

## XIX. ARTIFICIAL INTELLIGENCE\*†

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### RESEARCH OBJECTIVES

The purpose of our work is to investigate ways of making machines solve problems that are usually considered to require intelligence. Our procedure is to attack the problems by programming a computer to deal directly with the necessary abstractions, rather than by simulating hypothetical physiological structures. When a method for solving a problem is not known, searches over spaces of potential solutions of the problem, or of parts of the problem, are necessary. The space of potential solutions of interesting problems is ordinarily so enormous that it is necessary to devise heuristic methods<sup>1-3</sup> to replace the searching of this space by a hierarchy of searches over simpler spaces. The major difficulty, at present, is the excessive length of time required for building machinery or even for writing programs to test heuristic procedures. For this reason, a major part of our effort is going into the development of ways of communicating with a computer more effectively than we can now communicate. This work has two aspects: development of a system for instructing the computer in declarative, as well as imperative, sentences, called the advice-taker,<sup>4</sup> and development of a programming language called LISP<sup>5-7</sup> for manipulating symbolic expressions that will be used for programming the advice-taker system and will also be of more general use.<sup>8</sup> We are embarking on a major effort to integrate this work into the new M.I.T. time-shared real-time computer system.

Maintenance and further development of LISP will be continued by Professor J. McCarthy, who is now at Stanford University. We plan to continue close association with his group.

It is our belief that the field of artificial intelligence is limited only by the amount of qualified effort that can be put into it, and by the machine limitations that still prohibit more ambitious experiments. Our group is working in the following areas.

#### 1. Differential Equations Solved by Symbolic Methods

Dr. J. Slagle has completed his program, SAINT, for "first-year calculus" and is working on more powerful methods for symbolic solution of ordinary differential equations.

#### 2. Resource Allocation Heuristics

B. Bloom, D. J. Edwards, and others are working on the problems of conflicting goals that arise in the chess problem. T. P. Hart is working on related problems in the more tractable game of Kalah. Thesis students have been assigned problems in working out techniques for other games.

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†Several members of this group, working at the Computation Center, are not members of the Research Laboratory of Electronics: Prof. H. Rogers, Jr. (Department of Mathematics, M.I.T.), Dr. O. G. Selfridge (Lincoln Laboratory, M.I.T.), Dr. J. Slagle (Lincoln Laboratory, M.I.T.), and the following graduate students: B. Bloom, T. Evans, T. Jones, D. M. R. Park, B. Raphael, W. Teitelman.

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### 3. Pattern Recognition and other Problems in Visual Images

Professor Minsky and Dr. Selfridge are working on the general theory; the results will appear in a series of papers, two of which are completed. T. Evans has almost completed his study of pictorial-verbal analogies, which will appear in his doctoral thesis. I. E. Sutherland has completed his superb "Sketchpad" picture-description system, which will appear in his dissertation. D. J. Edwards and M. Minsky have started a study of relative merits of Bayes and matched-filter approximations for recognition. We are beginning work on programmed description of motion and animation. L. G. Roberts is exploring problems in description of three-dimensional forms.

### 4. Heuristic Reasoning about Bodies of Verbal Description Data

Work on systems related to the advice-taker is finally becoming concretely realized. T. Jones and M. Minsky are running preliminary versions of an advice-taker system. J. Slagle's differential-equations system will also be designed along these lines. B. Raphael is working on related systems concerned with interpreting language statements relevant to the state of an internal pictorial model. D. G. Bobrow is concerned with detailed interpretation of ordinary language statements concerning a mathematical domain: "word-problems" in a system for High School algebra.

### 5. Mathematical Aids and Models

P. W. Abrahams is completing his dissertation research on a symbolic proof-checking system, which expands relatively informal meta-statements about theorem proofs into detailed applications of the rules of inference from assorted logical subsystems, thereby providing a mechanization of the expression "the reader will easily verify." D. C. Luckham is working on a theory of program equivalence and simplification. M. Minsky is completing a book on computer-oriented theory of recursive functions, Turing machines, and Post systems.

### 6. Mechanical Hand

H. Ernst's work on his TX-0 mechanical hand was completed a year ago, and we are planning to continue such work, this time, in association with the M.I.T. time-sharing system. We hope also to work toward a computer-operated micromanipulation system under computer-sensed visual control.

### 7. Neural Nets

M. L. Minsky and O. G. Selfridge are working on theories of neural nets. They have completed an analysis of certain synaptic learning processes in loop-free nets, and plan to study the formation of certain kinds of assemblies in nets with cycles.

### 8. Time Sharing and the Mathematical Laboratory

We have an ambitious design for a laboratory in which mathematicians and physicists can apply new techniques for solving problems involving equations that are impractically cumbersome for hand-manipulation by ordinary mathematical techniques. What is needed is a control language for describing and executing the processes ordinarily carried out by a working research mathematician, implemented by a heuristic program. This system as now envisioned would be a new national research facility, for visits by scientists with appropriate problems. It is awaiting the development of a control language that involves new man-machine interaction problems, for the appropriate time-shared visual consoles that are necessary.

M. L. Minsky

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