Introduction to Session on Learning Machines

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THE FOLLOWING four papers treat various levels of complexity in machine systems which exhibit learning ability. It is perhaps a misnomer to label such devices as "learning machines," since it is not the machine itself, but the program that guides the machine toward its goal, which learns. This topic is unfortunately suggestive of the considerable publicity that has attended the "Giant Brain" ballyhoo directed toward digital systems, but it is not the intention of these four papers to indicate how to make "thinking" machines. The first effort in this direction is a careful definition of "thinking," which no one has yet given. It should be very carefully emphasized that machines may be said to "think" only to the extent that their users and designers have been able to penetrate sufficiently deeply into a problem so that all possible situations which might arise have been examined, and an adequate program written which describes to the machine an unambiguous criterion for its use in each case. Machine operation which results from such subtle programs is then an imitation or simulation of operations which have previously been thought through and established by human beings.

It is, however, the intention of these papers to describe certain experiments in which machine systems imitate some of the self-organizing and learning processes of the nervous system. Whether such simulations are true in the fine structure is of course unknown; much of the work described by these papers is sufficiently experimental that it is not even known that the simulation is completely correct functionally. The investigation of a process so subtle and complex as learning is not easy; the approach is by way of models which are set within the framework of a digital computing system. These papers do not suggest that future learning machines should be built in the pattern of the general-purpose digital computing device; it is rather that the digital computing system offers a convenient and highly flexible tool to probe the behavior of the models.

This group of papers deals with three distinct levels of complexity in learning systems. There is considerable similarity among the three, but the responses expected in each case and the questions asked of each system vary widely in detail. The paper by Farley and Clark deals with the most primitive and least complex level of learning. The system discussed by them is required to distinguish the simplest kind of decision and is rewarded for its correct responses. Input to the system is very restricted and there is no *a priori* set of operations which the system performs on its input. The two papers of Selfridge and Dinneen treat the next level of complexity. The input is now well organized in two spatial dimensions and exhibits a well defined topology. There is an established set of transformations for operating on this input data, although the criteria for choosing any sequence of such transformations are not *a priori* known. The paper by Newell treats the highest level of complexity—the game. Here there is a multitude of input data which must be inspected at many levels. There is a complex set of rules for interplay of this data but again the criteria for decision are *a priori* unstated.

As has been suggested by Selfridge, these levels of complexity may be likened respectively to the initial organizational efforts of neural nets in the earliest days of evolution (Farley-Clark), the learning of pattern recognition by a maturing individual (Selfridge-Dinneen), and the action of an entire man as he copes with the complicated problems of his life (Newell).

This group of papers suggests directions of improvement for future machine builders whose intent is to utilize digital computing machinery for this particular model technique. Speed of operation must be increased manyfold; simultaneous operation in many parallel modes is strongly indicated; the size of random access storage must jump several orders of magnitude; new types of input-output equipment are needed. With such advancements and the techniques discussed in these papers, there is considerable promise that systems can be built in the relatively near future which will imitate considerable portions of the activity of the brain and nervous system.

The subject matter of these papers extends over into several closely related fields. Accordingly, following the formal papers are invited comments from Walter Pitts, Research Laboratory for Electronics of the Massachusetts Institute of Technology, and George A. Miller, Associate Professor of Psychology, Harvard University. These two men have trained, respectively, as mathematical neurophysiologist and psychologist.

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