# PANEL ON DEALING WITH UNCERTAINTY

chairman
Randall Davis
MIT
Cambridge, MA, USA

## Participants

Shigetoko Kaihara
University of Tokyo Hospital
Tokyo, Japan

Edward Shortliffe
Stanford University Medical Center
Stanford, CA, USA

Lofti Zadeh
University of California
Berkeley, CA, USA

## Introduction

The problem of dealing with uncertainty arises in many areas of AI research and has been attacked with a number of mechanisms. This panel is intended to bring together several of the researchers who have had direct experience with the Issue, to report briefly on their efforts and discuss the relative merits of the various approaches.

The panel, originally entitled "Reasoning with Uncertainty", was renamed to encourage a broader view of the topic. "Reasoning", i.e., inference, in the face of uncertainty is only one of the manifestations of the problem and may as a result be too narrow a perspective. Part of the emphasis in the discussion will be to examine the utility of a broader view.

## The problem

In the few domains where concepts and inferences can be totally formalized (e.g., pure mathematics), there is no uncertainty of the sort we are discussing here. Unfortunately, In all real problems attacked by AI, we eventually run afoul of the Issue. The problem commonly has two sources. First, the basic data we have to deal with may be uncertain. This may occur due to noise (as in speech or vision), due to the fallibility of our measurement procedures (as in medical laboratory tests), or due to the inherently ill-defined nature of the concept involved (as in "block A is 'near' block B"). Second, the processing applied to that data may introduce its own uncertainty, typically because we lack a comprehensive understanding of the domain. In speech understanding, for instance, we have as yet no theory which allows us to proceed unerringly from waveforms to phonemes to words. At best we can offer plausible guesses at each stage, and must hedge our bets by making multiple such guesses.

## The Questions

To provide a focus for the discussion, the participants were asked to consider each of the following questions.

*Construing the issue of uncertainty in the broadest sense, what kinds of problems attached in AI appear to have dealing with uncertainty as a truly central issue? How is uncertainty manifested in those problem areas? For example, work on deductive inference [6], modelling some aspects of common sense reasoning [9], hypothesis formation [5], and signal understanding [1] all had to deal with uncertainty of slightly different form, and all developed different mechanisms.*

*The psychological connection: What kind of behavior do people display when dealing with uncertainty? What can we learn from this and ought we to try to mimic it in our programs?*

*What are the current interesting and unsolved issues in representing and dealing with uncertainty?*

*What would constitute a good solution to the problem? That is, what performance characteristics would it display?*

*Has there been too much attention paid to the numbers? All of the schemes developed so far eventually use some numeric representation of certainty, but in some the computation and propogation of those numbers is the central concern of the scheme. As we note below, it might be argued that this is an undesirable situation.*

Of these questions,the last appears to be potentially the most controversial; it might prove interest-ng to focus on it In more detail.

As Inspiration, consider the following argument that strong emphasis on the numeric aspects of the problem is misguided. First (perhaps not surprisingly) none of the schemes developed to date has a precise notion of uncertainty, a situation which is manifested in the ill-defined nature of the numbers involved and the processing applied to them. At best, we are given rough guidelines for what the numbers are to mean and some vague assurances that they can be assigned consistently. The arithmetic then done on them is typically ad hoc and its formal properties (e.g., its relation to other models of inference) often not wetl understood. The overall effect — ad hoc processing of ill-defined numbers -- does not inspire confidence in the result.

One common response is that not much attention is paid to the precise result, only the range it falls in or the overall ordering it produces. This brihgs up yet another problem, a by now traditional dilemma: if the systems built around these mechanisms are too sensitive to the numbers produced, that's bad because no one is ready to defend the precise numbers. Yet if the systems are relatively insensitive to the numbers, then all of that mechanism appears spurious. What is the "appropriate** level of sensitivity[7]

In more general terms, I suggest as a point for discussion the following claim: The numbers and numeric calculations involved in representing and dealing with uncertainty are at best artifacts. Any time the main focus of attention is on the numbers, that's a symptom of something wrong, most likely that there is too little power in the underlying approach to the problem. As a contrast, consider the HEARSAY-II [1] work on speech understanding, in which dealing with uncertainty was viewed as an issue of problem solving, and in which the system architecture and problem solving paradigm were designed to confront the issue. Various measures of uncertainty were introduced (e.g., the credibility of hypotheses, the focus of attention evaluations, etc.), but they played a far less central role because the basic approach — which included the use of multiple cooperating knowledge sources, best-first search, etc., -- was itself capable of reasonable performance in the face of Uncertainty.

As a specific example of the difference in methodology, consider HEARSAY'S use of word hypothesis credibility ratings. One way to attempt to get hip,h performance would have been to put effort into developing a finely tuned rating scheme which could be relied upon to give the best score to the correct hypothesis. But this was not done. Instead a version of best-first search was developed which first sought out multi-word hypotheses and then used these as "islands of reliability** from which to press forward the search for a good global hypothesis [2]. The power of the system came from its basic problem solving paradigm, not an elaborate arithmetic model of uncertainty.

Other mechanisms with similar abilities to deal with uncertainty have been explored in other problems:

*partial matching, in which the result of the match is not just success or failure, but a symbolic indication of how closely the match was achieved and what parts failed to match;*

*"constraint sharing", resolving uncertainty by taking advantage Of ways in which partial solutions to the problem mutually constrain each other. That is, rather than attempting to resolve every ambiguity as it arises by carefully ranking every alter native, the program continues processing and uses other results to rule out some possibilities. The technique has its roots in relaxation techniques developed for solving differential equations, but has since been applied in symbolic form to a range of AI problems (e.g., 18,3,7,4]).*

The success of such mechanisms on interesting problems and their deemphasis of numeric propogation schemes is, or should be, food for thought.

## Raferences

[1] Erman L, Lesser V, A multi-level organization for problem solving using many diverse cooperating sources of knowledge, *Proc 4th IJCAI,* pp. 483-490.

[2] Lesser V, et al, Selection of word islands in the HEARSAY-II speech understanding system, *Proc 1977 IEE Conf on ASSP.*

[3] Lesser V, Corkill D, The application of AI techniques to cooperative, distributed problem solving, Technical Report, COINS Dept, UMass at Amherst.

[4] Mackworth A, Consistency in networks of relations, TR75-3, CS Dept, Univ. of British Columbia, July 1975

[5] Pople H, The formation of composte hypotheses, *Proc 5th IJCAI,* pp 1030-1037.

[6] Shortliffe E, Buchanan B, A model of inexact reasoning in medicine, *Math Biosci,* 23,351-379(1975).

[7] Steele G, Sussman G, Constraints, AI Memo 502, Nov 1978, MIT.

[8] Waltz D, Understanding line drawings of scenes with shadows, in *Psychology of Computer Vision,* Winston, ed.

[9] Zadeh L, Fuzzy sets, *Info Control,* pp. 338-353 (1965).

# PANEL: HISTORY OF ARTIFICIAL INTELLIGENCE RESEARCH, 1956-61

Edward A. Feigenbaum, Panel Chairman
Computer Science Department
Stanford University
Stanford, CA 94305

Understanding the history of the development of a body of ideas is often a precondition for a creative contribution to that body of ideas. The AI field seems to lack a sense of its own history. It is a field of practitioners rather than scholars. This is paradoxical since the field is not yet a quarter-century old, and many of the principal scientists attending its birth are still vigorously active in its development.

Realizing this, the IJCAI Program Committee organized a panel on the history of AI at IJCAI77, and the current Program Committee chose to continue this biannual educational event. As it happened, the members of the 1977 panel chose to range broadly over the "pre-history" of the field—from the Greeks through post-war cybernetics. Not discussed in detail were the critical intellectual events of the formative period, 1956-61. It is to this period that the IJCAI79 panel will devote its attention.

The formative period can be characterized by its intellectual themes, by the programs that were written to test ideas, and by the individuals who made the contributions.

The two major themes of AI work--machines that reason and perceive, and information processing models of human cognition—were much more closely intertwined then than they are now. For example, the Logic Theorist (LT, 1956), along with Samuel's Checker Player (1955-56) the first heuristic programs that ran on computers, helped to launch the "smart machines" work of our field. LT alsowas a major event in Psychology when its description appeared in Psychological Review as "Elements of a Theory of Human Problem Solving" (Newell and Simon). Similarly, the General Problem Solver (GPS, 1957-59) was for years a major focus of AI's problem solving research, while at the same time standing as the most complex and detailed model of a human thought process that had ever been constructed and tested.

In the formative period, the major events were clustered in a Carnegie Tech/RAND Corporation collaboration, led by Newell, Shaw, and Simon; an MIT group led by McCarthy and Minsky; and IBM projects of Samuel and Gelernter, et. al. In a remarkable burst of creativity that began in late 1955, Newell, Shaw, and Simon conceived LT; invented list processing (IPLI and II) to handle the novel programming problems of writing LT; conceived and programmed GPS and the NSS Chess Flayer; and made various programming innovations that were embodied in IPLIII, IV, and V (all 1957-59). Seminally related to these events were papers by Newell (1955) on an adaptive chess machine and by Simon on a behavioral theory of rational choice and the influence of the environment on problem solving and decision making. These two papers of Simon were in a sense the culmination of years of study on the bounds of individual and organizational information processing and rationality; and the processes by which people and organizations made decisions and solved problems within these bounds. It is for this work, initially addressed to economists and behavioral scientists, that Simon won the Nobel Prize in 1978. The students of Newell and Simon also produced a number of key programs of the time including: the EPAM model of human verbal learning and memory (Feigenbaum, 1959); a model of hypothesis formation in binary-choice decision making (Julian Feldman, 1959); an early natual-language understander, SAD-SAM (Lindsay); and an application to a management science problem of assembly line balancing (Tonge).

At IBM, Gelernter and his group, with support from Rochester, proceeded to program the Geometry Theorem Prover. They too created a list processing system, FLPL (Fortran List Processing Language, 1959). Samuel continued developing and experimenting with his

Checker Player, particularly the learning feature in which self-improvement of the play took place by a "hill-climbing" adjustment of the weights of an evaluation function. And Bernstein, a programmer/chess master, developed another of the early chess programs.

Other important activity had a New England locus. Two important early conferences were held there: the Dartmouth Summer Conference on Artificial Intelligence (1956) and the meeting of the IEEE Professional Group on Information Theory (1956, a conference noted as the firs* formal presentations of LT and of Chomsky^ linguistic theory). At Lincoln Laboratory, Selfridge and Dineen wrote the first character recognition program (approximately 1955); and later Selfridge and his group wrote the influential pattern recognition system Pandemonium (1959).

McCarthy formulated a number of problems of the interaction of mathematics and mathematical logic with programming and artificial intelligence. Understanding the importance of the list structure and list processing innovations, and merging these with his thinking about formal representations and about proofs of the properties of programs, he invented the LISP notation that was the basis for the development of LISP translators at MIT in later years. Slagle, at MIT, extended ideas on heuristic search with his Symbolic Integration program, SAINT. Minsky labored to organize the cascade of early ideas and produced his important paper "Steps toward Artificial Intelligence". And McCarthy suggested the idea of time-sharing a computer, reflecting the concerns of the AI community for both economical interaction with running AI programs, and with programming efficiency.

Fortune smiled upon the editors of the collection Computers and Thought (Feigenbaum and Feldman, 1963), which turned out to contain an almost unblurred image of the intellectual activity of the formative period. Participants of this formative period have organized the IJCAI79 panel on the History of AI (1956-61). They are:

Professor Saul Amarel, Professor and Chairman, Computer Science, Rutgers University

Professor John McCarthy, Professor of Computer Science, Stanford University

Professor Herbert A. Simon, Professor of Computer Science and Psychology, Carnegie-Mellon University

Professor Edward A. Feigenbaum, Professor and Chairman of Computer Science, Stanford Univer sity,

## Refcrsngga

Bernstein, A. and Roberts, M. deV, 1958, Computer Vs. Chess-Player, SCIENTIFIC AMERICAN, June.

Feigenbaum, E., 1961. The Simulation of Verbal Learning Behavior, PROCEEDINGS OF THE WESTERN JOINT COMPUTER CONFERENCE, 19:121-132.

Feigenbaum, E., and Feldman, J., COMPUTERS AND THOUGHT, 1963, McGraw-Hill.

Feldman, J., 1961. Simulation of Behavior in the Binary Choice Experiment, PROCEEDINGS OF THE WESTERN JOINT COMPUTER CONFERENCE, May 9-11, 1961, pp. 133-1^.

Gelernter, H., 1959. Realization of a Geometry Theorem-Proving Machine,PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON INFORMATION PROCESSING, 1959, Paris:UNESCO House. pp273-282.

Gelernter, H., Hansen, J.R., and Loveland, D.W., 1960. Empirical Exploration of the Geometry Theorem Machine, PROCEEDINGS OF THE WESTERN JOINT COMPUTER CONFERENCE, May 3-5, 1960. ppl^-W.

Lindsay, R.K., 1962. A Program for Parsing Sentences and Making inferences About Kinship Relations, PROCEEDINGS OF THE WESTERN MANAGEMENT SCIENCE CONFERENCE ON SIMULATION.

McCarthy, J., 1959. Programs with Common Sense, PROCEEDINGS OF THE SYMPOSIUM ON MECHANISATION OF THOUGHT PROCESSES. National Physical Laboratory, Teddington, England, London: H. M. Stationary Office.

McCarthy, J., 1960. Recursive Functions of Symbolic Expressions, COMMUNICATIONS OF THE ASSOCIATION FOR COMPUTING MACHINERY, 3(1960).

Minsky, M.L., 1961. Steps Toward Artificial Intelligence, PROCEEDINGS OF THE IRE, 1961. Special computer issue.

Newell, A., 1955. The Chess Machine, PROCEEDINGS OF THE 1955 WESTERN JOINT COMPUTER CONFERENCE, Session on Learning Machines, pp 85-111, March 1-3, 1955.

Newell, A., and Simon, H.A., 1956. The Logic Theory Machine, IRE TRANSACTIONS ON INFORMATION THEORY, IT-2(3):6l-79.

Newell, A., and Shaw, J.C,, 1957.Programming the Logic Theory Machine, PROCEEDINGS OF THE WESTERN JOINT COMPUTER CONFERENCE, pp230-240.

Newell, A., Shaw, J. C, and Simon, H.A., 1958a, Elements of a theory of human problem-solving, PSYCHOLOGICAL REVIEW, March, 65: 151-166.

Newell, A., Shaw, J.C., and Simon, H.A., 1958b. Chess-playing Programs and the Problem of Complexity, IBM JOURNAL OF RESEARCH AND DEVELOPMENT, 2(4):320-335.

Newell, A., Shaw, J.C., and Simon, H.A., 1959. Report on a General Problem-Solving Program, PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON INFORMATION PROCESSING,1959, Paris: UNESCO House,

Newell, A., (ed.), 1961. INFORMATION PROCESSING LANGUAGE V MANUAL, Englewood Cliffs, NJ, Prentice-Hall.

Samuel, A.L., 1959. Some Studies in Machine Learning Using the Game of Checkers, IBM JOURNAL OF RESEARCH AND DEVELOPMENT, 3<3>: 210-229.

Selfridge, O.G., 1955. Pattern Recognition and Modern Computers, PROCEEDINGS OF THE 1955 WESTERN JOINT COMPUTER CONFERENCE, Session on Learning Machines, pp91-93.

Selfridge, O.G., 1959. Pandemonium: A Paradigm for Learning, PROCEEDINGS OF THE SYMPOSIUM ON MECHANISATION OF THOUGHT PROCESSES, National Physical Laboratory, Teddington, England, pp511-529.

Slagle, J., 1961. A COMPUTER PROGRAM FOR SOLVING PROBLEMS IN FRESHMAN CALCULUS (SAINT), doctoral dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Tonge, F.M., 1960. An Assembly Line Balancing Procedure, MANAGEMENT SCIENCE, 7(1):21-U2.

# PANEL ON APPLICATION OF LANGUAGE PROCESSING SYSTEMS

Makoto Nagao (Chairman) Kyoto University (Japan)
Hozumi Tanaka Electrotechnical Laboratory (Japan)
Donald Walker SRI International (USA)
Dave Waltz Univ. of Illinois, Urbana (USA)
Yorick Wilks University of Essex (UK)

Natural language is a powerful tool for communication among human beings. It has the flexibility for expressing information about any specifiable situation to any degree of precision required, while at the same time it also allows substantial amounts of ambiguity to be expressed. Natural language works well when the sender (speaker, writer) and the receiver (hearer, reader) are humans with similar backgrounds who are communicating in a well-defined, mutually understood context. When one of the participants is a machine, serious problems may arise.

Various attempts have been made since the early days of computing to give the machine a portion of the flexibility characteristic of the human interpretation of natural language. Procedures have been developed to provide syntactic analysis, semantic interpretation, discourse analysis, and learning, and these efforts have required representations for the different kinds of knowledge entailed and complex mechanisms to activate and control the components to yield the best interpretation possible for a given system configuration. Applications of these capabilities have been made to produce question-answering systems, natural language access to data bases, machine translation and computer aids for translators, and automated office environments. However, all of these applications are still in the experimental stage and not in actual use in a practical setting.

This panel deals with some of the problems associated with the application of language processing systems. In particular, it will address:

(1) What are the major obstacles to the realization of practical natural language processing systems in view of the accomplishments of recent research?

(2) What will be the promising areas of application in the next few years?

(3) What approaches should be taken to ensure that these predictions will be satisfied?

In addition, we want to discuss:

(4) What are the essential differences between Indo-European languages and Japanese for the construction of language processing systems: considering the characteristic forms of writing and speaking, grammatical structures, discourse, and even intrinsic patterns of thinking and knowledge representation?

(5) How can we break through the computer natural language barrier, and how will artificial intelligence contribute to that accomplishment?

# A PANEL ON INDUSTRIAL APPLICATION OF ROBOTICS

Yoshiaki Shirai (Chairman)

Information Science Division
Electrotechnical Laboratory
2-6-1 Nagatacho, Chiyodaku
Tokyo 100, Japan

## Objectives

This panel deals with issues of computer controlled manipulators and computer vision applied to industry. The main issues include the followings.

1. What progress has been made during these five years?
2. What are the fundamental and practical limitations of our current techniques?
3. What kinds of approach should be taken to solve the problems?
4. What are the potential applications of robotics?

## Background and Some Questions

Many industrial robots are now working in factories. But they *are* not much different from those developed fifteen years ago except that current computer controlled manipulators have some flexibility to change jobs by choosing a program stored in computer. Most of them work only by position control. Some have tactile sensors. Few have eyes. Is there no demand for sophisticated sensors or computer vision?

Recently, much progress has been achieved in the application of computer vision. In Japan, for example, many electric companies produce and use automatic wire bonders with TV cameras for IC assembly. There are also equipments for inspection of printed circuit boards, IC chips and LSI mask patterns.

Most of the systems employ special hardwares for processing binary input images. The success of computer vision application might owe mainly to the cheap hardware cost. But few systems deal with gray images. Hardwares for processing gray images are now being developed in the PIPS project in Japan, in the ARPA project in the USA and so on. Are they going to make a contribution to industrial application?

Now the cost of computer is still considerably high. Some systems take a hierarchical organization of one computer and many image processors or actuators. The processor cost is getting less these years. Then, what will be suitable system organizations? What kind of processors are required?

Another problem is how to make computer programs efficiently. Robots usually interact with the environment which can not clearly be determined beforehand. Languages are now being developed for arm control such as AL. In computer vision, many studies have been made for learning by showing. Are they really applicable to industry?

Some researchers find importance of three-dimensional modeling for CAD/CAM and for computer vision. If such a three-dimensconal model can easily simulate the environment, it may greatly decrease programming efforts for arm control and vision.

## Participants and Background

Toshiro Numakura, Hitachi Production Engineering Research Laboratory: Productivity technology

Walton A. Perkins, General Motor Research Laboratories: Industrial application of computer vision

Masahiko Yachida, Osaka University: Machine parts recognition, image sequence analysis

Yoshiaki Shirai, Electrotechnical Laboratory: 3-D computer vision

Ed Fredkin, Massachussetts Institute of Technolog
Artificial Intelligence Laboratory.