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AAAI 1991 Fall Symposium Series Reports

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Discourse Structure in Natural Language Understanding and Generation

Computational modeling of discourse structure is a fundamental component of theoretical and application-oriented work in natural language processing. A representation of the underlying structure of a discourse enhances the ability of a natural language system to interpret and generate a wide variety of linguistic phenomena. This symposium was designed to bring together researchers in different areas of discourse to identify common issues, goals, and techniques and exchange associated theoretical and practical results. Fifty-seven people representing the fields of cognitive science, communications studies, computer science, linguistics, and psychology attended from Canada, Italy, Japan, the United Kingdom, and the United States. Over 25 percent of those attending were students.

The workshop included a lively panel entitled "Discourse Modeling: Where Are We Now and Where Should We Be Going?" chaired by Karen Sparck Jones, with panelists Barbara Grosz, Livia Polanyi, and Bonnie Webber. There were also eight paper sessions and a poster session. Topics of the paper sessions ranged from empirical methodologies for discourse studies to analyses of particular linguistic constructions to computational modeling of cognitive phenomena.

The session entitled Empirical Perspectives on Discourse included reports of experiments in online translation ("Interpreted Telephone Dialogues: A Look at Real-World Discourse Complexities," Sharon Oviatt) and the generation of descriptions of physical scenes ("The Structure of Natural Descriptions," Donia Scott and Lyn Pemberton). Discussion focused on appropriate methodologies for empirical studies of discourse and how the results of such studies might be applied to building natural language processing systems. A session entitled Conversational Modeling also involved the analysis of recorded interactions and consisted of papers proposing theoretical accounts of the collaborative nature of discourse. The need to model conversational coordination was described in "Conversation Actions," David Traum and James Allen, and the importance of establishing mutual belief between speaker and hearer served as an explanation for "Redundancy in Collaborative Dialogue" by Marilyn Walker.

Several sessions centered on discourse-oriented analyses of particular linguistic phenomena. Tense, aspect, and temporal adverbials were the topic of one of these sessions, with papers entitled "Tense Trees as the 'Fine Structure' of Discourse," by Chung Hee Hwang and Lenhart Schubert, and "Temporal Analysis and Discourse Processing," by Fei Song. In a session on the discourse functions of syntactic constructions, Judy Delin and Jon Oberlander discussed the interpretation of cleft constructions in "Clefts, Aspectual Class, and the Structure of Discourse," and Daniel Hardt presented "A Discourse Model Approach to VP Ellipsis." A session on anaphoric reference in discourse produced the most memorable examples of the workshop and included papers by Rebecca Passonneau entitled "Persistence of Linguistic Form in Discourse Processing" and Gregory Ward, Gail McKoon Roger Ratcliff, and Richard Sproat entitled "How Morphosyntactic and Pragmatic Factors Affect the Accessibility of Discourse Entities." Intonation and Discourse, a relatively new area in discourse studies, was the title of another session. The session included papers by Beth Ann Hockey on the interpretation of the discourse marker "ok" ("Prosody and the Interpretation of 'Okay'") and Richard Oehrle ("Grammatical Structure and Intonational Phrasing").

The types of knowledge that should be included in a discourse model were the focus of one session, with proposals from Lynn Lambert and Sandra Carberry ("A Tripartite, Plan-Recognition Model for Structuring Discourse"), Susann LuperFoy and Elaine Rich ("A Three-Tiered Discourse Representation for Multi-Agent Discourses"), and Johanna Moore and Cecile Paris ("Discourse Structure for Explanatory Dialogues"). The importance of AI reasoning and representation techniques to discourse studies was the topic of a session that included papers entitled "Discourse Generation, Temporal Constraints, and Defeasible Reasoning," by Jon Oberlander and Alex Lascarides and "An Abductive Account of Repair in Conversation," by Susan McRoy and Graeme Hirst. In "Risk Taking and Recovery in Task-Oriented Dialogue," Jean Carletta proposed a characterization of communicative strategies as a trade-off between communicative effort and miscommunication risk.

There were many lively discussions during the workshop and several recurring themes and issues: (1) the importance of using larger and more carefully designed corpora and applying sound methodologies to their analysis, (2) the need to look at spoken discourse as well as text and multispeaker discourse as well as narrative, (3) what the relationship between bottom-up and top-down approaches to discourse analysis might be, and (4) the importance of developing formal and computational models of discourse phenomena and the obstacles to such development. The workshop revealed that there is great interest in discourse studies in computational linguistics and related fields and that there is a growing consensus about what goals and methodologies are appropriate to the field.

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Knowledge and Action at Social and Organizational Levels

Contemporary research in AI and cognitive science concerns the nature of knowledge and intelligent action in people and machines. AI and cognitive science researchers model, theorize about, predict, and emulate the activities of people. People are social actors; moreover, knowledgeable machines will increasingly be embedded in organizations comprising people and other machines. Heretofore, AI research has largely been asocial, and thus, it has been inadequate in dealing with much human behavior and many aspects of intelligence.

A growing community of researchers is beginning to investigate the social and organizational dimensions of action and knowledge as fundamental categories of analysis. The aim of this symposium was to bring together researchers to address the question of modeling knowledge and intelligent action at more aggregated analytic levels than that of the individual actor. A second aim was to reexamine some of the premises and formalisms on which notions such as representation and reasoning, or knowledge and action, have classically been located.

Researchers attending the symposium represented numerous AI-related fields as well as a number of fields that had heretofore been pictured by many as having only limited relevance to AI, including sociology, anthropology, economics, and international relations.

One way to examine the issues raised during the symposium is to look at what happens to problems of representing knowledge and action as the scale of interaction is changed. At a simple, individual scale, we might picture a single agent that interacts with an environment (which can comprise several other agents). At the next level of complexity, we can imagine some number of agents that explicitly interact with each other as well as with a more generalized environment. This focus introduces questions such as how to deal with multiple interacting viewpoints and histories, stable organization, asynchrony, and conflict or coherence of action. At a still higher level of complexity, we could envision a large number of agents interacting, giving rise to large-scale emergent phenomena as well as local dynamics. Not all researchers work on issues that arise at all levels; however, researchers representing all levels of analysis attended the symposium.

A large part of the symposium was devoted to exploring the space of social-level knowledge and activity at these different levels and to learning more about the specifics of ongoing work in the related fields. The symposium was structured with four primary speakers, each followed by two prepared discussants and several hours of lively discussion. Gerhard Fischer (University of Colorado at Boulder) discussed his research in building AI-based design systems and traced his movement toward seeing design as a reciprocal argumentation process, a collaborative person-machine design effort. Discussants were Natalie Dehn (Martin Marietta) and Walt Scacchi (University of Southern California). Phil Cohen (SRI International) presented his work with Hector Levesque and others on a formal model of teamwork based on models of the belief and goal states of the agents involved. Discussants were Yoav Shoham (Stanford University) and Christiano Castelfranchi (Rome Laboratory). Cohen and Levesque's research aims to provide a set of logical specifications for agents engaged in teamwork that guarantees that the agents following the specifications will jointly be committed to carrying through the team activity when it is possible. Robert Stephens (Bristol Polytechnic) spoke on a large-scale, distributed, intelligent automation project that involves concurrent control of electric power generation and distribution. Discussants were Jerry Hobbs (SRI) and Mark Bickhard (Lehigh University). Finally, Bernardo Huberman (Xerox Palo Alto Research Center) surveyed the results of several studies and simulations that investigated the probabilistic performance improvements that arise when agents cooperating in heuristic search processes are able to exchange hints (partial solutions) in a hierarchical organizational structure. Discussants were Danny Bobrow (Xerox) and George Kiss (Open University).

The most striking aspect of the symposium was the ability of investigators from a wide variety of disciplinary backgrounds to address topics of common concern. Participants were more or less unanimous in sharing two values: (1) the possibility of characterizing one's ideas in precise computational terms (precision) and (2) a responsibility to the phenomena of human society, whether for purposes of modeling society or embedding complex systems within it (realism). Developing theories and models that are precise and realistic is obviously a large goal. It is inevitable that each of the proposals is stronger on one count or the other. Computationalists need to simplify things to get experiments started; investigators with a background in the social sciences worry about oversimplification. These themes were heard often. For example, Huberman was able to demonstrate encouraging results from a problem-solving scheme in which large numbers of simple agents communicate by sharing hints in the form of potential partial results. Discussion on a technical level isolated specific properties of such constraint-resolution problems that allowed the sharing to take place. Discussion from a broader perspective, however, found participants with social-scientific concerns questioning whether Huberman's model of sharing simplifies away the real problems of mutually coherent interpretation.

This pattern of argument was found on a larger scale in the discussion following Phil Cohen's talk and in Jerry Hobbs' response to Robert Stephens' talk, both of which emphasized the familiar belief-desire-intention (BDI) model and its associated perspectives of action and knowledge. Because this model is highly developed and well understood in the context of a variety of past computational issues, it is naturally the first horse out of the gate in the development of models on social and organizational levels. Many investigators with backgrounds in the social sciences have strong a priori concerns about the basic commitments of the BDI model. It is axiomatic in many parts of the social sciences that the single human individual is not a useful unit of analysis for many important social phenomena. Indeed, a great deal of social theory concerns how to account for large-scale social phenomena without treating people as uniform automata whose lives are wholly laid out by society. Accordingly, several questions were raised about BDI models. Where is the locus of representation of goals, beliefs, and so on, at higher levels of aggregation? Where is the locus of control? What about issues of mutually coherent interagent interpretation of statements about beliefs and intentions (a recursive problem)? How can one account for objective social relations such as relations of social power and relations among social institutions? Responses from BDI proponents, however, demonstrated that they were aware of such questions, had nontrivial approaches to them, and were busily engaged with real data, reexamining within their framework some of the same phenomena that have led many social scientists to markedly different conclusions.

A related area concerned the nature of representation. Many of the participants have been influenced by the widespread social-scientific insistence that representations never have definite and unambiguous meanings, and to the contrary, their relevance to each setting of practical activity must always be interpreted anew or, perhaps, negotiated among a number of actors. This view appears on the surface to conflict with the conventional logical approach to representation in which a given system of representations has a definite range of possible models. In particular, a logical view of communication appears to suppose that all participants agree on the meanings of all their terms a priori. In the discussion, however, there was disagreement about whether logic necessarily entails such things and about the degree of indeterminacy that real representations actually possess.

The symposium ended with an extended discussion of what the key problems and research issues are and how this dialog should continue. Not all the participants shared the same ultimate goals: Some want to build models of social phenomena, others want to build systems to support cooperative work, still others want to take inspiration from social phenomena in building systems for other purposes, and yet others want to understand human society in any way that yields inspiration. No doubt the interests of industrial and theoretical-academic researchers, for example, diverge at some point. However, the participants did make a good first pass at articulating the deep issues that still unite these projects and that are likely to keep uniting them for some time.

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Principles of Hybrid Reasoning

Unlike the topics of other symposia in this series, few outsiders know what hybrid reasoning is. Despite our best efforts to avoid the problem of defining hybrid reasoning, the issue arose several times during this symposium. Indeed, one speaker, Jeff Pelletier, addressed the question directly in arguing that hybrid reasoners don't exist.

AI research progresses without a good definition of AI, so it appears that we can get on in our research without an airtight definition of hybrid reasoning. Nonetheless, a working definition would be useful, so let me take a crack at it: A *hybrid reasoner* consists of two or more integrated subreasoners, each operating on a distinct representation. It is common, although certainly not essential, for the subsystems to use distinct representation languages and distinct inference methods.

The presentations and discussions in our symposium were concerned solely with deductive reasoning. Although the research of the participants covers a broad range of issues and approaches, they all find hybridization to be one of the most promising approaches to designing automated reasoning systems. The attendees are apparently not alone in this opinion: In his report on the 1991 AAAI Spring Symposium on Implemented Knowledge Representation and Reasoning Systems (*AI Magazine* 12(4): 31–37), Chuck Rich said that "almost all the implementers were concerned with the related issues of hybrid architecture and extensibility."

The most common form of hybridization presented at the symposium was integrating special-purpose reasoners into more general-purpose reasoning systems. Typically, the general-purpose reasoner passes off certain subproblems to subservient special-purpose reasoners. The aim is to improve efficiency because, as everyone knows, a special-purpose reasoner can be much faster, exploiting the extra structure that exists in its special domain.

Not all hybrid systems are of this form. The temporal reasoning system presented by Peter Ladkin is naturally thought of as a set of cooperating decision procedures, neither part of which is subservient to the other. In addition, not every system that uses special-purpose inference methods is a hybrid. For example, paramodulation is a special rule for reasoning with equality, but a system consisting of, say, resolution and paramodulation is not hybrid because the two inference rules are applied to the same set of formulas; the inference rules do not have their own representation.

The topics of the presentations and talks illustrate the diversity of hybrid reasoners that are being developed and studied and the range of applications that are being investigated. The integration of constraint-processing techniques into computational systems was a recurring topic, with sessions on their integration into programming systems and their integration into deductive systems and a talk on their integration into deductive databases. One session addressed hybrid reasoning for attribute-value logic. Another session was devoted to issues in implementing and using large hybrid systems. There were also talks and discussion on procedural attachment and the use of specialized inference rules and decision procedures to accelerate deduction. Perhaps the most vigorous discussion was sparked by Ramesh Patil's criticism of the practice of restricting the expressiveness of languages for representing concept definitions to ensure acceptable worst-case response time.

This symposium was about the principles of hybrid reasoning. As in other areas of computer science, researchers would like a set of principles that describe and explain the relationship between a system's behavioral characteristics and its architectural characteristics. The architectural characteristics of a hybrid reasoner include the method in which its components are integrated; what kind of information is communicated among the modules and when; what kind of information can be represented in each of the modules; and the architectural characteristics of the modules themselves. The behavioral characteristics of any kind of deductive reasoning system include what information can be deduced from the information that it has and how efficiently the system can perform such deductions. As an example, my research has identified a class of hybrid reasoners, called *substitutional reasoners*, whose architecture is kept simple by restricting the kind of information that can flow from a subsidiary reasoner to a primary reasoner and requiring that this information be used only in computing instances of formulas. Results of the research identify conditions on the represented information that are necessary and sufficient for the completeness of any substitutional reasoner. To obtain completeness for information that does not meet these conditions, a system needs more mechanisms and communication flow than permitted by the substitutional architecture.

The class of hybrid reasoners is far too diverse for us to expect a grand theory of them all. Rather, what we see and what we will probably continue to see is the development of principles for classes of similar hybrid reasoners. We currently have some idea of what some of these classes are, but over time, we can expect new class boundaries to be introduced and existing boundaries to be shifted and eliminated.

We made little progress toward identifying common principles, which should not be surprising considering how long it usually takes to uncover the principles underlying computational systems. In the meantime, researchers will have to settle for money and success. More positively, as a result of the symposium, each participant became more aware of work that is related or potentially related to his/her own, and everyone increased their awareness of the diversity of the area.

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Sensory Aspects of Robotic Intelligence

A recurring theme at this symposium concerned the two binaries that exist today in the discourse on robotic intelligence: One consists of sensory versus stored knowledge and the other of deliberative versus reactive behavior. Some believed that the tension between the two parts in each binary are mediated by the representation used by a robot for its environment. Others were more swayed by the imperative that the computations be as economical as possible; this group expects the imperative to be the final determinant of the ratios in which the parts of the two binaries will ultimately enter robotic intelligence.

It is important to realize that much progress was made during the last decade in pushing the research frontier as it relates to sensory aspects of robotic intelligence. A decade ago many aspects of sensor-based robotics seemed hopelessly difficult. Now, however, it is not too difficult to design a structured-light–based three-dimensional vision system capable of recognizing and localizing objects in scenes characterized by considerable clutter and occlusion. The part of the computation that would have been of exponential complexity a decade ago is now of low-order polynomial complexity and decreasing. It is now possible to design systems that use run-of-the-mill laboratory computing hardware and can recognize fairly complicated looking objects in bins in just a few seconds. What has made this possible is the discovery of special data structures and object representation schemes that allow pose and identity hypotheses to be verified with virtually no search.

Another area that has also progressed is mobile robot navigation in indoor environments using vision for self-location. It is now possible to design a vision system that can track the uncertainties in the position and orientation of a mobile robot and use the bounds on the uncertainties to limit the search required for the recognition of predesignated spatial features in a Kalman filter–based position-updating scheme. It is now possible for such a mobile robot to traverse hallways at speeds of 8 to 12 meters per minute in the presence of stationary and moving obstacles.

Yet another area where impressive progress has been made is the use of force and torque sensing for high-precision assembly. It is now possible to devise error detection and recovery strategies that allow a robot to automatically recover from the control problems generated by the ever-present noise when a grasped part is brought into contact with another part under tight tolerances.

It was evident that all participants enjoyed the symposium. I believe that much of the success can be attributed to the presence of a varied group of people. The symposium drew individuals from robotics, computer vision, intelligent agent design, and other groups. There was a sense that the state of the art had finally punched through the blocks world barrier and that we were on the threshold of a new research era in which we could expect robots to reason about real-world objects in real-world situations.

The program was a mix of position statements and contributed presentations. Each session began with a 15-minute position statement, followed by a 30-minute discussion session.

The tone of the symposium, with respect to the quality of the technical discourse and the nature of the repartee, was set by the position statements, which by fiat had to be controversial and provocative. In particular, the first position statement, by Matt Mason, entitled "Kicking the Sensing Habit," got the symposium on a rolling start. Mason's assault on these wily sensor pushers and his repudiation of most sensing set the stage for a point-counterpoint type of discussion between him, his respondents (Rod Grupen, Ming Tan, and Sue Gottschlich), and the audience. Subsequent position statements succeeded in maintaining the spirit of the dialog. In "A Lennonist Perspective on Autonomous Agents, or, Nothing Can Be Seen That Isn't Shown," Bruce Donald proposed a formalism that would be based on perceptually equivalent classes, ostensibly to help a robot economize on compute power in its sensory decision making. Because Donald's position was more a comment on what should be done, as opposed to what is wrong with what is currently done, he got off easy with his respondents (Maria Gini and Gary Ogasawara) and the audience. In his position statement, "Divine Inheritance versus Experience in the World: Where Does the Knowledge Base Come From," Ed Riseman took the stand that humans will find it impossible to specify knowledge bases for robots engaged in outdoor navigation and, therefore, that all the humans can do is to provide a learning framework for the robots to acquire most of the required knowledge on their own by observation. In response, the designated respondents (Lambert Wixson, Ramin Zabih, and Steve Blask) and the audience raised a number of issues, including whether it would ever be possible to develop a principled approach to the acquisition of knowledge for outdoor robots given that the environment is so weakly constrained.

In her position statement entitled "An Active Approach to Functionality Characterization and Recognition," Ruzena Bajcsy made a strong case for the functional paradigm that departs from the purely geometric and structural approaches, the current mainstay of robot vision. Her respondents (Seth Hutchinson and Robin Murphy) expanded on the functional theme by pointing out the context dependency of functional tags and introducing a recently implemented system that uses functional reasoning to recognize three-dimensional shapes. Saburo Tsuji's position statement, "Perceptual Zoom: From Omni-Vision to Fixated Vision," was based on a new system that he and his co-workers developed to help an outdoor robot track its global environment; by sampling the outdoors through a slit aperture, this system greatly economizes on the memory required for storing vast stretches of vision data for outdoor scenes. His respondents (Jim Hendler, Douglas Reece, and Keith Nishihara) and the audience concurred with him on the need for special representations by mobile robots navigating outdoors.

In "The Multiple Dimensions of Action-Oriented Robotic Perception: Fission, Fusion, and Fashion," Ron Arkin made a case for channeling sensory perception directly to motor behavior. His respondents (Erann Gat, Marcos Salganicoff, and Min Meng) and the audience raised the issue that it is difficult to specify metrics to evaluate behaviors, especially when a robot is supposed to exhibit more than one behavior simultaneously. The final position statement, by David Lowe, entitled "No Recognition without Representation: Knowledge Access through Learning," argued that simple representations often suffice for recognition, even recognition of articulated objects such as a box with its lid in any position and that these representations can be learned through sensing. His respondents (Ian Horswill, Ross Beveridge, and Yoel Gat) raised issues relating to the upward scalability of schemes designed for learning the various parameters of a parameterized object representation.

Twenty-four contributed presentations were also made. Unfortunately, space limitations do not permit individual descriptions. Therefore, I want to mention that in addition to the respondents named so far, who also gave talks on their work, excellent presentations were also made by David Miller, Jean-Pierre Muller, David Chapman, John Budenske, John Woodfill, Jim Jennings, Lee Spector, and Kurt Konolige.

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