

LEARNING OF ABSTRACTIONS FROM STRUCTURAL DESCRIPTIONS OF PICTURES

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ABSTRACT

The acquisition of concepts induced by structural descriptions of pictures is discussed and a representation scheme is presented which allows the construction of various abstractions based on different points of views and their storage in a simulated associative memory.

INTRODUCTION

In order to introduce the material contained in this paper, we will follow the views and terminology used by Hayes-Roth and McDermott in their recent work /1/, /2/ :

"Concepts are pattern templates : events which match a concept are recognized as belonging to the class delimited by that concept. (...) The machine learning problem with which we are concerned can be stated in the following way : given a collection of concepts (...) and a way of describing events in terms of their structure, construct a machine which is able to induce additional concepts (...) from training data. " (/1/, p. 156)

From there, they identify three distinct problems :

- 1) the description problem, asking for a "formal scheme for describing complex events which facilitates the generation of abstractions"
- 2) the comparison problem, i.e. the problem of finding commonalities between two examples of the same concept or abstraction
- 3) the storage problem, i.e. the problem of storing discovered abstractions in such a way that they could be used as templates for recognition of events, and as knowledge representations to be improved by learning, learning being viewed here "as a continual process of knowledge expansion, that is, as the acquisition, in adaption to training experiences, of higher-order, more complex and more elaborate knowledge structures".

We propose in this paper a different solution to each of these problems, our approach being motivated by a rather divergent view on the modalities of knowledge expansion.

TWO POSSIBLE APPROACHES FOR KNOWLEDGE EXPANSION

The approach taken by Hayes-Roth and McDermott is, in their own wording, to improve the precision of the knowledge representations by learning, if new instances of the same concept are provided. More precisely, according to the example they give, they first construct an initial (actually too narrow) concept by listing all common properties of two selected events, and then refine it (actually extend it) by removing some commonalities not found in a third event, and so on : this amounts to first retaining all constituents as potential properties of a concept and then gradually discarding some of them. The matching involved in recognition is then a partial matching.

On the other hand, the approach we have taken consists of isolating first basic constituents, and classifying them according to various points of views, thus defining basic concepts in different contexts; a global concept is then constructed by combining basic concepts into more elaborate, higher-order concepts, and so on, until gradually all constituents have been taken into account : the matching involved is thus a complete matching, dissimilarities being removed by means of equivalence classes, or subconcepts.

A consequence of our approach is that learning cannot be considered as an autonomous process, but must necessarily interfere with a complementary tutoring process, providing the frame for

the differentiation of contexts, classification of constituents and the naming of concepts. This will be first illustrated by means of a simple example of a teaching session conducted on our interactive graphic system.

Example :

In a first step, the teacher will be asked to draw simple connected patterns (i.e. basic constituents), and to provide the appropriate names for equivalence classes, thus defining basic concepts by extension:

pattern	concept name
	nose
	eye-mouth
	shape

In a second step, he can draw pictures with more complex structures (i.e. single or multiple events, or instances of higher-order concepts), together with concept names:

picture	higher-order concept name
	face

A definition by generalization of the corresponding concepts will be constructed by substituting basic concept names for occurrences of simple connected patterns (first level of abstraction). To verify that these concepts have been learned, the teacher can then draw pictures, asking for recognition:

picture	response
	face
	face
	?? (unrecognized)

The learning process could go on in two different directions :

- first by drawing more and more complex pictures, for example introducing body configurations with heads, arms and legs, leading to higher levels of abstraction
- secondly by defining alternate basic concepts (i.e. different equivalence classes of the same patterns) for analyzing the same pictures, thus implicitly referring to another context or frame of intentionality and achieving various levels of differential abstraction

e.g.	pattern	concept name
		sad
		happy
		undefined

pictures	differential concept name
	happy face
	sad face

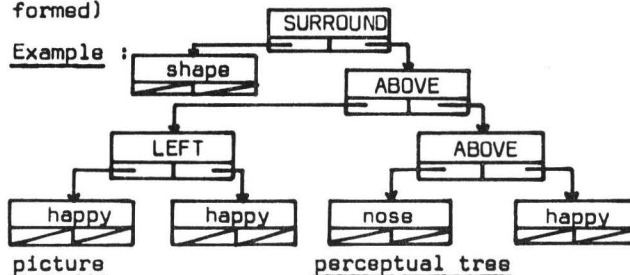
The solutions to the three problems mentioned above will be now reviewed in detail.

THE DESCRIPTION PROBLEM

The interface between the teacher (human operator) and the learning system (computer program) is a graphic tablet together with a display. A fairly complex software analyzes line drawings and identifies simple connected patterns such as those presented in the above examples. This primary capability of the learning system could be viewed as a pure sensorial perception. In order to obtain a satisfactory structural description, a few more primitive perceptual capabilities are required. Our present (rather incomplete) system allows for the determination of the relative position of simple connected patterns using the three binary relations ABOVE, LEFT, and SURROUND.

The structural description resulting from this perception is given in the form of a binary tree, the perceptual tree, where basic concept names have been substituted for any of their instances (i.e. a first level of abstraction has been performed)

Example :



It is noteworthy that this description, in contrast to that in /1/, is not parameterized, the identification of each constituent being taken into account by its position in the binary tree.

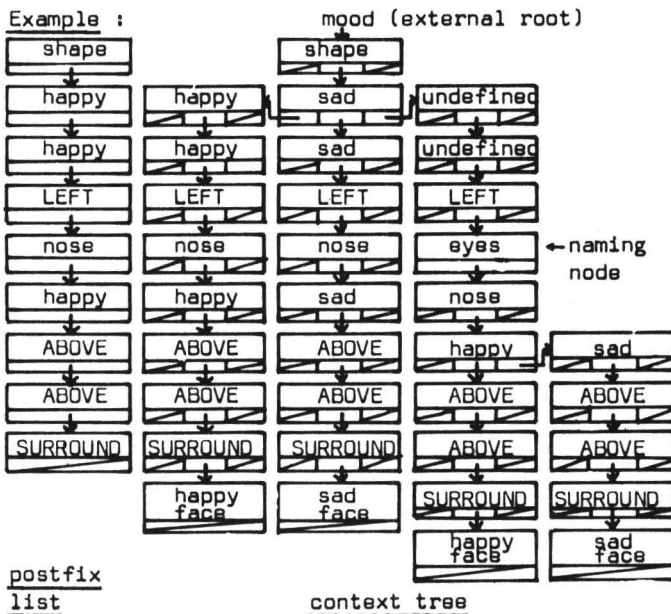
THE STORAGE PROBLEM

The solution to the storage problem, which in Hayes-Roth and McDermott terminology refers to the way of representing abstractions or concepts, will be presented next to allow for an easy

treatment of the comparison problem.

The purpose of classifying constituents into multiple equivalence classes, is to allow for the recognition of events in various contexts. A workable knowledge representation can thus be obtained by a mere reshaping of perceptual trees, grouping multiple concept definitions based on the same point of view into a ternary tree, each such tree representing a context.

More precisely, each perceptual tree is first rewritten as a list in postfix order, and then imbedded in a binary search tree where leading common sublists are factorized (or shared) for economical memory storage and quick access. The appropriate concept name is then attached to the queue of each list in a so-called naming node. The resulting structure forms a context tree. Leading sublists can be used to define subconcepts by inserting naming nodes, which have then to be jumped over.



THE COMPARISON PROBLEM

With the type of knowledge representation just described, finding commonalities and recognizing events becomes equivalent to retrieving, in context trees, concepts whose definitions match subtrees of perceptual trees.

More precisely, recognition of an event given by its perceptual tree will be conducted by successive reductions : each subtree (of a given perceptual tree) matching a concept's definition

will be replaced by the name of that concept; if the perceptual tree eventually reduces to a unique naming node, a global concept will thus be identified.

Knowledge expansion, on the other hand, is achieved by the insertion in postfix order, into appropriate context trees, of reduced, but unrecognized, perceptual trees.

The reduction algorithm itself consists of three imbedded recursive procedures : the most inner procedure is the classical recursive version of binary search with insertion using a sentinel, modified to jump over naming nodes; the second inner procedure traverses subtrees of perceptual trees in postfix order, each node being in turn searched for at a given level in a context tree; this amounts to attempting a partial match on subtrees; the outer procedure traverses perceptual trees in postfix order, attempting a partial match at each node, i.e. on each subtree.

EXPERIMENTS PERFORMED WITH THE SYSTEM

This system has been used primarily in an experiment involving the learning of chinese characters /3/. The range of candidates (a subset of 70 characters based on 50 basic patterns have been selected) was imposed by the limited perceptual power of the system. On a configuration involving a CDC CYBER 73 computer, a character abstraction or recognition takes from less to 0.1 to 0.5 sec depending on the character's complexity.

REFERENCES

- /1/ Hayes-Roth, F., and McDermott, J., Knowledge Acquisition from Structural Descriptions, Proc. 5th IJCAI, 1 (1977), 356-382
- /2/ Hayes-Roth, F., and McDermott, J., An Interference Matching Technique for Inducing Abstractions, CACM 21,5 (May 1978), 401-410
- /3/ Tran Van Nam, Syntactic Pattern Recognition, A General System for Description of Handprinted Text Written on a Graphic Tablet, Ph.D Thesis, Swiss Fed. Inst. of Techn. (EPFL Lausanne 1978)