

Research in Progress

MIT Artificial Intelligence Laboratory

The MIT AI Laboratory has a long tradition of research in most aspects of Artificial Intelligence. Currently, the major foci include computer vision, manipulation, learning, English-language understanding, VLSI design, expert engineering problem solving, common-sense reasoning, computer architecture, distributed problem solving, models of human memory, programmer apprentices, and human education.

Understanding Visual Images

Professor Berthold K. P. Horn and his students have studied intensively the image irradiance equation and its applications. The reflectance and albedo map representations have been introduced to make surface orientation, illumination geometry, and surface reflectivity explicit. Recent work has centered on modelling the effects of the atmosphere which distort intensity values and make classification of terrain and related computations using the albedo map inaccurate. Horn and Brian Schunk have recently proposed a mechanism for determining optical flow which is remarkably resilient. William Silver has completed an implementation and elaboration of the idea of photometric stereo introduced earlier in the group by Dr. Robert Woodham.

Natural Vision

Professor David Marr and his colleagues Drs. Eric Grimson, Keith Nishihara, Shimon Ullman, and Kent Stevens, together

with Ellen Hildreth, have made considerable progress on a computational theory of human vision. The approach gives key emphasis to a succession of explicit descriptions at varying levels of visual processing, including the zero-crossing map, the primal and $2\frac{1}{2}$ D sketches, and the so-called Spasar 3D representation. Recent work has centered on directional selectivity, evidence for a fifth, smaller channel for early processing, the Marr-Hildreth theory of edge detection, a model of the retina, a computational theory of stereopsis and its implementation, surface reconstruction by filling in from a sample of values in the $2\frac{1}{2}$ D sketch, texture gradients, surface contours, and a study of the sufficiency of the zero-crossing map by attempting to extend Logan's theorem to two dimensions. Recently, Dr. Mike Brady has joined the Laboratory and has initiated a study of the psychology of reading.

Manipulation

Dr. John Hollerbach has developed a theory of human handwriting and shown that it accounts for much of the available empirical data. He has also shown that the Lagrangian formulation of the equations of motion of a 6 degree of freedom manipulator can be formulated as recurrence relations leading to an exact solution in linear time. Other work has concerned the control theory necessary to make manipulators move quickly, an analysis of compliant motion, and a theory of spatial planning by Lozano-Perez. We have constructed a tendon finger and touch sensor, a cartesian arm, and have a tendon shoulder under construction. Berthold Horn and his students have further developed the configuration state model for manipulator control.

Over the past two years we have started a program of research into the development of VLSI systems. Professor Gerald Sussman, John Holloway, Tom Knight, Howie Shrobe, and others have developed a number of systems, including a single ship SCHEME processor. We have TTL implementations of a number of our vision algorithms, and we are in the process of switching some of them to VLSI.

Expert Problem Solving and VLSI Design

Traditional automated synthesis techniques for circuit design are restricted to small classes of circuit functions for which mathematical methods exist. Professor Gerald J. Sussman and his group have developed computer-aided design tools that can be of much broader assistance. The work has developed the idea of analysis by propagation of constraints. Guy L. Steele developed a language to support such programming, Johan de Kleer studied causal and teleological reasoning in the recognition of circuit function from schematics, and Howie Shrobe has worked on constraint satisfaction and the development of an interactive knowledge-based system for substantially supporting VLSI design. Jon Doyle has studied belief revision via truth maintenance and non-monotonic logics, as well as self-conscious adaptive deliberate reasoning programs. Richard Waters, Charles Rich, and Howie Shrobe have developed the idea of a programmer's apprentice.

Learning and Language

Professor Patrick H. Winston has studied systems that reason by analogy. During the past year, he has worked out a theory and implemented a system. Professor William Martin has continued his work on computer understanding of natural language. Robert Berwick has developed a theory and system that can learn a substantial part of the syntax of English, based on a theory of syntactic recognition developed in the laboratory by Mitchell Marcus. Other work on Natural Language understanding has centered on determination of focus during discourse and response generation.

Personal Machines and Computing Concepts

Intelligent information processing places enormous demands on computing resources, and the computational facilities required to effectively support research in Artificial Intelligence are equally large. About five years ago it became clear to Richard Greenblatt and his associates that our computing needs would be best served by powerful personal computers which execute LISP extremely efficiently and which maintain the level of system support. Currently we have eleven LISP machines and plan a further nine over the next couple of years. All our machines are interconnected through an eight-megabit packet switched network called the CHAOSNET.

On the theoretical side, Professor Randall Davis has developed a theory of distributed problem solving which he calls the Contract Net, in which goals are broadcast to sub-contractors, who then bid for them based on their current work load, the description of the contract, and their abilities. Professor Carl Hewitt and his colleagues have developed an architecture for large scale distributed systems which they call the Apiary, and which is based on the migration of processes to free processors to optimize throughput and achieve load balancing. They have introduced a descriptive formalism called OMEGA, which contributes to many of the issues of current concern in knowledge representation, and they have applied it to describe the various structured entities such as messages in a study of cooperating sequential programming.

Basic Theory

Professor Marvin Minsky has worked on a theory of human thinking, which likens the mind to a society of agents and attempts to combine a number of insights from psychoanalytic, developmental, and cognitive theories of mind. Further work by Richard Greenblatt and Dr. Lucia Vaina develops the idea of thread memory.

Information Sciences Institute University of Southern California

ISI is an off-campus research center in the University of Southern California's School of Engineering. The Institute engages in a broad set of research and application oriented projects in the computer sciences. These projects range from advanced research efforts aimed at producing new concepts, through development of prototype systems, to operation of a major Arpanet computer facility. Except for the Computer Services group, these projects range from one up to ten people. ISI is composed of about 130 full time people plus a number of part-time graduate research assistants and, except for a small operation in San Diego, is entirely housed in facilities at Marina del Rey, California. ISI currently operates about a half-dozen Tenex and TOPS-20 systems as network facilities. Part of these facilities support in-house research; the remainder supports research at other ARPA-supported sites.

AI-Related Projects

Specification Formulation, Testing, and Implementation

Robert Balzer, Lee Erman, Martin Feather, Neil Goldman,
Philip London, and David Wile

This is an area of three interrelated projects aimed at facilitating the creation, testing, and optimized implementation