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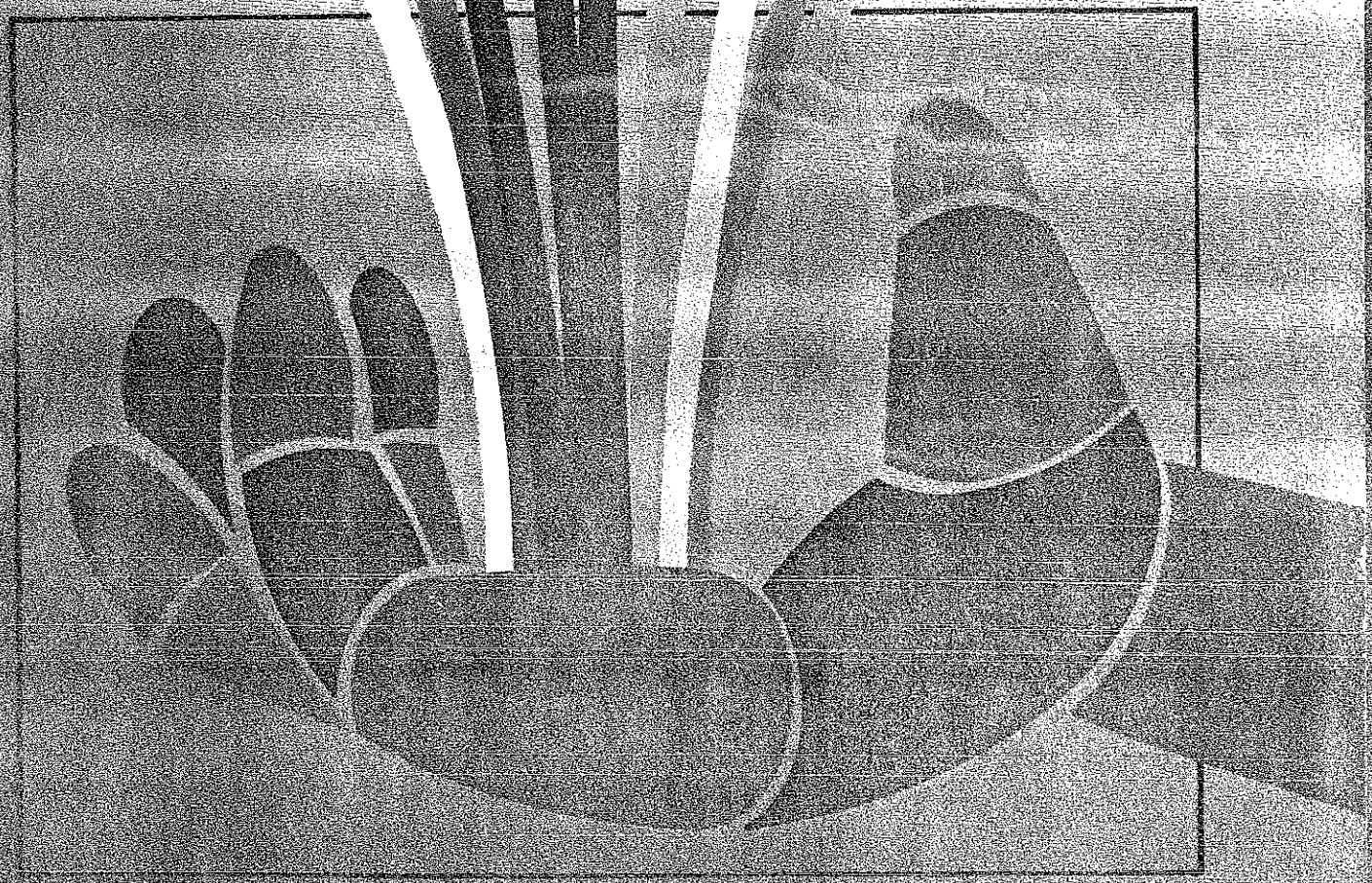

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A MULTILEVEL REPRESENTATION SCHEME

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RESUME

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Dans ce travail on étudie les relations entre deux corps de connaissances, l'un étant la représentation de l'autre, et la nature de ces relations.

On propose un schéma de représentation R* à plusieurs niveaux, et on définit les concepts de "Forme de reproduction" et "Relation reproductive" entre deux corps de connaissances dans le but de clarifier la nature de leurs relations. Ces définitions contribuent à une meilleure compréhension de la nature de certains processus de transformation nécessaires pour passer d'une représentation à une autre.

SUMMARY

ABSTRACT

In this work we study the relationships between two different bodies of knowledge one of which is the representation of the other, as well as the nature of such relationships.

We propose a multilevel knowledge representation scheme R*, and we define the concepts of **"Reproduction form"** and **"Reproductive relation"** between two bodies of knowledge, with the aim of clarifying the nature of the relationships between them. Such definitions may contribute to a better understanding of the nature of certain transformation processes required to convert one representation notation into another.

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A MULTILEVEL REPRESENTATION SCHEME

0. INTRODUCTION

Knowledge Representation (**KR**) in Artificial Intelligence systems has been understood as an enterprise of developing and implementing sufficiently precise representational schemes and notations.

We focus the attention of this work on elaborating some reflections on a selected aspect of **KR**, specifically the study of the relationships between two different bodies of knowledge one of which is a representation of the other, with the aim of clarifying the nature of such the relationships.

We propose a methodology of analysis of reality based on Wittgenstein's **Philosophical Investigations (PI)** and **Tractatus Logico-Philosophicus (TLP)**, and in the improvement and implementation of the model proposed by Furbach et al **/FURB84/**.

1. ANALYZING REALITY

Let **M** be the universal set of all events of some fragment of reality; and **R** a definition process (or set of processes) of objects and structures of **M** that allows their interpretation. M^* contains the set of logical images of **M** (as in **TLP $2.18, 2.19**). This enables us to formalize a logical analysis of the relationships between **M** and M^*.

Let R^* be a process (or set of processes) and definitions in M^* which permits us to represent the events of **M**. R^* is said to be an scheme of representation. Let us define a **body of knowledge** as the structure **(M,R)** or (M^*, R^*). The existence of a transformation **c** between **(M,R)** and (M^*,R^*) assures an external interpreter of the possibility of interpreting the elements of the structure R^* as the representation of the events $E_1,\ldots,E_n$ of **M**, and this representation is a complete one. Then our model of a Knowledge Representation System has the form: (M,R,M^*,R^*,c) as has been proposed by Furbach et al **/FUR84/**. In figure 1 is shown a possible organization of the representation of the world **M**, that we want to represent. This structure has been called R^*, and allows us to talk about the "objects" that exist in M^*.

Let **I** be the set of all possible images of **M**. In this context, we will accept an image (a picture of one scene) as a model of an event E_i of **M** (as in **TLP** $2.12). The relation between the elements of the image assures its existence, the existence of

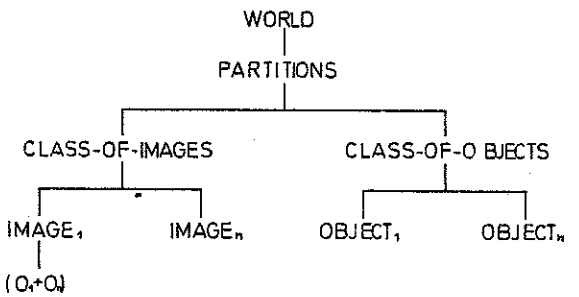

FIGURE 1.
The structure M^*.

these relations gives a structure, called **image's structure** (**TLP** $2.15). If we designate by E_i an event of **M**, and e_i an image in **I** of E_i, we can think in the structure of the image e_i as the coordination relation that exists between

the image and reality (see figure 2), and that assures that e_i is a complete representation of E_i.

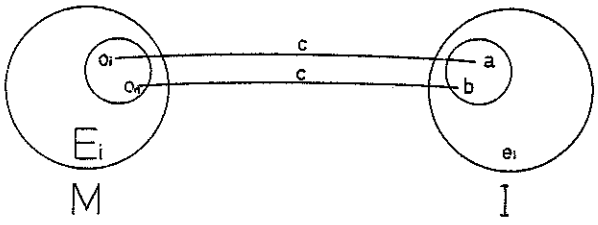

FIGURE 2.
The coordination relation between M and I.

Let us call this the **reproductive relation** (TLP §2.153,2.1514). The reproductive relation allows the representation of the existing properties of the objects and the relations between them in an event E_i of M. We will give the name **reproduction form (c)** to the function that allows to relate an event E_i of M with an image e_i of I (TLP §2.17,2.172). The reproduction form permits us to represent those properties of the relations between the elements of E_i that are not preserved in e_i (image of E_i) but need to be represented explicitly.

It is possible to extend this analysis to the propositions of a natural language. Let P be the set of all a propositions of grammatical natural language. If proposition p_i of P is an image of M (as in TLP §4.01), then all that a proposition communicates about an event of M is its **reproductive relation** (TLP §4.03); this is because a name corresponds to an object, another name corresponds to another object and the relation between them is an event of M (TLP §4.0311, see figure 3). It is important to point out that a proposition without a correct grammatical structure is not an image of M (TLP §4.032).

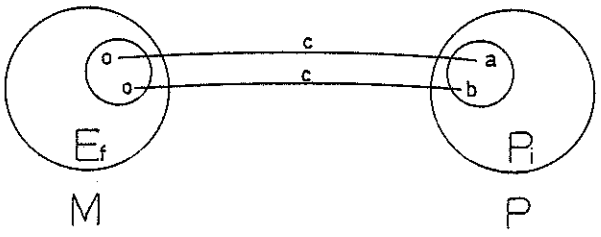

FIGURE 3.
The coordination relation between M and P.

The reproduction form is necessary for an image e_i of I (or a proposition p_i of P) to be a complete representation of an event E_i of M. We can follow from this the next conclusion: "All descriptions of an event E_i that is in M, obtained from I, P and M^* must be logically equivalent" (TLP §2.18). That is, we want to have the possibility to refer to R^* either by means of propositions of P or by means of images of I, or even both (see figure 4).

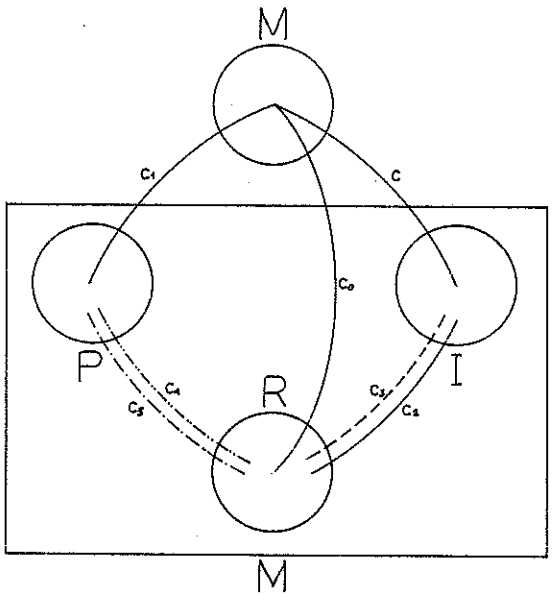

FIGURE 4.
R^* structure of M^*.

2. A MULTILEVEL REPRESENTATION SCHEME

The central idea in the construction of our multilevel representation scheme is to unify, in a compact structure, the information obtained by means of several perception mechanisms from **M**. This information may be numerical or linguistic, as well as precise or fuzzy.

The structure **(M,R)** provides a complete determination of the types of objects and relations which are defined in **M**. The existence of this structure provides the opportunity of tailoring specific representation systems.

The structure (M^*,R^*) is a set of processes and definitions that enables the complete representation of the events of **M**. In R^* we group a set of structures such as:

Image of E_i :=(<name of E_i>(<name>
(<name><relation><name>)
(<name><relation><name>),...,
(<name><relation><name>)))
(1)

and the set of processes that classify these structures. The **CDR (Image of** E_i**)** corresponds to the reproductive relation. The **<relation>** between objects could be in a particular case a spatial relation, for instance **ABOVE-OF, TO-THE-RIGHT-OF, IN-FRONT-OF.** Each **<name>** corresponds to an object and its general form of representation is as follows:

<object>::=(<name>,(<physical descriptors>)
(<linguistic descriptors>)) **(2)**

The equations (1) and (2) are general structures (for a complete definition see **/CORT84/**). The representation of an **<object>** is used as the basic element to construct a hierarchical representation structure, in M^*, of a particular world **M** (Figure 1).

2.1. MULTILEVEL CLASSIFICATION

The computational implementation of a set of processes that enables a machine to construct a particular set of representations of **M**, is the implementation of an R^* structure. This requires the creation of a specific representation taxonomy of **M**, as shown in figure 1, and the processes of acquisition, classification, identification and transmission of the information contained in a particular model of reality as an image or representation proposition.

In a particular structure R^* we can choose as the basic elements of M^* those represented by the equations (1) and (2). It is possible to go beyond (2) and to construct a hierarchical representation structure. The first step is to group **<objects>** with common features into a **<class-of-objects>** with the form:

<class-of-objects>::=(<name>,(<kernel>),
(list of components))
(3)

where **<kernel>** is the minimal set of common features which permits us to classify an object into a given class. The classification process consists of a set of predicates in terms of which we test the values of the **physical** and **linguistic** descriptors.

The idea of **class** has been introduced in order to reduce the search effort in the process of identification of one structure. **/see FREK81/.**

It is possible to use the **Image-of-**E_i structure (1) as a single object and apply the process of classification to the set of images of **M**. The resulting structures the **classes-of-images** structures can be used as new objects too. These structures have the form:

class-of-Image::=(<name>,(<kernel>),
(list of components)) **(4)**

The result is R^*, and from this it is possible to tailor a specific representation structure for a particular problem, as in **/CORT84, FURB84/.**

The structures described correspond to the **archetypes** of some of the R^* structures. These archetypes could be expanded through the introduction of new slots. The information of the archetype slots could be used for: (1) identification, (2) classification, and (3) inferences about an object o_i in a context K_i.

2.2. THE SIMULATION OF A KNOWLEDGE REPRESENTATION SYSTEM

To test the efficiency of our scheme, we have designed the simulation of a "language game" (as in PI$7) which allows us to analyse the interaction of a user **A** with an "elementary intelligent" system **B** **/CORT84/.**

The basic situation is the following: **A** instructs **B** by showing it objects and events of **M** (in this particular case **M** is composed of blocks and cylinders); **A** shows these objects by means of images of the type e_i, and assigns a name to each object or event by means of a proposition of the type p_i that **B** gets by constructing a proposition r_i of R^* (as in PI$6). **B** expands its knowledge base by means of the interaction with **A** described above.

The classification process of the propositions r_i is described in section 2.1.

In the simplest case, **B** works with images with only one object, and its representation structure is:

Object::=(<name>,(<physical descriptors>))
(5)

Here **A** could indicate an object o_i of **M**, giving it a name through a proposition p_i. After the localization of the object's representation, **B** will give back the image e_i of o_i -formed by its physical descriptors- if the object is known. Alternatively **A** could show to **B** the image e_i of o_i, and B's answer will be the name of o_i if the object has been recognized.

We have to point out that when **B** names an object, or shows its image, it is preparing itself to describe it (as in PI$49). If **B** does not know the object, that is, if it has failed in the process of recognizing an object o_i, then it has the capability of asking-for-a-name to associate it to the physical descriptors list that has been obtained from e_i. At this level, the computational problem is reduced to a sequential search of a name or a structure.

We wil call **Archetype** O_i to the representational proposition of an object o_i created by **B**. In a particular image, when **B** tries to identify a solid object, this object will be treated as a particular instance o_i of the archetype O_i.

This permits **B** to match two instances o_i and o_j using only the physical descriptors of the archetype O_i and avoiding the use of particular features such as color, weight, etc.; and to "decide" if o_i and o_j are instances of the same archetype. The creation of archetypes is very important in concept acquisition process. The notion of archetype allows **B** to acquire the concepts of object, class-of-object, image, etc.

In the second level we introduce the notion of class-of-objects C_i. To do this, it is necessary for **B** to extract from images or propositions features expressive enough for it to discriminate between objects that are

not in the same class, and describe the likeness relations between members of a given class. Our notion of "class" exploits the idea of likeness between the members of a family so that can be constructed a "kernel" for each class which permits to identify its members (as in PI§66, 67).

At this level, **B** could refer to the classes and to the objects indifferently. The computational problem is reduced, because **B** must look only at the kernel of each class, identify one and look in its list of elements. **/CORT84, FREK81/.**

Finally we have introduced a new level where the images admit more than one object. At this level, **A** could assign a name to an image e_i (see the formula 1). Again, **B** treats this image as an object. This permits the creation of a new structure called the "class-of-images". Our scheme does not introduce any discontinuity in M^* because any image r_i or proposition p_i completely contains the possibility of the non-existence or the inexistence of an event E_i of **M** (as in **TLP** 2.201). The **reproduction form** assures the conservation of the representation proposition in a very natural way: this information is captured in the slots as properties of an object. However, the comparison between r_i (a representation proposition of R^*) and E_i will be the only validation method.

3. CONCLUSIONS

R^* is a **KR** structure which permits the manipulation of images, propositions or both. The representational propositions of R^* are more general than the ones used by López de Mántaras **/LOPEZ80/.** Our definition of a **KR** system satisfies all the theoretical requirements described by Furbach et al **/FURB84/.**

With our representation scheme R^* it is possible to analyse separately the operations of reasoning and the operations of representation. This structure can be used as a critical instrument in the study of other schemes.

The notions of **reproduction form** and the **reproductive relation** aim at the clarification of the nature of the relationship between two different bodies of knowledge in the context of knowledge representation theory **/FREK84/.** These notions imply the completeness of the propositions r_i of R^*. Currently we are developing a bibliographical data-retrieval system that is based on the KR-structure described.

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