within the descant and bass. The program generates chorales from left to right, using a generate-and-test technique with intelligent backtracking, until a solution satisfying all the constraints is found. A substantial number of heuristics are used for biasing the search toward musical solutions. Results of acceptable competence have been obtained. To provide the execution efficiency that appears to be mandatory for tonal music generation, we have designed BSL, a new logic programming language that compiles into C, to implement the CHORAL system, and we have investigated the foundations of BSL.

This research is supported by a grant from the National Science Foundation. (For further information, see Ebcioglu, 1985.)

*Participants:* Kemal Ebcioglu and John Myhill.[2]

## Rule-Based Expert Systems for Image Understanding

Research is currently being done to develop rule-based expert systems for the visual domain. The systems being investigated consist of the following components: (1) a knowledge base that is made of multiple levels of production rules which embody the "knowledge" of the different characteristics of document images and (2) an inference engine that uses this knowledge base to perform detailed analysis of the image data in order to arrive at consistent interpretations of the identities of the various logical "blocks" in the image.

The control system in the inference engine applies the different levels of rules progressively on the image data in order to identify the blocks. The lowest level of rules are knowledge rules, which examine the intrinsic properties of the blocks. Control rules guide the search and act as the focus-of-attention mechanism. Strategy rules determine whether at any point in time a consistent interpretation of the image has been achieved. A system applicable to postal images is being implemented in Prolog. Another system, applicable to computed tomography images, is in LISP and C.

This research is supported by the U. S. Postal Service and by a SUNY Research Foundation Research Development Award (For further information, see Srihari *et al.*, 1985, Kumar & Srihari, 1985.)

*Participants:* Debashish Niyogi, Rakesh Kumar,[3] and Sargur N. Srihari.

## High-Speed Interpretation of Ill-Formed Messages

We have automated the interpretation of daily reports from ships for the U.S. Coast Guard. Although very heavily knowledge-based, the system that emerged from the project can be viewed as a nontraditional expert system, because it employs new methods to handle control and data flow. The process of interpretation of daily reports from ships requires considerable amounts of task-specific knowledge, a large degree of flexibility in processing, and an efficient error-recovery mechanism. This is because these reports are ill formed and can contain enormous amounts of noise. Building a computer program that can handle this interpretation task requires designing and implementing powerful focusing and understanding mechanisms which can operate under severe real-time demands with over 75% reliability.

From the start, this project presented us with the interesting double challenge of coordinating the theoretical and the applicative aspects of the work with the goal of design completion and implementing the system in twelve months. In addition, we had to make sure that the final system (product) is a maintainable piece of software— a low-priority task in a university research environment. At the moment, we are investigating further the general dynamics of variable-depth processing and of knowledge-based focusing of attention in natural language parsing.

This project is sponsored by the U.S. Coast Guard. (For further information, see Hardt *et al.,* 1985; Hardt & Rosenberg, 1985, 1986.)

*Participants:* Jay Rosenberg and Shoshana L. Hardt.

## Device Modeling for a Versatile Maintenance Expert System

We are developing a versatile maintenance expert system (VMES) for troubleshooting a wide variety of electronic devices. The system diagnoses a malfunctioning device based on structural and functional descriptions of the device, which have been widely used by other fault diagnosis researchers, as a solution to the difficulties of empirical rule-based diagnosis systems in knowledge acquisition, diagnosis capability, and system generalization. The diagnosis efficiency and effectiveness, as well as the system generality, are being investigated. We find the device model, that is, the structural and functional representation of the device, to be vital to the performance of the system. The system is implemented in the SNePS Semantic Network Processing System (Shapiro, 1979). The structure of the

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device is currently represented as instantiation rules, resulting in a compact representation and better system versatility. Functions are implemented as Lisp functions that allow device simulation during diagnosis. Graphic displays are used to communicate with the user (see Representation of Visual Knowledge below). We are also investigating the applicability of SNePS Belief Revision (SNeBR) for fault isolation (see SNeBR: A Belief-Revision Package).

This work is sponsored by the Rome Air Development Center (RADC) and the Air Force Office of Scientific Research through the Northeastern Artificial Intelligence Consortium (AIC). (For further information, see Shapiro, Srihari *et al.,* 1985, 1986.)

*Participants:* Stuart C. Shapiro, Sargur N. Srihari, Ming-Ruey Taie, James Geller, and Scott S. Campbell.

## Spatial Structure and Function in Diagnosis.

We are developing a model-based expert system for neurological consultation: NEUREX. A key element in building a model-based expert system is the representation of spatial structure and the function associated with the components of that structure. Spatial structure, synonymous with three-dimensional physical structure, captures the physical characteristics of the components and their interconnections. The representation of three-dimensional spatial structure can be divided into two categories: analogical and propositional representations. An *analogical representation* is a detailed geometrical description, such as the exact shape and position of the spatial entity represented. A *propositional representation* represents entities and spatial relations between the entities topologically. Because much of the relevant structure of the nerve system and of digital circuits is networklike, semantic network structures implemented in the SNePS Semantic Network Processing System (Shapiro, 1979) will form analogical, as well as propositional, representations of these domains. Because most methods proposed for such systems are usually based on a structural representation from one of the two categories, they lack generality and their capability is limited. The method of representation should accept both analogical and propositional information concerning the structure, support function association, provide for diagnostic reasoning, and allow for graphics and language interfaces. We are investigating the features and benefits of this dual representation.

This research is supported by a SUNY Research Foundation Research Development Award. (For further information, see: Xiang, Srihari, *et al.,* 1984, 1985; Xiang & Srihari, 1985; Xiang, Chutkow, *et al.,* 1986.)

*Participants:* Zhigang Xiang, Sargur N. Srihari, Stuart C. Shapiro, and Jerry G. Chutkow.[4]

[4]SUNY at Buffalo Department of Neurology

## Computer Vision and Pattern Recognition

In these areas, our research includes projects in letter and word recognition, document image understanding, and visual processing.

## A Cognitive Model of Letter Learning and Recognition

Most cognitive science research in letter recognition is based on the use of feature models. In this research, a different approach has been tried. At acquisition time, letters are subjected to a form of object-oriented quadtree analysis. All acquired letters are integrated into the same quadtree, and object knowledge and density values of the graphic representation are added to this structure. At recognition time, quadtree analysis and densities of the present letter are compared to the stored density quadtree. The algorithm will then return the name of the letter that the present letter is most similar to. Experiments in recognizing new distortions have so far been quite encouraging. (For further information, see Geller, 1985.)

*Participant:* James Geller.

## A Computational Theory of Word Recognition

This project centers on the development of a computational theory of word recognition by adapting components of psychological theories to the machine reading problem. When explanations of human reading are compared to the state of the art in comparable algorithms, a large discrepancy is apparent. For example, it has been known since the nineteenth century that word recognition is not a character-by-character identification process followed by dictionary lookup. However, this is the way most algorithms are designed. As an alternative to this strategy, a word-recognition algorithm with a mixture of holistic processing and feature analysis is being investigated.

The holistic cue of word outline shape that has been suggested as an aid to word recognition in humans was the subject of a recent series of computational experiments to determine its usefulness to a reading algorithm. The results of these experiments provide convincing evidence for the use of such a holistic cue in a word-recognition algorithm. Because on the average only a small number of words have the same shape, the decision space of any further processing is much smaller than it would otherwise be. The reexamination of psychological results attributed to word outline shape is also suggested because of the predictive ability of the new definitions as well as computational results which show that much more visual information than just outline shape is available to human readers. Future work in this project includes the development of a complete word-recognition algorithm in which the feature analysis strategy is determined from the subset of the dictionary specified by the shape of an input word. Work is under way on the modeling of a dictionary by a graph that condenses prefixes and suffixes and the development of a hypothesize-and-test recognition strategy that uses this data structure. This approach has analogies to theories of human word recognition based on the importance of the first and the last characters in a word and the selective extraction of features from a word image.

This research is supported by the U. S. Postal Service. (For further information, see Srihari & Hull, 1982; Hull, 1985.)

*Participants:* Jonathan J. Hull and Sargur N. Srihari.

### Document Image Understanding

A document image is an optically scanned and digitized representation of, say, the title page of a journal article, a newspaper page, the face of a stamped and addressed envelope, and so on. Document image understanding involves deriving a high-level description that retains the spatial structure of the document; assigns labels to various components such as text, figures, titles, addresses, and so on; and allows extraction of relationships such as reading order. We are investigating the development and coordination of the visual, spatial, and linguistic processes necessary for this task. They include visual processes to determine objects from the background by edge detecting, edge grouping, and texture analyzing, spatial processes to label regions using knowledge of how a typical document is structured, and determining the font and identity of characters. Reading words of text is being investigated as a process that involves visual, spatial, as well as linguistic knowledge.

The interpretation of images of postal mail pieces is the domain of this investigation. Our efforts have included the development of various operators for visual data processing and image segmentation. The invocation of these routines and the interpretation of the information they return is determined by a control structure that uses a variant of relaxation combined with a rule-based methodology. This approach is designed to capitalize on the spatial relationships between blocks of image data (for example, postage is to the right and above the destination address in, say, 89% of all cases) and to propagate the influence of classifications in a controlled fashion.

This research is supported by the U.S. Postal Service. (For further information, see Srihari *et al.,* 1985.)

*Participants:* Sargur N. Srihari, Jonathan J. Hull, Paul Palumbo, and Ching-Huei Wang.

### Selection and Use of Image Features in Early Visual Processing

One of the important issues in vision is determining which features of an image should be processed in the early, parallel stages of visual processing. Another way of saying this is that we need to determine what types of image representations are most useful for preattentive processing. This is important because the efficiency of visual computations depends on the representation used; many representations will be complete, but few will be ideally matched to the required computations.

Another important issue is to determine how the features are used (where features might be relations). An important distinction here is the difference between the uses of features in the early preattentive stages versus the uses in stages of higher processing. It is possible for different stages to use different features or for the same features to have different uses at different stages. One of the thrusts of our research is to investigate novel uses of features at the preattentive level. For example, the presence of a particular feature can be used to alter the processing of an associated region of the image. Thus, it is possible to have early processing that is both selective and parallel.

These issues are addressed by searching for features that capture the structure and uniformity of nature using the following four criteria: (1) features should be perceptually valid for humans (as determined through psychophysical experimentation); (2) feature sets should be geometrically complete; (3) features should have low probability of accidental occurrence and should allow useful inductive inferences to be made from simple assumptions, such as the representativeness of both viewpoint and position; and (4) features should be locally computable in parallel

This research is supported by a grant from the National Science Foundation. (For further information, see Walters & Weisstein, 1982a, 1982b; Walters, Biedermann, & Weisstein, 1983; Walters 1984, 1985, and forthcoming.)

### The Vision Group

It is becoming increasingly important for vision researchers in diverse fields to interact, and the Vision Group at SUNY Buffalo was formed to facilitate that interaction Current membership includes 25 faculty and 25 students from 10 departments (computer science, electrical and computer engineering, industrial engineering, geography, psychology, biophysics, physiology, biochemistry, philosophy, and media studies). The group organizes a colloquium series and provides centralized information about activities both on campus and in the local area that are of interest to vision researchers.

*Contact:* Deborah Walters.

## Knowledge Representation

Although most of the projects discussed so far have knowledge representation as a major component, the projects mentioned in this section are directly concerned with it.

### Representation of Visual Knowledge

We are investigating methods of representing visual knowledge in a knowledge representation system integrated with traditional conceptual and propositional knowledge. Visual knowledge is knowledge about how to display objects, attributes of objects, and relations between objects on a graphics terminal screen. At the most basic level, the visual form of an object is a Lisp function that draws the object on the screen when evaluated. However, visual knowledge can also be distributed among nodes in the traditional hierarchies: The knowledge of how to display a particular hammer can be stored at the level of the class of hammers; the knowledge of how to display a person can be distributed among the nodes for heads, arms, hands, and so on; locations of parts are relative to their wholes. Attributes of objects can be seen as functionals that modify graphic-form functions. We are using visual knowledge in our development of a versatile expert maintenance system for digital circuits (see Device Modeling for a Versatile Maintenance Expert System above) implemented in the SNePS Semantic Network Processing System (Shapiro, 1979). Interaction with the user is carried out through the graphic images, including requesting and obtaining data, displaying dynamic traces of the reasoning, and showing the final conclusions.

This research is a project of the SNePS Research Group, and is sponsored by RADC and the Air Force Office of Scientific Research through the Northeastern AIC and by the Southeastern Center for Electrical Engineering Education. (For further information, see Shapiro, Srihari, *et al.,* 1985, 1986.)

*Participants:* James Geller, Stuart C. Shapiro, Sargur N. Srihari, and Ming-Ruey Taie.

### Knowledge Organization Schemes for Psychiatric Diagnosis

Cognitive modeling of the expertise exhibited by a psychiatrist during a diagnostic session provides us with an opportunity to confront some of the central research problems in the field of AI. In this project, we are developing an on-line, computerized assistant that can aid a clinician performing psychiatric diagnoses. In particular, we are investigating (1) the advantages of a computer assistant over a complete computer diagnostic system, (2) the parameters of a domain that indicate its suitability for gaining support from a computer assistant, (3) a functional specification for a computer assistant, and (4) the constraints that this specification places on how to organize the knowledge base around processing structures. Currently, the project centers on the implementation of the psychiatric diagnosis system, Diagnosis and Understanding of Natural Experiences (DUNE), which specializes in affective and anxiety-related disorders. DUNE is based on the idea that successful diagnosis in a complicated domain involves the parallel pursuit of multiple hypotheses. Each hypothesis is implemented as a cluster of processors, and the system involves elaborated processor communication and self-evaluation schemes.

*Participant:* Shoshana L. Hardt.

### Intensional Semantics for Propositional Semantic Networks

A semantic network is a representation in which each concept (including relations between concepts) is represented by a specific node, and nodes are linked to each other by a small set of arcs. The SNePS Semantic Network Processing System contains an inference package that supports forward, backward, and bidirectional inference using rules which are represented in the SNePS network. It also provides for interactive graphics for data entry and explanation, image analysis, and natural language interfaces.

SNePS is one of the few semantic network processing systems that is fully intensional in the sense that nodes only represent intensional entities. Previous attempts by some researchers to provide a semantic interpretation for the system have relied on the "semi-"intensional formalism of possible world semantics. In this project, we are providing a semantic interpretation using a fully intensional theory based on the philosophical theories of Alexius Meinong.

This research is a project of the SNePS Research Group and is supported by a grant from the National Science Foundation. (For further information, see Rapaport, 1978, 1981, 1985a; Shapiro, 1979; Maida & Shapiro 1982; and Shapiro & Rapaport, 1985.)

*Participants:* William J. Rapaport and Stuart C. Shapiro.

## Reasoning

Our reasoning projects include commonsense reasoning, intuitive reasoning, and belief revision.

### Commonsense Reasoning about Diffusional Processes

Naive physics is the body of knowledge that people have about the surrounding physical world. This knowledge is an important part of the commonsense knowledge that enables people to effectively deal with the world. The main enterprise of studying naive physics as a part of AI is to discover or invent the information-processing schemes that can enable computer programs to explain, describe, and predict changes in the physical world. Because people have decades of experience interacting with their immediate physical surroundings, they inevitably develop extremely rich knowledge structures that capture this continuous experience. In an important sense, people are experts in the domain of simple physical events, utilizing amazingly large amounts of knowledge.

Because most people find the dynamics of diffusional processes to be counterintuitive, investigating the way people fail to correctly reason about situations involving these processes might serve as a window on the intuitions people have about the physical world. From the viewpoint of the science of physics, there are at least three general and distinct perspectives from which the process of diffusion can be described. These perspectives look at the process (1) from the level of the movements of individual particles, (2) from the level of isolated flows of collections of particles, and (3) from the level of the system as a whole. These three perspectives correspond roughly to the three theories developed in physics to capture the dynamics of processes at different levels of description, namely, the kinetic theory, fluid mechanics, and thermodynamics. When examining the way people reason about diffusion problems presented to them, it becomes apparent that they use knowledge structures which mix these clearly defined levels of description. This seems to support the conjecture that mental models which provide people with the reasoning power for dealing with everyday physics problems deviate in a significant fashion from scientific perspectives.

The current state of the research project involves the development of theoretical concepts related to the nature of commonsense reasoning in general and naive physics in particular. Among the research topics involved are knowledge organization schemes that can facilitate the reasoning task, a vocabulary for the representation of geometrical shapes, the differences in quality and quantity between expert and novice knowledge, and effective knowledge reorganization schemes. All of the theoretical work is centered around the development of the computer program High Intuition Yields Advanced Learning (HIYAL) that should learn and reason about diffusional processes in complicated geometries.

This project is sponsored by a grant from the National Science Foundation.

*Participant.* Shoshana L. Hardt.

## Architectures for Intuitive Reasoners

We are investigating possible architectures for systems that reason about causal models of the world in general and the physical world in particular. Our reasoners view the world as consisting of behaviors that can be generated by typical devices. A device is an abstract model that generates the same behavior in many situations, and this observed behavior can be decomposed into interacting device behaviors. A database of typical behaviors can be built by modeling the devices and generating their behavior by simulation. Substantial work has been done by other researchers on device simulation in the past five years.

We view the knowledge in our reasoning systems as organized around two computational metaphors: the compiled knowledge that constitutes the database of behaviors and the "general principles" part. When the reasoner encounters an observed behavior, it will attempt to decompose it to match parts with the database entries. If the search succeeds, the reasoner can then proceed to analyze and explain the physical situation and make predictions. However, the more interesting case is when the search for an atypical behavior fails. This situation can arise if the decomposition could have been done in more than one way. In this case, the reasoner will attempt alternative decompositions guided by the "general principles" part of the knowledge base. If all these attempts fail, then the reasoner will start making "educated guesses" about the situation at hand. This mechanism will also be guided by the "general principles" part of the reasoner's knowledge base. We are currently concerned with identifying and modeling typical behaviors and identifying and representing "general principles."

*Participants:* Shoshana L. Hardt and Kulbir S. Arora.

## SNeBR: A Belief-Revision Package.

The SNePS Semantic Network Processing System (Shapiro, 1979) has been extended to handle belief revision, an area of AI research concerned with the study of the representation of beliefs and belief dependence, the development of methods for selecting the subset of beliefs responsible for contradictions, and the development of techniques to remove some subset of beliefs from the original set of beliefs. (For an overview of the field, see Martins, forthcoming.)

SNeBR is an implementation in SNePS of an abstract belief-revision system called the Multiple Belief Reasoner (MBR), which, in turn, is based on a relevance logic called SWM (Shapiro & Wand, 1976; Martins, 1983; Martins & Shapiro, 1983, 1984). SWM deals with supported well-formed formulas (wffs) of the form: $A|t, o, r$, where $A$ is a wff representing a proposition, $t$ is an origin tag indicating how $A$ was obtained (for example, as a hypothesis or as a derived proposition), $o$ is an origin set containing all and only the hypotheses used to derive $A$, and $r$ is a restriction set containing information about contradictions known to involve the hypotheses in $o$. The origin tag, origin set, and restriction set of a wff are computed when the wff is derived, and its restriction set can be updated when contradictions are discovered.

In MBR a context (any set of hypotheses) determines a belief space, which is the set of all the hypotheses defining the context together with all propositions derived exclusively from them. The origin sets of the propositions in the belief space defined by a given context are contained in that context. The only propositions that are retrievable at a given time are the ones belonging to the current belief space (whose context is the set of all hypotheses under consideration at that time).

A contradiction can be detected either because an assertion is derived that is the negation of an assertion already in the network or because believed assertions invalidate a rule being used (where an assertion invalidates a rule). In the former case the contradiction is noted when the new, contradictory assertion is about to be built into the network, because a uniqueness principle (Maida

& Shapiro, 1982) guarantees that the contradictory assertions will share network structure. In the latter case (where an assertion invalidates a rule), the contradiction is noted in the course of applying the rule. In this case, it might be that the contradictory assertions are in different belief spaces (only the new one being in the current belief space); if so, the restriction sets are updated to reflect the contradictory sets of hypotheses, and nothing else happens. If the contradictory assertions are both in the current belief space (which will be the case when one of them is a rule being used), then, besides updating the restriction sets, the user will be asked to delete at least one of the hypotheses underlying the contradiction from the current context. Management of origin sets according to SWM guarantees that, as long as the current context was originally not known to be contradictory removal of any one of the hypotheses in the union of the origin sets of the contradictory assertions from the current context will restore the current context to the state of not being known as inconsistent.

This research is an ongoing project of the SNePS Research Group. It has been supported by the National Science Foundation and by RADC and the Air Force Office of Scientific Research through the Northeastern AIC.

*Participants:* João P. Martins[5] and Stuart C. Shapiro.

## Cognitive Science

Many of the projects discussed above have a cognitive science aspect to them. In this section, we discuss two projects that are explicitly within the multi-disciplinary field of cognitive science.

### Machine Understanding and Data Abstraction

This project consists of an investigation of the applicability of the notion of abstract data types and their implementations to resolve various philosophical controversies surrounding John Searle's "Chinese Room" thought experiment, Daniel Dennett's notion of the "intentional stance," and the problem of the existence and nature of "qualia." In particular, mental states and processes (for example, understanding a language) are properly understood as abstractions (on a par with abstract data types) that both humans and computers implement. (For further information, see Rapaport, 1986a, 1986b.)

*Participant:* William J. Rapaport.

### Graduate Group in Cognitive Science

Cognitive science is an interdisciplinary effort intended to investigate the nature of the human mind. This effort requires the theoretical approaches offered by computer science, linguistics, mathematics, philosophy, psychology, and a host of other fields related by a mutual interest in intelligent behavior.

The Graduate Group in Cognitive Science was formed to facilitate cognitive science research at SUNY at Buffalo. Its activities have focused on language-related issues and knowledge representation. These two areas are important to the development of cognitive science and are well represented at UB by the research interests of faculty and graduate students in the group.

Since its formal recognition in April 1981, the graduate group has grown quickly. Currently, its membership of over 150 faculty and graduate students is drawn from the departments of computer science; psychology; linguistics; communicative disorders and sciences; philosophy; instruction; communication; counseling and educational psychology; educational organization, administration, and policy studies; the intensive English language institute; geography; and industrial engineering as well as other area colleges and universities. The group sponsors lectures and informal discussions with visiting scholars; discussion groups focused on group members' current research; an interdisciplinary, team-taught graduate course, Introduction to Cognitive Science; and a cognitive science library.

**Deictic Centers in Narrative: An Interdisciplinary Cognitive Science Project.** A research subgroup of the Graduate Group in Cognitive Science is developing a model of a cognitive agent's comprehension of narrative text. (The term cognitive agent includes both normal and language-impaired humans as well as nonhuman or artificial agents.) Our model will be tested on a computer system that will represent the agent's beliefs about the objects, relations, and events in narrative as a function of the form and content of the successive sentences encountered. In particular, we will concentrate on the role of spatial, temporal, and focal-character information for the cognitive agent's comprehension.

We propose to test the hypothesis that the construction and modification of a deictic center is of crucial importance for much comprehension of narrative. We see the deictic center as the locus in conceptual space-time of the objects and events depicted or described by the sentences currently being perceived. At any point in the narrative, the cognitive agent's attention is focused on particular characters (and other objects) standing in particular spatial and temporal relations to each other. Moreover, the agent "looks" at the narrative from the perspective of a particular character, spatial location, or temporal location. Thus, the deictic center consists of a WHERE-point, a WHEN-point, and a WHO-point. In addition, references to characters' beliefs, personalities, and so on, are also constrained by the deictic center.

We plan to develop a computer system that will "read" a narrative and answer questions about the deictic infor-

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mation in the text. To achieve this goal, we intend to carry out a group of projects that will allow us to discover the linguistic devices in narrative texts, test their psychological reality for normal and abnormal comprehenders, and analyze psychological mechanisms which underlie them. Once we have the results of the individual projects, we will integrate them and work to build a unified theory and representational system that incorporates the significant findings. Finally, we will test the system for coherence and accuracy in modeling a human reader and modify it as necessary.

*Participants:* In the department of Computer Science, William J. Rapaport and Stuart C. Shapiro, principal investigators, Michael Almeida, Janyce M. Wiebe, and Albert Hanyong Yuhan; in the department of Psychology, Gail Bruder, Erwin Segal, principal investigators, and Joyce Daniels; in the Department of Communicative Disorders and Sciences, Judith Duchan, principal investigator, and Lynne Hewitt; in the department of Linguistics, David A. Zubin, principal investigator, Naicong Li, and Soteria Svorou.

## Northeastern Artificial Intelligence Consortium

The Northeastern AIC is an association of AI researchers at nine universities—Syracuse University, SUNY at Buffalo, the University of Rochester, the University of Massachusetts at Amherst, Clarkson College of Technology, Colgate University, Rensselaer Polytechnic Institute, Rochester Institute of Technology, and the Air Force Institute of Technology. Initial sponsorship of AIC is being provided by RADC and the Air Force Office of Scientific Research.

The purpose of AIC is to enhance research and education in AI at the participating universities and at RADC. In particular, the participants are conducting joint and cooperative research, seminars, workshops, and conferences; providing cooperative educational programs in which students and RADC staff members can take courses at various participating universities; and expanding their AI research and instruction by recruiting additional AI-oriented faculty and students, expanding AI course offerings, and enhancing their AI computing facilities.

*Participants:* Stuart C. Shapiro and Sargur N. Srihari, principal investigators.

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## AAAI-86 CONFERENCE REGISTRATIONS

A final reminder that late registration for the AAAI-86 conference (11-15 August 1986) must be received in the AAAI offices by 11 July 1986. (On-site registration will be available at a higher price.) Late Technical Program Registration fees are $180.00 for members ($225 for nonmembers) or $90.00 for student members ($125 for nonmember students). Late Tutorial Registration fees are $225 per tutorial for members ($260 for nonmembers) or $110 per tutorial for student members ($125 for nonmember students).

*Payment and Registration Notes;* Request for refunds will be honored until 15 July 1985. All refund requests must be in writing.

Only government purchase orders, checks drawn on US banks, international money orders, travelers' checks, or bank transfers (in US funds) will be accepted.

For bank transfers, please add an additional $18.00 to cover bank charges.

We will not accept any registration forms delivered after 11 July 1986. After that date, walk-in registration *only* will be accepted at the conference registration site: Plaza lobby, Philadelphia Civic Center, commencing Sunday, 10 August 1986 between 2:00 pm and 5:00 pm.

*Important Dates to Remember:* Wednesday, 2 July: Deadline for University Housing requests, refunds, or changes.

Thursday, 10 July: Deadline for hotel reservations accepted by the Philadelphia AAAI-86 Housing Bureau.

Friday, 11 July: Deadline for Late Registrations - Technical and Tutorial Programs.

Tuesday, 15 July: Conference Refund Deadline (written requests only *no telephone calls.*)

Sunday, 10 August: Commencement of on-site registration, Philadelphia Civic Center.

*Technical Program Benefits:* Benefits associated with the technical program registration fee are: admission to the science and engineering tracks and the main plenary session; a copy of the *AAAI-86 Conference Proceedings;* a conference registration packet and a copy of the conference issue of the *AI Magazine*; admission to the Exhibit Program; and admission to all receptions, except the gala reception on wednesday night, 13 August 1986.

*Tutorial Program Benefits:* Benefits associated with the tutorial registration fee (each tutorial is a separate fee) include: attendance at the tutorial(s); a copy of the tutorial syllabus; a conference registration packet; admission to the exhibit program; and admission to all conference receptions, except the gala reception on wednesday, 13 August 1986.

*Registration Inquiries:* Please send all inquiries to AAAI-86, American Association for Artificial Intelligence, 445 Burgess Drive, Menlo Park, California 94025. (415) 321-1118 or (415) 328-3123.