

A BASIC MODEL FOR LEARNING SYSTEMS

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A learning system (LS/O) is designed and implemented on a computer. The LS/O exchanges information with its environment through three kinds of message strings. Given a question string, the LS/O produces the response string, then the answer string is shown to the LS/O as the correct response string. The LS/O iterates such interactions infinitely. The most important feature of the LS/O is that it tries to produce the correct response to the unexperienced questions. To do this, the LS/O organizes the previously acquired information and generates the hypothesis or the knowledge structure. When the response fails to meet the answer, the LS/O renews the hypothesis or reorganizes the knowledge structure to explain the answer. In the LS/O, the network-like structure called label net plays an important role to represent the knowledge structure.

1. INTRODUCTION

The inductive process must be realized by the learning system so that it can improve the hypothesis or the knowledge structure as it acquires the new instances from the environment. The total information that the learning system must store increases quite rapidly in the course of the learning process, and the intelligence of the system depends mostly upon the knowledge structure which is constructed from this large and unorganized set of information. The problem to be solved in the design of the learning system is, therefore, how to construct the representation space, the set of possible knowledge structures, and how to

realize the algorithm to create, reorganize and utilize the knowledge structure. In order to solve this problem, the learning system LS/O is designed and implemented on a computer. The aim of this paper is to explain the outline of the

QUESTION	ANSWER
1 DOG=?	DOG=DOG
2 CAT=?	CAT=CAT
3 LION=?	LION=LION
4 L(12,4)=?	12
5 L(34,45)=?	34
6 L(876,6)=?	876
7 R(34,67)=?	67
8 WHATISCAT	ITISANIMAL
.	.
.	.

Fig. 1 An environment EV_1

LS/O. The details of the LS/O and the basic theory of the learning systems will be reported in the subsequent papers.

2. THE LEARNING SITUATION

We shall consider the sequence of question-answer pairs. This is called an environment (EV).

$$EV = [(Q_1, A_1), (Q_2, A_2), (Q_3, A_3), \dots]$$

where Q_t and A_t are strings on the alphabet Σ , the set of alphanumeric characters except "#", and are called the question and the answer, respectively. Fig. 1 shows a typical example of the environment. We shall denote the environment by EV_1 hereinafter.

The interaction is an information exchange between the learning system and the environment. It consists of three phases: Q, R and A. In the phase Q, the environment gives a question string Q_t to the system. In the phase R, the system must reply a response string R_t to the question Q_t . In the phase A, the environment shows the system an answer string A_t as the correct response to the question Q_t . An interaction at time t can be represented by (Q_t, R_t, A_t) .

The system infinitely iterates the interactions with the environment. The infinite sequence of interactions is called the question-response-answer process (Q-R-A process) or the learning process (LP).

$$LP = [(Q_1, R_1, A_1), (Q_2, R_2, A_2), (Q_3, R_3, A_3), \dots]$$

Fig. 2 shows an example of the learning process,

which is the sequence of interactions between the LS/O and the EV₁, and is called LP₁ hereinafter.

The interaction is said to be successful when the response and the answer strings are the same. The system is evaluated by the rate of successful interactions in the Q-R-A process.

3. THE LEARNING SYSTEM

A system which operates under the situation described in section 2 is designed in this paper. This is called LS/O and is implemented on a computer as a FORTRAN program. The system LS/O is composed of three elements: the execution element, the learning element and the memory element. The execution element receives a question string and generates a response string by utilizing the knowledge acquired so far in the memory element. The learning element makes specific changes in the knowledge in the memory element to improve the future responses. The memory element stores the learned knowledge, which is often called the state of the system.

The learned knowledge in the memory element of the LS/O is mainly represented by the network-like structure called the label net. The examples of the label net is shown in Fig. 3 (1)-(8). The label net is reviewed briefly in what follows. The details were reported in [1]. The label net can represent much wider variety of structures than the Fig. 3 shows.

The label net consists of finite vertices and finite labels. Each vertex corresponds to a set of strings and each label represents the relation between the set of strings. Strictly speaking, the label net is a set of equations with the variables of sets of strings.

QUESTION	RESPONSE	ANSWER
1 DOG=?	???	DOG=DOG
2 CAT=?	???	CAT=CAT
3 LION=?	LION=LION	LION=LION
4 L(12,4)=?	L(12,4)=L(12,4)	12
5 L(34,45)=?	L(34,45)=L(34,45)	34
6 L(876,6)=?	876	876
7 R(34,67)=?	R(34,67)=R(34,67)	67
8 WHATISCAT	???	ITISANIMAL
.	.	.
.	.	.

Fig. 2 The learning process LP₁ between the LS/O and the EV₁

The meaning of the label net is well explained by the following example. The label between V1 and V2 in Fig. 3 (4) means that the set of V1 contains the string " $\alpha=?\#\alpha=\alpha$ " if the set of V2 contains the string " α ". The two labels pointing toward V2 in Fig. 3 (4) means that the set of V2 contains "DOG" and "CAT". These relations determine the set of V1, S(V1), and the set of V2, S(V2).

S(V1) = { DOG=?#DOG=DOG, CAT=?#CAT=CAT }
S(V2) = { DOG, CAT }

The knowledge stored in the label net is utilized during the course of the learning process through the vertex V1. when there exists a string " $\alpha\#\beta$ " in the set of V1, the structure implies that the string " β " may be the correct response to the question string " α ".

4. THE LEARNING PROCESS OF THE LS/O

In order to show how the LS/O interacts with the environment and how it improves its knowledge structure, the learning process LP₁ in Fig. 2 and the state change of the LS/O during the learning process are described in the following.

The system LS/O starts with the initial state shown in Fig. 3 (1).

(1-Q) DOG=?

The first question is given to the LS/O by the EV₁. The question is "DOG=?".

(1-R) ???

The state (1) in Fig. 3 indicates the LS/O has no knowledge on the EV₁. The LS/O was designed to reply "???" when it fails to find any strings to the given question.

(1-A) DOG=DOG

The string "DOG=DOG" is given to the LS/O as the answer. After this interaction, the LS/O changes the state from (1) to (2) in Fig. 3. The state (2) means that "DOG=DOG" is the correct response to "DOG=?".

(2-Q) CAT=?

(2-R) ???

The clue which the LS/O has at this point is only the knowledge (2). The LS/O replies "???" again.

(2-A) CAT=CAT

The interaction at time 2 causes the state change from (2) to (3). The structure (3) stores information gained from the interactions at time 1 and 2 separately. The learning element of the LS/O further tries to organize the structure and gains the state (4). The vertex V2 was newly generated. The learning element assumes that the set of V2 might be equal to the set Σ^* , the set of all strings of any length including zero

length one. This changes the state from (4) to (5).

(3-Q) LION=?

(3-R) LION=LION

The state (5) enables the LS/O to reply the string "LION=LION".

(3-A) LION=LION

The response is found to be correct. The state changes to (6).

(4-Q) L(12,4)=?

(4-R) L(12,4)=L(12,4)

This response is generated by the execution element utilizing the structure (6).

(4-A) 12

The answer string at time 4 shows the correct response is not "L(12,4)=L(12,4)" but "12". The LS/O stores this information in (7).

(5-Q) L(34,45)=?

(5-R) L(34,45)=L(34,45)

(5-A) 34

After storing the new information to (7) by adding the labels "L(34,45)=?#34" and "L(34,45)" to V1 and V4, respectively, the LS/O tries to reorganize it and constructs the structure (8).

(6-Q) L(876,6)=?

(6-R) 876

The LS/O utilizes the structure (8) and generates the response "876".

(6-A) 876

This interaction is found to be successful. The information gained at time 6 is stored by adding the same label "876#6" to both V5 and V6.

(7-Q) R(34,67)=?

(7-R) R(34,67)=R(34,67)

(7-A) 67

The answer string of the EV₁ again forces the LS/O to reorganize its knowledge structure. The learning process between the LS/O and the EV₁ continues infinitely in this manner.

REFERENCE

- [1] Akama, K. and Ichikawa, A. "Representation of Set of Symbol Strings for Learning Systems." Trans. Institute of Electronics and Communication Engineers of Japan. J61-D No.9 (1978)

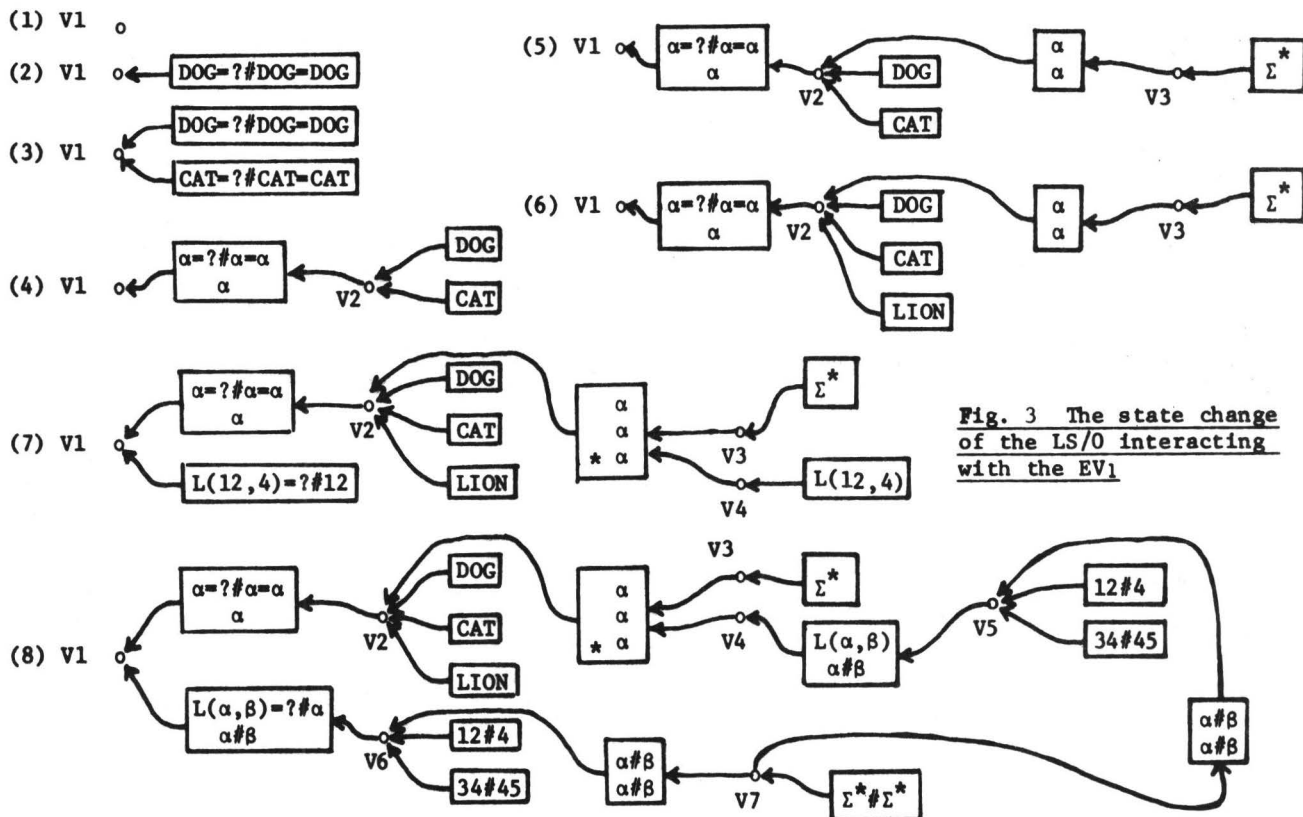


Fig. 3 The state change of the LS/O interacting with the EV₁