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REPRESENTATION OF REGOGNITION STRATEGIES BY USE OF ACTIVE COGNITIVE NETWORKS

Representation de statégies de reconnaissance par réseaux de connaissances actifs

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RESUME

Danse l'article nous proposons un formalisme de la representation de systemes reconnaissance. Nous avons le nommé le formalisme de reseaux de connessance actifs. Il s'est formé sous l'influence du style de la representation de la connaissance à l'aide de reseaux semantiques et de modèle de la conservation d'acteur. La reconnaissance est presentée comme ume action de la recherche du reseaux cognitif. Il est piloté d'après modèle d'acteur. Dans l'article nous analysons les facons de la limitation d'espace de la recherche par une génération des projects, qui representent la stratégie de la reconaissance. Nous donnons des schémes de la strategie de faire des projets dans le cas de la structure horizontal et vertical.

SUMMARY

The formalism for representation of recognition systems is proposed in the paper. We have called it active cognitive networks formalism. It has been influenced by semantic networks style of representing knowledge and actor model of behaviour. Perception is represented as a search process in cognitive network which is controlled locally in an actor manner. We analyze ways of constraining search by generating plans which constitute recognition strategy. We give patterns of planning strategies in the cases of horizontal and vertical structuring.

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INTRODUCTION

In Bielik, 1983 we proposed a formalism for representing recognition descriptive knowledge. It is an extended and elaborated version of semantic net formalism (Brachman, 1979). We outline here briefly our formalism extended by procedural part, which consists in control mechanism distributed among nodes of cognitive network. It has been influenced by Hewitt, 1977 and Hoare, 1978. Next we discuss ambiguity of a typical knowledge of recognition systems and analyze strategies of constraining search which arises during interpretation process in ambiguous recognition space. We do this on the example of two basic interpretation processes: vertical structuring (grouping) and horizontal structuring (labelling). One of search constraining strategies is planning. We show the representation in our formalism of generating and using plans in aggregated recognition spaces. This formal representation explaines why and to what extent planning yields eficiency.

ACTIVE COGNITIVE NETWORK

An active cognitive network is a network of concepts (units) linked by established epistemological relations. Two sets of concepts: initial and goal are distinguished in the network. A process of interpretation (recognition) consists in searching the network for a path from the initial concepts to some of the goal concepts. Since, in general, any concept may be linked ambiguously to many others, there has to be adopted a certain strategy of exploring possible alternatives. We decided to distribute this strategy among units of the cognitive net. That is why the network is called active.

UNITS

Units (of knowledge) are elementary, nondivisible objects. They may be linked by epistemological relations. They are active, that is they can perform independently certain actions. Internal structure of a unit is inaccessible to the system, only state of the unit can be accessed. A unit is defined by a set of its ports and a program of its activities. Ports are places where relations can be appended. Program of a unit is a set of labelled actions followed by continuations. Action is a condition-operation pair. After Dijkstra, 1975 we admit guarded actions. That means, that in an action a set of conditioned operations may be specified and at the moment an operation randomly chosen from those with satisfied conditions is executed. Continuation is a label of another action to be executed next. State of a unit is composed of the state of its ports (i.e. what is connected to them), label of action currently in execution and matching state. Matching state describes the degree of recognition of what a unit is intended to recognize. Matching state can take one of the following values: "matched", "not matched" or "do not know".

Condition may be elementary or compound. Compound conditions are composed from elementary ones by means of logical connectives. Elementary conditions include: testing existence of a unit or relation, testing state of a unit or equality of units.

Operation may be elementary or compound. Compound operation is either sequence of elementary operations or a set of elementary operations executed in parallel. Elementary operations include: creating and deleting units and relations, and sending and receving messages. Message can take one of the following values: "do" or "quit". The operation of sending a message is executed until the addressee receives it. The operation of receiving a message is executed until the addressee sends it.

All units act in parallel and sending messages suplies a synchronization mechanism.

A unit can access only: itself, units connected to it by single relations and parts and instances inherited along specialization chains (see section on relations).

There is a set of elementary units, and conditions and operations specific for them, predefined in the language of active cognitive networks.

RELATIONS

We distinguish four epistemologically primitive relations between concepts: decomposition and interpretation relations: denotation, generalization, and namigg. They are adequate for all kinds of knowledge.

We say that concepts C and P are in the decomposition relation (denoted $C \rightarrowtail P$) if the concept C has the property represented by P or if P represents part of it. The decomposition relation may form a hierarchy - not necesserily a tree (as for all epistemological relations in this paper). As an example: sides of a square are its parts. An object representing a problem domain relation has arguments of that relation as its parts. We distinguish among parts of a concept the so called secondary parts. These are parts having parts which are parts of the concept considered. E.g., P2 from Fig. 1 is the secondary part of C. Secondary parts (properties) play a role of constraints which a concept and its parts must satisfy.

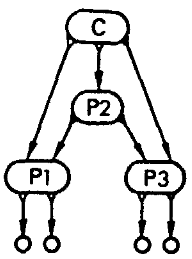

Fig. 1. Constraint P2 imposed on the structure of the concept C

The existance of secondary properties on a certain level of the decomposition hierarchy introduces new quality on this level and causes irreducibility of this level to the lower ones.

The next three epistemological relations concern interpretation. The first of them - denotation - holds between concepts I and C (denoted $I \longrightarrow C$) such that I is the instance of the concept C. Then we say that C denots I and that I is the instantiation of C. This corresponds to the relationship between the set and its element. The relation of denotation forms a hierarchy. As an example, we may say that the (mathematical) concept of square denotes a certain particular square (with established size and so on). Similarly, a concept of square denotes some particular drawing of a square.

The basic property of denotation is shown in Fig. 2a. It says that parts of an instance of the concept are instances of parts of that concept. We call parts Pi characteristic attribute properties of C with regard to C', and parts Pi' - characteristic value properties of C' with regard to C.

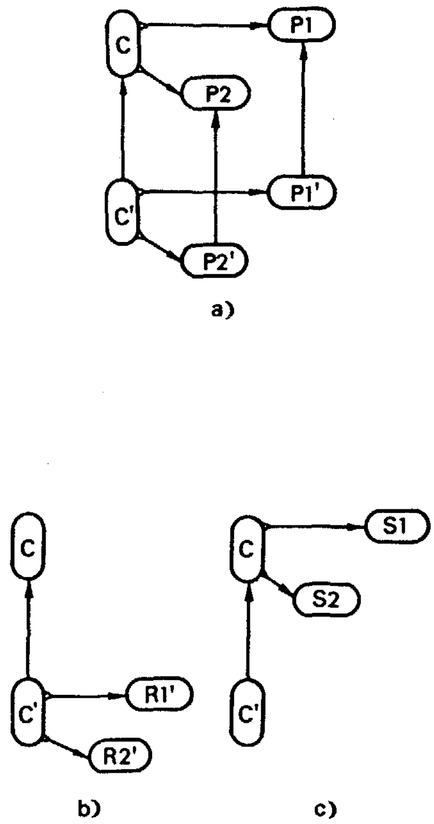

Fig. 2. Basic relationships between denotation and decomposition

However, both concepts C and C' may have properties which are not characteristic with regard to the other concept (Fig. 2b and c). We call properties of type Ri' (Fig. 2b) - casual properties of C' with regard to C (the level of abstraction of C has abstracted them), while properties of type Si - metaproperties of C with regard to C'. We stress the relativeness of types of properties: it may be, for example, that a property is characteristic with regard to one concept, whereas it is casual with regard to another one.

The next epistemological relation is that of generalization. We say that the concept C is a generalization of S (and that S is a specialization of C) (which we denote by S $\Longrightarrow$ C) if the meaning (denotation) of C is broader than that of S. This corresponds to the relation between the set and the subset. The relation of generalization also forms a hierarchy. For example the concept of square is a generalization of the concept of black and white drawing of square. Square is specialized here by acquiring optical properties. It might have been specialized in other ways.

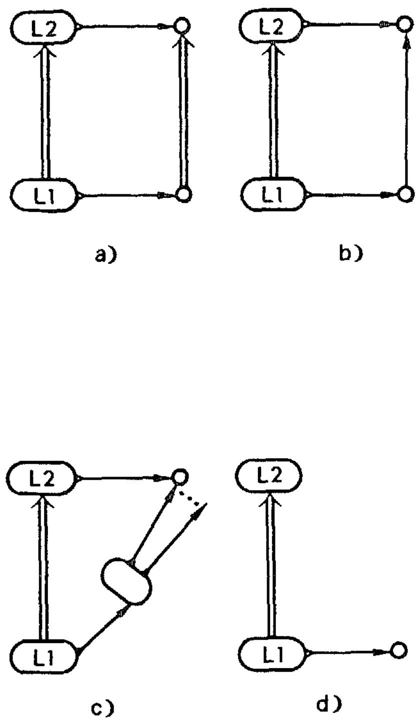

Fig. 3. Basic relationships between specialization and decomposition

Possible ways of specializing a concept are depicted on Fig. 3. Namely, a concept may be specialized by: (a) specialization of its property, (b) instantiation of its property, (c) forcing constraints on its properties, or (d) adding new properties. In the case of the relation of specialization we can speak of inheritance of properties along the specialization hierarchy. We say that an object inherits a property of its generalization if it possesses that same property as well (Fig. 4).

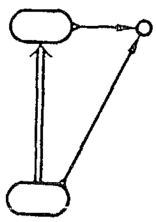

Fig. 4. Inheritance of properties

Inheritance of properties along the specialization hierarchy obeys the following lows: (a) characteristic atribute properties are always inherited (Fig. 5a), (b) characteristic value properties are inherited provided that the concept is the instance of the concept of which its generalization is the instance (Fig. 5b), (c) inheritance of a property takes place when it is neither specialized nor instantiated in the specialized concept.

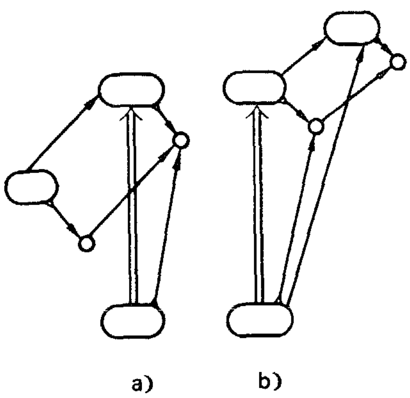

Fig. 5. Laws of inheritance

The fundamental relationship between generalization and denotation is expressed by the rule from Fig. 6. It states that when a concept denotes a certain concept then it also denotes every generalization of the latter. In other words it may be called reverse inheritance of instances along specialization hierarchy.

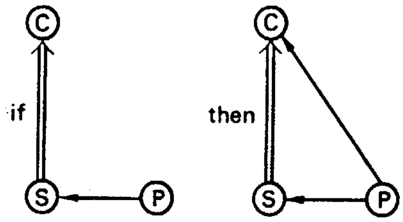

Fig. 6. Relationship between generalization and denotation

The last epistemological relation in our model is that of naming. It expresses purely conventional ascription of a name N to a concept C (denoted by N ⟶ C), the object N plays the role of a sign or a symbol for C. The relation of naming may form a hierarchy, like all of our epistemological relations. As an example, the inscription "square" is the name for the square. Contrary to other epistemological relations, the relation of naming does not obey any epistemological laws. Any connections with other relations are conventional and domain specific.

STRUCTURINGS

In Bielik, 1983 we distinguished two basic schemes of interpretation: vertical structuring (grouping) and horizontal structuring (labelling).

Vertical structuring consists in introducing constraints vertically (Fig. 7).

Grouping picture points into edge elements can serve as an example of grouping. In R local region of points Pi is placed. The constraint stating that Pi form an edge is placed in C. Q represents the region with edge.

Horizontal structuring consist in introducing constraints horizontally (Fig. 8).

Here the set of concepts Pi is specialized into Qi so that constraint C be satisfied. In such a way Qi get new meaning (as if Pi were labelled). The classical example of labelling

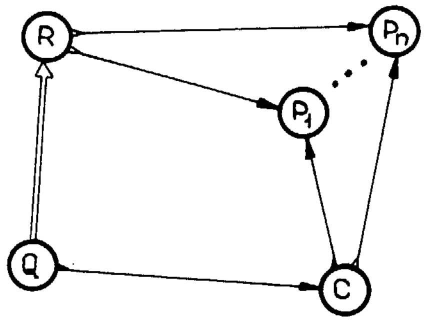

Fig. 7. The pattern of grouping

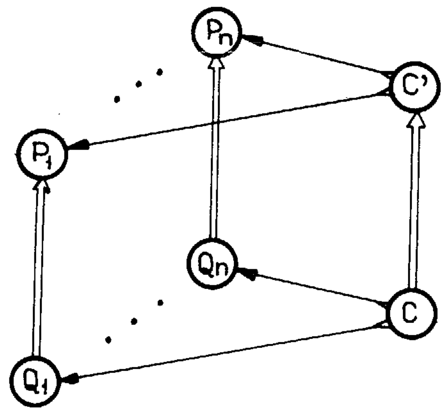

Fig. 8. The pattern of labelling

is 3-D interpretation of lines in 2-D line drawings by means of constraints at vertices. The configuration of 2-D line segments Pi in a vertex is represented by C'. After labelling Qi represent 3-D lines, e.g. concave block edge. 2-D configuration C' represents projection of 3-D configuration C.

STRATEGIES OF STRUCTURINGS

In real life recognition systems groupings and labellings are ambiguous (Fig. 9 and 10). Ci may represent in Fig. 9 different kinds of edges, line elements, etc.
Ci may represent in Fig. 10 possible 3-D lines configurations projected onto the same pattern C.

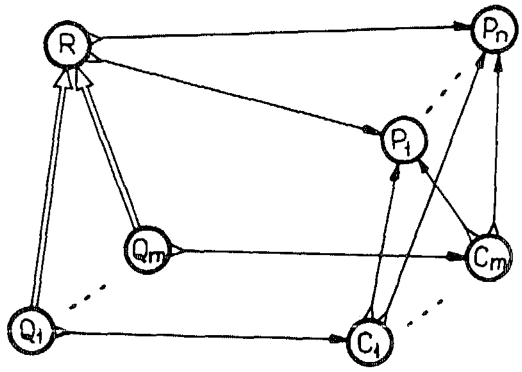

Fig. 9. Ambiguous grouping

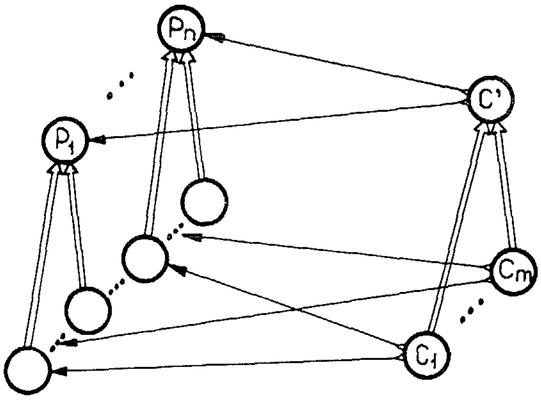

Fig. 10. Ambiguous labelling

A search process in needed in order to perform structuring from level P to level Q. One way to constrain this search is to discriminate hierarchically the set of possibilities. We show this in the case of grouping on Fig. 11 (the case of labelling is similar). Constraints may be decomposed at the same time. The strategy of interpretation is distributed in this case among units Si. It is expressed as programs, which first demand interpretation from appropriate constraints (i.e. check them). If this fails the unit reports it up the discrimination hierarchy, if not - demands interpretation from lower level units in a certain order.

Another way of constraining search is planning, as shown in Fig. 12 - for grouping, and in Fig. 13 - for labelling, where double dash arrows mean unambiguous aggregation (i.e. grouping followed by abstraction of unessential features, see Bielik, 1983).

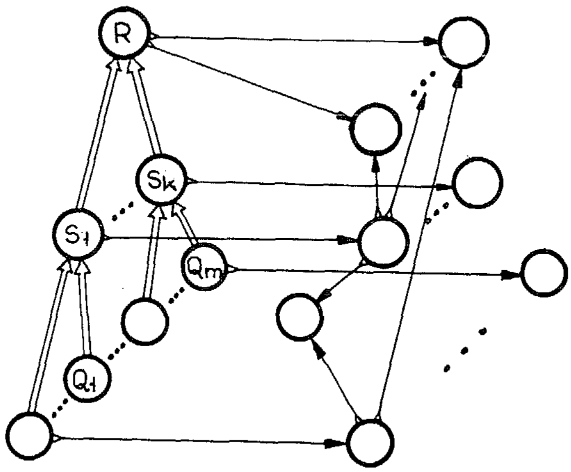

Fig. 11. Discrimination in grouping

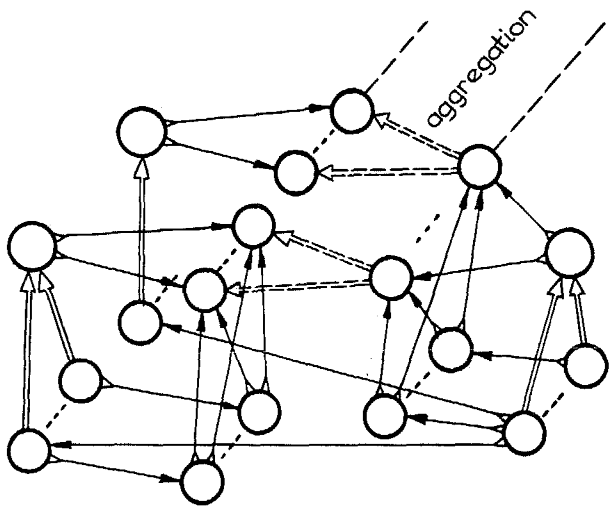

Fig. 12. Planning in grouping

In both cases after aggregation the same structuring is perfomed but in a smaller search space. The strategy of planning is composed of: generating plan (through aggregation), performing structuring in the plan, coming back in a lower (structured) level, and finally refining structure in the initial space.

Since all above strategies are realized locally, they can be easily mixed together.

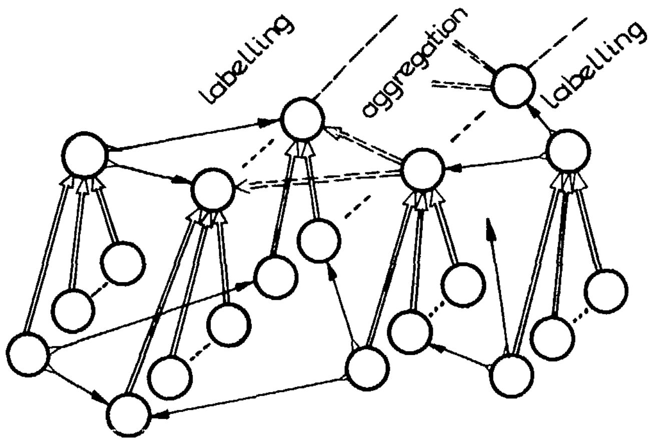

Fig. 13. Planning in labelling

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