
WORKSHOP REPORT

The 1985 Workshop on Distributed Artificial Intelligence

Les Gasser

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The 1985 Workshop on Distributed Artificial Intelligence (DAI) was held at Sea Ranch, California, 3 to 6 December 1985. Twenty-eight participants gathered in this rugged, windswept northern California coastal village to debate the theory and practice of DAI.

In content, the 1985 meeting differed from prior meetings (reports on prior DAI workshops can be found in Davis 1980, 1982; Fehling and Erman 1983; and Smith 1985). First, there has been a clear movement beyond the early, classical large-grained DAI implementation "successes": HEARSAY, the contract net system, the University of Massachusetts (UMASS) distributed vehicle monitoring test bed, and the Rand Corporation air traffic control (ATC) and remotely piloted vehicles (RPV) studies. The earlier work introduced several problem-solving architectures--the contract-net negotiation framework, the blackboard-based distributed HEARSAY framework, and the hierarchical versus anarchic control regimes developed at Rand, for example--and developed principles for cooperation and organization. New experimental research is refining these architectures and control strategies and providing frameworks for integrating heterogeneous strategies.

At UMASS, Victor Lesser, Dan Corkill, Ed Durfee, and their associates continue to refine their principles of organizational structuring, metalevel control, and self-design using experimental tests of coordination and communication strategies. One remarkable finding that they present-

ed at the workshop came from experiments which compared problem solvers that have organizational knowledge and exchange metalevel control information and those which don't. In environments where problem solvers work with overlapping (that is, redundant) information, exchanging metalevel control information radically improved efficiency. These experiments indicate that achieving both efficiency and reliability (by way of overlap and redundancy) requires metalevel control knowledge in a group of problem solvers.

New experimental DAI research is emerging at the Alberta Research Council, the University of Southern California (USC), and Worcester Polytechnic Institute. Ernest Chang of the Alberta Research Council discussed support for collaborative problem solving in participant systems. Les Gasser of USC presented an overview of his work on modeling negotiations, including bargaining and exchange processes, using the multiagent computing environment test bed. Peter Green of Worcester Tech presented the activation framework model, a message-based test bed for distributed problem solving. In addition, several groups have begun to extend prior work in DAI to practical applications. Van Parunak of the Industrial Technology Research Institute attended and presented his work on YAMS, a contract-net-based system for factory control.

The second difference was the increasing emphasis on the formal bases for representing belief, knowledge, and rational interaction. Two

groups (at SRI International and Stanford University) are developing formal theories of multiagent interaction. Mike Genesereth, Matt Ginsberg, and Jeff Rosenschein at Stanford use game-theoretic and decision-theoretic approaches to modeling rational choice. They have developed strategies for rational interaction in circumstances where agents have some beliefs about each other's options and values but cannot communicate. Phil

research methodologies. The UMASS group presented numerous experimental studies of coordination mechanisms, some of which led to surprising findings. Mike Huhns of Microelectronics and Computer Consortium (MCC) presented his work on the multiple intelligent node document-servers (MINDS) system in which results of experimental and simulated studies were used as feedback to generate improved heuristics for learning

centers at the Alberta Research Council, Boeing Computer Services, the Industrial Technology Research Institute, USC, and Worcester Polytechnic Institute.

Several research problems have become salient, including massively parallel systems, the modeling of uncertainty (for example, future uncertainty about the world), self-organization of problem solvers, and bargaining and exchange in negotiation. New implementation problems and practical problems have also materialized: how to choose among alternative organizational models and how to design flexible frameworks for integrating several problem-solving styles.

In summary, the DAI world slowly shifts its focus, with emphasis placed on formal description, stronger attention to research methodology, and a wider and deeper experimental basis and the flowering of new research groups and the waning of some familiar ones.

Presentations were given in four sessions: (1) distributed problem solving among powerful machines or agents, (2) the theory of DAI, (3) distributed problem solving among "primitive" processors, and (4) hardware and software architectures for DAI. In addition, V. Jagannathan and Rajendra Dodihiawala of Boeing Computer Services, although not present at the workshop, supplied an annotated bibliography of work in DAI. Abstracts of the papers and talks presented at the workshop follow.

Distributed Problem Solving among Powerful Machines or Agents

"Speech Acts and Rationality"

Phillip R. Cohen, SRI International, and Hector J. Levesque, University of Toronto

This paper derives the basis of a theory of communication from a formal theory of rational interaction. The major result is a demonstration that illocutionary acts need not be primitive and need not be explicitly recognized. As a test case, we derive Searle's conditions

Fine-grained distribution of activity in intelligent systems has emerged as a salient issue in the world of DAI

Cohen, Mike Georgeff, Amy Lansky, Rich Waldinger (who presented papers), and others at SRI (for example, Kurt Konolige) have been developing formal theories and representations for processes, actions, beliefs, and plans that will provide a foundation for reasoning about the actions of others in multiagent worlds. Phil Cohen presented his work with Hector Levesque on formal, rational bases for speech acts. Rich Waldinger presented work on basic planning problems (for example, plans with tests). Peter Ladkin of the Kestrel Institute presented his work on modeling time using multiple representations among which a system can choose.

Fine-grained distribution of activity in intelligent systems has emerged as a salient issue in the world of DAI, as it has in other branches of artificial intelligence (AI). Lokendra Shastri of the University of Pennsylvania presented his work on massively parallel encoding of semantic information, and Rich Sutton of GTE Laboratories, Inc., discussed his work on highly parallel approaches to learning world models.

New research methodologies have begun to emerge, and attention is being paid to the validity of research methodologies and their impact on results. During discussion, Mike Genesereth issued a strong call in DAI research for explicit statements of assumptions, hypotheses, criteria for success, and measurements that determine if systems meet these criteria.

As the DAI field matures, controlled experimentation and empirical investigation are gaining importance as

document-storage patterns of individuals.

Several groups reported on new flexible software and hardware architectures for DAI. Roberto Bisiani of Carnegie-Mellon University (CMU) described the design of the AGORA system, targeted for DAI systems on heterogeneous multiprocessors. AGORA is being developed to support real-time speech-understanding research at CMU. Lee Erman presented the ABE framework for integrating many modules with differing styles of problem solving. Rich Filman surveyed a number of possible DAI architectures with possible application to space station problems.

Several participants addressed low-level language and architectural issues. Al Davis of Schlumberger Palo Alto Research Center gave an entertaining and visually beautiful presentation on the design of the FAIM-1 parallel machine's user interface. Vineet Singh of Stanford described his work with Mike Genesereth on parallel models for executing logic-programming languages. Natesa S. Sridharan of Bolt, Beranek, and Newman described his work on SALT-PEPPER, an approach to semiapplicative programming where maximum parallelism is given, and constructs are introduced to inhibit parallelism where it is undesirable. Carl Hewitt of the Massachusetts Institute of Technology (MIT) gave a provocative talk on the limits of logic as a formalism in multiagent open systems.

Several new DAI research groups have appeared. These groups include

on requesting from principles of rationality coupled with a Gricean theory of imperatives. The theory is shown to distinguish insincere or nonserious imperatives from true requests. Extensions to indirect speech acts and ramifications for natural language systems are also briefly discussed.

"Decision Procedures"

Matthew L. Ginsberg, Stanford University

Distributed artificial intelligence is the study of how a group of individual intelligent agents can combine to solve a difficult global problem; the usual approach is to split the original problem into simpler ones and to attack each of these independently. This paper discusses in very general terms the problems which arise if the subproblems are independent but instead interrelate in some way. We are led to a single assumption, which we call common rationality, that is provably optimal (in a formal sense) and which enables us to characterize precisely the communication needs of the participants in multi-agent interactions. An example of a distributed computation using these ideas is presented.

"Manufacturing Experience with the Contract Net"

H. Van Dyke Parunak, Industrial Technology Institute

We have implemented a control system for a discrete manufacturing environment that partitions tasks using a negotiation protocol. The application domain differs in interesting ways from domains to which contract nets have previously been applied.

This report outlines our architecture, summarizes some differences between the factor floor and other problem domains, and discusses how we accommodate these distinctive features. This is a working paper, describing work in progress. Some of the refinements discussed are not yet fully operational.

"DAI Research at GTE Labs: Cooperative, Time-Constrained Problem Solving"

Ralph W. Worrest and Henrik S. H. Sandell, GTE Laboratories, Inc.

Our approach to distributed intelligence is based on the social metaphor of interacting, individually intelligent people. These people are capable of tackling sets of problems that no single member of the group could do individually--sometimes because the problems at hand require "more than two hands" sometimes because they require the person "to be in two places at once," and sometimes because "two heads are better than one."

Our "people" are rich expert systems. They have a specialty implanted in them that is based on years of training and experience. They have a general knowledge of the domain incorporating their specialty and common sense knowledge about problem solving. Finally, they know about social interaction and cooperation.

Our "people" do not yet exist (outside the metaphor). We know how to develop the expert knowledge of solving special problems in a domain. There are many people working on how to encode and utilize first principles knowledge. We are concentrating our efforts on the last body of knowledge, social interaction and cooperation, calling it Cooperative, Time-Constrained Problem Solving.

"Unsolved Problems in the Blocks World"

Zohar Manna, Stanford University, and Richard Waldinger, SRI International

It is commonly said that the blocks world is a solved problem and that planning researchers should have moved on to more realistic domains long ago. Systems such as Winograd's, Sussman's, and Fahlman's are thought to have beaten the blocks worlds to a pulp. Indeed, much recent planning work has a decidedly real-world flavor. Systems have dealt with planning factory processes, scheduling tasks on an aircraft carrier, and tracking vehicles. Others have moved into planning for

multiple communicating agents. Researchers still dealing with the simple blocks world have become apologetic or defensive.

Of course, it would be no great contribution at this stage to concoct a slick ad hoc planner that relies on the relative simplicity of the blocks world, just as a chess-playing system relies on properties of the game of chess. On the other hand, we have found that many basic planning problems that have not been solved or settled in any planning domain occur quite naturally in the blocks world. These problems must be solved sometimes, and, until we solve them in the blocks world, there is little advantage to moving to more complex domains.

"Negotiations and Distributed AI"

Les Gasser, University of Southern California

Distributed AI is the branch of AI concerned with the problems of coordinating the actions of multiple agents for problem solving and intelligence. Among other things, research into DAI is useful because it helps us to explore the fundamental aspects of self-hood and intelligent behavior which are the outcome of interaction with others--the intelligence which springs, in part, from interaction--it is "social intelligence" in the sense that it does not exist apart from social interaction. More conventionally, DAI research can help to reveal and formalize the kinds of intelligence necessary to exhibit "social" behavior: interaction among groups of agents. What do agents have to know and how do they have to reason in order to interact in organized ways? In this paper we present an overview of some work on modeling negotiations among agents for conflict resolution. We believe that it is important to understand negotiation because it is a fundamental strategy for social organization; toward this end, we briefly discuss how work is cooperatively organized and show the place of negotiations. Then we develop a specific computer-implementable model of negotiations which we are building and which we expect to apply in several domains. This work is part

of a larger project concerned with the theoretical nature of Distributed AI and the implementation of a multi-processor DAI testbed and language called MACE (for Multi-Agent Computing Environment).

Theory of DAI

"A Theory of Process"

Michael P. Georgeff, SRI International Artificial Intelligence Center

The notion of process is essential for reasoning about the behavior of agents in dynamic worlds. The purpose of this paper is to show why reasoning about process is so important and to contrast this with other approaches in artificial intelligence (AI) that are based primarily on the allowable behaviors of agents. A model of events is constructed that provides for simultaneous action, and a model-based law of persistence is introduced to describe how events affect the world. No frame axioms or syntactic frame rules are involved in the specification of any given event, thus allowing a proper model-theoretic semantics for representation. It is indicated how an algebra of processes can be employed to ascertain critical properties of multi-agent systems, as freedom from deadlock, and how systems of processes can be reasoned about given specifications of the component processes. A notion of hidden (internal) events is then introduced, whereupon it is shown how this provides an abstraction capability that can be used to avoid the combinatorial explosion typical of other AI approaches to multi-agent planning. Finally, it is shown how the law of persistence, together with notions of causality and derived predication, makes it possible to avoid most of the difficulties associated with the frame problem.

"New Foundations for Intelligent Systems"

Carl Hewitt, Massachusetts Institute of Technology Artificial Intelligence Laboratory

This paper explores some ideas for

new foundations for artificial intelligence. Limitations of traditional approaches such as problem spaces and logic are outlined. Analysis of the nature of knowledge bases of physical systems lead to the conclusion that their axiomatizations contain contradictions. These contradictory knowledge bases challenge the suitability of logic as a foundation for decision making in intelligent systems. We propose a methodology called due process reasoning to overcome limitations of previous foundations.

"A 'Behavioral' Approach to Multi-Agent Domains"

Amy L. Lansky, SRI International

This paper discusses a new approach to the specification of properties of multi-agent environments and the generation of plans for such domains. The ideas presented elaborate previous work on a formal model of concurrent action, called GEM (the Group Element Model), which encourages the description of domain properties in terms of behavioral constraints, rather than using more traditional state predicate approaches. Behavioral descriptions emphasize the causal, temporal, and simultaneous relationships among actions and are particularly suited to describing the complex properties of multi-agent domains. This paper also presents some initial ideas on how GEM can be used as a framework for multi-agent planning. Given a set of constraints describing a problem domain, a GEM-based planner would generate plans through a process of incremental constraint satisfaction.

Distributed Problem Solving among Primitive Processors

"Cooperating Knowledge Systems"

M. Benda, V. Jagannathan, and R. Doshiwala, The Boeing Artificial Intelligence Center

Expert systems are like idiot savants--they can perform tasks in constrained

domains efficiently and effectively. The question addressed in our research is how to organize such systems so that they cooperate most effectively. Cooperation of knowledge sources is a function of how they are organized and how they communicate with each other. One reason for studying these questions is that intelligent behavior (or the appearance of intelligent behavior) can be a result of a complex structural arrangement of un-intelligent individuals. In this paper we explore how various modes of organization affect "intelligence," where "intelligence" is proportional to the rate of convergence to a solution of a specific problem.

Several hypotheses were investigated. The hypotheses fall into two separate categories--one related to the modes of cooperation and the other related to the implementation framework. Experiments were designed to test the following hypotheses. The hypotheses related to organization are whether a more inherently parallel organization is also the more effective one and whether a better organization of the agents increases their effectiveness. The hypotheses related to blackboard implementation are whether the architecture is well suited for the implementation of cooperation between multiple agents who adopt diverse forms of organization and whether the framework efficiently supports and exploits parallelism that may be inherent in a problem.

"An Intelligent System for Document Retrieval in Distributed Office Environments"

Uttam Mukhopadhyay, Larry Stephens, and Ronald Bonnell, University of South Carolina and Michael Huhns, Microelectronics and Computer Technology Corp.

MINDS (Multiple Intelligent Node Document Servers) is a distributed system of knowledge-based query engines for efficiently retrieving documents in an office environment of distributed workstations. By learning document distribution patterns, as well as user interests and preferences during system usage, it customizes document retrievals for each user. A

two-level learning system has been implemented for MINDS. The knowledge base used by the query engine is learned at the lower level with the help of heuristics for assigning credit and recommending adjustments; these heuristics are incrementally refined at the upper level.

"Coherent Cooperation among Communicating Problem Solvers"

Edmund Durfee, Victor Lesser, and Daniel Corkill, University of Massachusetts

When two or more computing agents work on interacting tasks, their activities should be coordinated so that they cooperate coherently. Coherence is particularly problematic in domains where each agent has only a limited view of the overall task, where communication between agents is limited, and where there is no "controller" to coordinate the agent. Our approach to coherent cooperation in such troublesome domains has been developed and implemented in a distributed problem solving network. This approach stresses the importance of sophisticated local control by which each problem solving node integrates knowledge of the problem domain with (meta-level) knowledge about network coordination. This allows nodes to make rapid, intelligent local decisions based on changing problem characteristics with only a limited amount of conferring with each other to coordinate these decisions.

In this article, we describe three mechanisms that improve local control decisions and enable nodes to cooperate coherently. These mechanisms are an organizational structure which provides a long-term framework for network coordination to guide each node's local control decisions, a planner at each node which develops sequences of problem solving activities based on the current situation, and meta-level communication about the current state of local problem solving which enables nodes to dynamically make short-term refinements to the long-term organization. We provide empirical results showing the benefits and limitations of these mechanisms

in a variety of problem solving situations. Moreover, these mechanisms are not without cost, and we provide performance results showing the mechanisms to be particularly cost-effective in complex problem solving situations. Finally, we describe how these mechanisms might be of more general use in other distributed computing applications.

"A Massively Parallel Encoding of Semantic Networks"

Lokendra Shastri, University of Pennsylvania

This paper presents a highly distributed solution to the problem of representing and reasoning with conceptual information. It describes how knowledge about concepts, their properties, and the hierarchical relationship between concepts (e.g., the IS-A relation) can be encoded as an interpreter-free massively parallel network of simple processing elements. It also describes how such a network can solve the inheritance and categorization problems in time proportional to the depth of the conceptual hierarchy.

"Learning Distributed, Searchable, Internal Models"

Richard Sutton, GTE Laboratories, Inc.

Although searching an internal model of the world is a standard planning technique, how such searchable world models can be learned is poorly understood. We have been taking a highly-distributed, connectionist approach to this problem. The learning system consists of a large number of individual learning elements, each of which takes responsibility for learning about a different aspect of the external world. For example, for each state descriptor there might be an element devoted to learning when a state that meets that descriptor will occur, and for each possible operator there might be an element devoted to learning when that operator is likely to be applied. Typically, many more elements are used, corresponding to various combinations of descriptors or combinations of operators and descriptors.

Hardware and Software Architectures for DAI

"AGORA: An Environment for Building Problem Solvers on Distributed Computer Systems"

R. Bisiani, Carnegie-Mellon University

Carnegie-Mellon University is developing a speech recognition system for recognizing continuously spoken English without previous knowledge of the identity of the speaker. This research is part of the DARPA program in Strategic Computing. The eventual goal of the system is to handle a 10,000 word vocabulary in real-time. The intermediate goals are to recognize a 200 word vocabulary by 1986, a 1,000 word vocabulary by 1987, and a 5,000 word vocabulary by 1989. The system being developed by CMU uses a feature-based approach in which basic phonetic units of speech are recognized from the acoustic signal. The phonetic units are then combined into words and the words into sentences. Custom signal processing hardware is being used to process the input speech and derive parameters such as amplitude, zero crossings, pitch, and energy levels. There are two major thrusts in the CMU speech program--to develop algorithms for recognizing continuously spoken English and to develop an environment within which the algorithms can be integrated with suitable control. This paper describes such an environment.

"A Taxonomy of Participant Systems"

Ernest Chang, Alberta Research Council

Participant Systems (PS) are computer systems that support the collaboration of persons working together on a common intellectual problem. For instance, an architect, engineer, contractor, and client may design a building using a computer system that supports common visual space, action space, and cognitive space through the use of a single problem representation,

while the participants may be physically distributed over several locations. The system would contain one or more knowledge-based modules, such as an expert system in the structural use of materials, another in interpretation of the building code, another in design methodology, and so on.

"The FAIM-1 User Interface: Human Engineering for the Fifth Generation"

Shimon Cohen, Al Davis, and Shane Robinson, Schlumberger Palo Alto Research Center

One of the critical system problems that Fifth Generation architects must address is not just how the system will work but also how the user is going to interact with the system in order to understand what is going on. Multiprocessor system architectures present new human interface barriers due to their inherently complex nature. In a system where a potentially large number of concurrent activities may be asynchronously operational and where myriads of complex communication patterns may be formed for relatively short durations, it will indeed be very difficult for the user to maintain an accurate mental model of the system's behavior. We therefore contend that in order to use and create these new highly concurrent systems, an equally new generation of man-machine interface tools and concepts will need to be developed. We have addressed certain aspects of this problem as part of an effort to create a highly concurrent symbolic multiprocessing system known as FAIM-1. In general, the approach is to use a set of mechanical assistants to collect information about the system ensemble in a variety of ways and to display it either graphically, textually, or both in a way that is customizable to the user's specification. This paper presents a status report of our current work in this area. Primarily, it covers user interface issues in two domains: (1) architectural simulation and (2) run-time system monitoring. Both areas are discussed in general, but examples are in the context of their use of the FAIM-1 system.

Multiprocessor system architectures present new human interface barriers

"ABE: Architectural Overview"

Lee Erman, Michael Fehling, Stephanie Forrest, and Jay S. Lark, Teknowledge

The ABE project at Teknowledge is producing a new environment for industrializing the development of intelligent systems. We are motivated by the requirement to provide application developers with facilities to support reuse of previously-constructed components, integration of diverse components, and large-scale application system development.

Central to ABE is a multi-level architecture for developing intelligent systems. This architecture supports aggregations of cooperating, more-to-less autonomous, problem-solving components. In this paper we briefly describe the multiple levels and concentrate on the general model of computation that forms the lowest level.

"AF: A Framework for Real-Time Distributed Cooperative Problem Solving"

Peter E. Green, AI Research Group, Worcester Polytechnic Institute

This paper reports current research into real-time intelligent decision-making systems. Such systems often require the use of multiple interconnected computers which may be geographically distributed. This paper describes a software framework which supports the implementation of artificial intelligence programs which must run in real-time on such systems. The framework, called AF for Activation Framework, is based on the paradigm of expert objects communicating by messages in the manner of a community of experts. One of the principal features of AF is the use of message priority levels as the basis for distributed scheduling and focus-of-attention mechanisms.

This paper traces the evolution of

AF from HEARSAY II, through the Distributed Sensor Network (DSN) testbed, to current work on real-time systems in the area of robotics. The DSN testbed used a distributed HEARSAY II approach to acoustically track low flying aircraft in real-time and provided valuable insight into the issues that a real-time distributed AI system must address. The paper describes these issues and shows how AF addresses most of them.

The paper describes the expert Activation Framework Objects, the message formats, and the software frameworks into which they are embedded. It describes how the concept of activation, drawn from neural network modeling, is used as a basis for scheduling the running of expert objects and as the basis for making decisions with incomplete data. It also describes how concurrency is achieved and how expert objects can be written in a language appropriate to the problem domain.

Finally, this paper describes the status of current work. It describes in some detail a framework written in the C language which is being applied to robotic systems. It also briefly describes a Lisp framework which is under development and current work on the development of a VLSI activation cell processor which will implement the AF paradigm in an architecture that is similar to that of a data flow computer.

"PM: A Parallel Execution Model for Backward-Chaining Deductions"

Vineet Singh and Michael Genesereth, Stanford University

This paper describes PM, an execution model for automating backward-chaining deduction on multiple processors. The term execution model refers to the state, messages, and procedures required to perform the computation correctly. The target multiprocessor is characterized by (1) a large number of small processors, (2) inter-processor communication via messages, and (3) a distributed database. The key distinguishing feature of PM is simultaneous exploitation of and-parallelism or-parallelism and pipelining in this scenario.

"Semi-Applicative Programming: An Example"

N. S. Sridharan, AI Department, Bolt, Beranek and Newman Laboratories

Most current parallel programming languages are designed with a sequential programming language as the base language and have added constructs that allow parallel execution. We are experimenting with an applicative base language that has implicit parallelism everywhere, and then we introduce constructs that inhibit parallelism. The base language uses pure Lisp as a foundation and blends in interesting features of Prolog and FP. Proper utilization of available machine resources is a crucial concern of programmers. We advocate several techniques of controlling the behavior of functional programs without changing their meaning or functionality: program annotation with constructs that have benign side-effects, program transformation, and adaptive scheduling. This combination yields us a semi-applicative programming language and an interesting programming methodology.

We have been successful in starting with the specification of a context-free recognizer and in deriving variants of the recognition algorithm of Cocke-Kasami-Younger, which is a bottom-up recognizer which works left-right on the input string. One version is the CKY algorithm in parallel. A second version includes a top-down predictor to limit the work done by the bottom-up recognizer. A third version uses a cost measure over derivations and produces minimal cost parses using a dynamic programming technique. In another line of development we arrive at a parallel version of the Earley algorithm.

"Distributed Artificial Intelligence: An Annotated Bibliography"

V. Jagannathan and R. Dodhiawala, Boeing Computer Services

Distributed Artificial Intelligence (DAI) refers to the subarea of AI which is concerned with the problem of utilizing multiple processors in the solution of AI problems. The question is

how does one harness the advance of the hardware technology in a meaningful manner? This has spurred research in a variety of theoretical and practical issues. On the theoretical side, there has been considerable interest on the issue of modeling human cooperation. On the practical side, for instance, the blackboard model has been proposed as a vehicle to implement such cooperation.

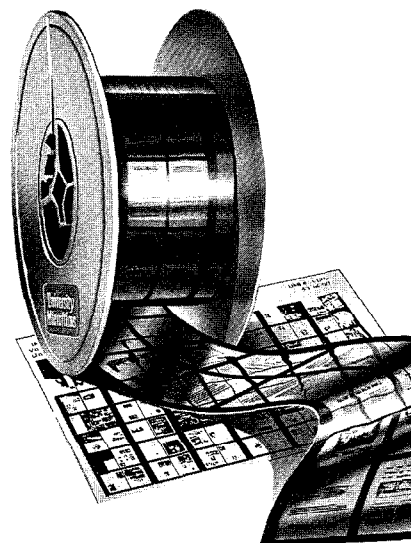
Considerable work has been done on identifying the intrinsic parallelism in AI problems which can then be exploited using multiple processors. This has resulted in an ongoing debate on the granularity of the parallelism, an area that needs further study. On the one hand, we have the concept of a knowledge source that basically defines a unity of knowledge, as well as the granularity level. On the other, we have the logic programming group which envisions granularity at the individual clause level. This annotated bibliography is an effort to compile the various perspectives prevalent in the AI literature which are relevant to the area of DAI. The annotations have been organized on the basis of the institutions to which the first author belongs. This approach was selected to allow the reader to identify those institutions which currently are emphasizing development of the subject material.

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Editor's Note: We are in the process of catching up on some of the many AI workshop reports submitted to the magazine. This issue covers the 1985 workshop on DAI. The next issue will contain a report on the 1986 workshop, written by N. S. Sridharan.

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