COMPUTER LEARNING THROUGH ASSOCIATION

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Summary

In this report a computer program is described which attempts to model the techniques by which human beings take information about an initially unknown environment and use it to develop rules for coping with the environment.

The environment chosen is a simple game, similar to tic-tac-toe. The computer program and a randomly playing opponent alternately place their symbols on a three by three board. After nine such moves the program is told whether it won or lost the game according to a predetermined set of rules. The model is programmed to develop a strategy for successive games. As the computer plays more games the rules and strategy become more sophisticated.

Two fundamental hypotheses were used in the implementation of the learning process.

1) Learning is achieved through association on simple observable phenomena (game results), to more complex concepts. This gives direction to the learning process.

2) Learning is based on a type of economic system in which concepts are developed only when their worth in playing an effective game exceeds their cost in complexity.

The program was written in IPL-V and implemented on the IBM 7044 at the State University of New York at Buffalo.

Little is known about the basic process by which human beings observe limited phenomena in their environment and generalize on these observations to develop rules for coping with the environment.

This paper describes a computer program for which several basic principles of human behavior are proposed. A simple competitive environment is chosen. The computer program reacts with the environment applying these principles of behavior to extract from the environment sufficient information with which to cope with it.

The model described by the program, is based on the following two hypotheses made for the explanation of human pattern recognition behavior.

Association Hypothesis: Humans recognize patterns by learning basic concepts contained within the patterns. This learning is aided by associating these basic concepts with each other, according to their observed coincidence in the pattern environment. Highly associated basic concepts may be combined to form more complex concepts. Examples of such concepts used in the model are depicted in Figure 4.

Economic Hypothesis: Human behavior is guided by an economic system. Humans take a course of action that yields the greatest gain and only take a certain course of action when the worth of that course of action exceeds the corresponding cost.

In order to develop the model in detail a particular environmental task is proposed.

A simple game is posed that is played on a board 3 squares by 3 squares. The game is played by two opponents who choose a square alternately. After all nine squares have been taken, the game is over and the winner is determined by a predefined rule. The rule consists of a pattern class (or concept). The player who went first would win if the finished game fits the pattern class; otherwise, the second player would win. The players play the game without knowledge of the winning pattern class. They are told only who the winner is of each game.

One objective, then, is to learn the pattern class from the outcome of each game played, to use as an advantage for future games.

A second objective is to develop a strategy based on the hypothesized winning pattern class or concept so as to maximize one's chances in winning the game.

It is suggested that, as simple as the game may be, it presents a good example of an environmental task with which a study of learning machines may prove to be lucrative in the direction of obtaining insight into general considerations of pattern recognition and learning.

The computer simulated model is built around this game. It is designed to be the first player all the time, so that its winning corresponds directly with the presence of the winning concept. It's opponent is an internal random number generator and is considered to be a part of the environment. This built-in opponent facilitates play when run on the computer.

The recognition of concepts that occur in the environment is learned through an association process which is implemented by means of an association network. Figure 1 depicts this network. The network inter-relates various concepts as they are observed within the environment. In the program, the network has the form of a list structure having lists, corresponding to each concept, that list an association value for other concepts inclusive of itself. The network is initially void at the commencement of a run, but grows throughout the running by addending new association entries as it is exposed to different combinations of concept coincidence, and by incrementing or decrementing existing entries.

Secondly, a playing strategy is developed for use with a particular working concept by adjusting a worth value corresponding to each move, which is conditioned on the previous two moves. The adjustment is based on the relative effect towards success each time the model tries that particular move. The strategy is developed in the program in the form of a list structure shown in Figure 2.

The model used a strategy by choosing a move with the highest value for a particular situation, thus employing the Economic Hypothesis.

Program of the Model: The model is simulated by a program written in IPL-V and run on an IBM 7044 computer at S.U.N.Y.A.B.

IPL-V was chosen because it is an available list processing language having dynamic storage allocation. Dynamic storage allocation is necessary for the growth of the association networks used in the model. The program is approximately 2000 IPL-V instructions in length.

The structure of the program is illustrated in the flow diagram of Figure 3. The programmed model consists of four modes of behavior described as:

Mode 1: The model starts in mode 1 at a naive state of knowledge relative to the preseding winning pattern. In this mode it plays, the game according to a general strategy which has been preprogrammed, while making observations that are stored in a short term memory (STM).

Mode 2: Mode 2 examines observations stored in STM, forming associations by augmenting values for new combinations of coincident observed concepts. It then chooses a working concept which has the maximum total association value over all concepts in STM.

Mode 3: This mode uses the working concept for playing the game while developing a strategy peculiar to the particular working concept. It also verifies or rejects the working concept according to game results.

Mode 4: Mode 4 is similar to Mode 3 and is included in the model to facilitate future expansion.

Following are some observations made on the model's behavior:

1. Generalization: The association of similar concepts tends to aid in the selection of the correct concept by favoring all concepts of a type similar to concepts observed in a pattern.

2. Discrimination: It is observed that the existence of similar concepts hinders discrimination between these concepts, since similar concepts tend to coincide. This problem is effectively circumvented by trying out each of these similar concepts until the correct one is discovered.

3. Learning Barriers: An interesting observation was made on the results of the model run that had not been anticipated. The model could never learn certain concepts simply because it could never win a game when these concepts were specified as the winning pattern. The reason the model could never win such games is that the winning of these games depends on taking moves upon which the model places a low value in its general strategy.

4. Convergence: For all of the runs made with the model, recognition of the correct pattern was eventually accomplished if the model was able to win. This indicates that the model, at least for the runs made, does not get caught into absorbing situations that would prevent it from recognizing the specified winning pattern.

Future use of this model will include comparison between it and humans. In particular, certain situations arising within the model run will be presented to human subjects and conversely. Thus, in this way, direct comparison will be facilitated between the model and human behavior; and thus, allowing a means of gathering insight into the general problem of Pattern Recognition.

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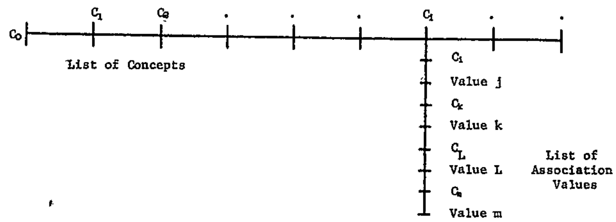

C_0 is a list of all concepts. Each concept on the list, say C_i, has a Q list, Q_i. The Q list consists of concept-association value pairs, where a concept label occurs first followed with the association value of that concept with the concept heading the list.

Network of Concept Interralation Values

Figure 1

DØ List of move tables corresponding to list of concepts.

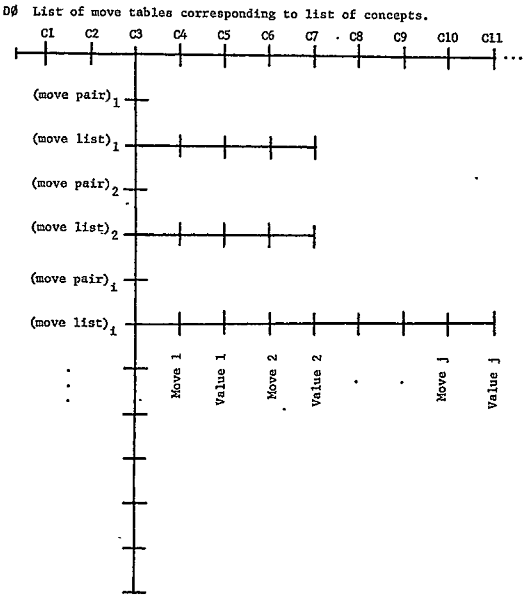

Diagram Depicting Strategy Development in the Model

Figure 2

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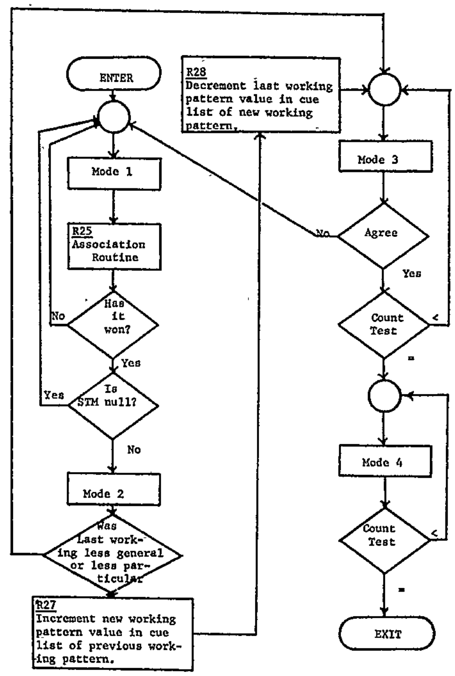

EXECUTIVE ROUTINE

Flow diagram representing the four modes of behavior and the conditions of flow between them.

Figure 3

The model presently contains 17 defined concepts, three of which are shown below - Figure 4.

Concept: Examples:

C1 is the concept of 3 symbols in a row. (3 symbols)

C2 a chess knight's move (3 symbols)

C3 Letter L. (3 symbols)

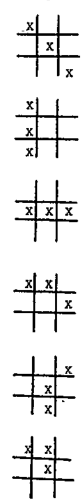

Figure 4