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The Evolving of Concept System based on Representation Redescription

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Abstract. An adaptable concept system with rich connotation is important to the improving of the performance of knowledge-based artificial intelligence systems. But it's hard to construct such a system. Fortunately the researches about human cognition show us a way to measure up. Karmiloff-Smith's Representation Redescription (RR) hypothesis describes a concept-acquisition process that re-describes a lower level representation of a concept to a higher one. This paper is inspired by this developmental psychology viewpoint. We use an object-oriented (OO) approach to explain and simulate RR hypothesis from the formal semantic perspective, because the OO paradigm is a natural way to describe the outside world, and it also has strict grammar regulations. We designed and realized the representations of concept-acquisition and their evolutions from one to another at different levels. Our results solidify the semantics and pragmatics of a concept acquired by RR through a kind of visible, verifiable and replicable carrier—an OO language. Further, in an environment of materializing concepts by objects, an OO language makes the refinement of concepts and the construction of a concept system more operable and controllable.

Keywords: Knowledge representation, Representation redescription, Object-orient

1. Introduction

Knowledge acquisition and knowledge representation is the foundation of knowledge-based system. How to acquire knowledge from the outside world, and how to efficiently use of the acquired knowledge has great significance for constructing a knowledge-based system.

There are two main problems in the construction of expert systems: the bottleneck of knowledge acquisition and the narrow scope of knowledge system. The former involve that how to translate the knowledge in the real world into the knowledge that the expert system can use, while the latter involve that expert system only adapt to domain-restricted problem solving, once related to the issue of domain-opened, its capacity of problem solving will become very vulnerable. The main reason for these problems is that the knowledge of expert system is almost mechanical and lack of the support of the underlying semantics. They are not from the perspective of the development of concept to construct a concept system.

Representational Redescription (RR) model proposed by Karmiloff-Smith is a very promising hypothesis[1]. It depicted a complete outline of cognitive development. The model has four representational levels and claims that people acquire knowledge through a proper *Representational Redescription* progress. However, because of the difference on research purpose and method, RR model still have some gaps between artificial intelligence. A lot of details and mechanisms of realization aren't considered. So the RR theory is not complete.

Since the theory is still very vague, this paper proposes a multi-level representation approach for representing and constructing concept system. The approach is based on RR. It uses object-oriented language syntax specification as a means of semantic formalization, and depicts the process of concept representation and development on the levels RR. It provides a detailed scheme for realizing the RR hypothesis, including the specific form of the four representation levels and three change phases. Furthermore, it depicts the process of concept acquisition and cognitive development through the change of representation form. It helps to know more about the representational form and the using principle of concept system.

2. Related work

The paper [4] analyzed the structure of experts' knowledge specially and extracted experts' tacit knowledge and represented it. These researches did not take into account the psychological model of human, so they can not improve the sharing and flexibility of knowledge in an intelligent system fundamentally. The human being's problem solving ability is related to their knowledge structure. However, very little researches explained the relation between them clearly[7]. The researches on the representation and development of concept structures are paid more attention to increasingly. Their motive is to construct knowledge structures and broaden the base of problem solving. The representational methods among them not only include the classical knowledge representation, such as semantic network and framework etc., but also involve Concept Graphs[8],[9],[3]、Ontology[5],[6],[8]、Concept Lattices[9] etc. However, these methods are only suitable for the knowledge which has good structure, and they did not consider the process of concept formation. The problem solving served by these methods is merely some simple ones. Therefore, there is a long way between the semantic form of sign and concept connotation

There are also many popular applications of knowledge system. One of them is WordNet [10] which is used as a lexical dictionary. WordNet forms a structure of lexical related words. We can find related words as well as the word we search. But WordNet is far from a concept system. It only has the functions such as searching and matching lexical related words. There isn't enough information to interpret complicated facts. Other systems such as MindNet [10] are similar to WordNet and can't be regarded as concept systems.

3. Representation redescription

3.1. What is representation redescription

Karmiloff-Smith proposes the *Representational Redescription* (RR) model [1]. She believes that people acquire knowledge through a proper *Representational Redescription* progress and the same knowledge can be stored in various forms and levels. The whole process consists of three phases and four different levels of representation. Different levels have different representational forms. The four levels are: implicit I, explicit E1, explicit E2 and explicit E3. The different forms of representation are not related to the increasing age. They are occurred repeatedly in different micro-fields and the whole process of cognitive development. The following are the characters of each level which are depicted by psychological language.

Implicit I: The form of representation is the module that reflects and analyses the outside stimulus. These modules are stored as independent instance, and their behavior is holistic. They can not form representational relation too, so the presentation of implicit I is not flexible. In this representational level, information is coded in the form of program which includes a sequence of atomic operations.

Explicit E1 and E2: Several representational instances of implicit I are induced. A flexible cognitive system is formed gradually, and then children's immature theory is established. These representation of explicit E1 can be operated and contact with other representation which has been redescribed. At this level, the representational form is acquired by re-coding and compressing the program of implicit I. It is worth noting that the former representation of implicit I still stored in the minds of the children intact, and it still adapt to certain specific cognitive goal. Although the representation of explicit E1 can be used as a systemic material, it can not access to consciousness and be reported in the form of language. Accessing to consciousness needs to redescribe the presentation of explicit E1, so the explicit E2 appeared, but it has the similar coding with explicit E1. This representation may access to consciousness, but still can not be reported by using language.

Explicit E3: Representation at this level not only can access to consciousness, but also can be reported in the form of language, knowledge is re-coded to the new form that can cross different system. This general form is very close to natural language, and it is easy to translate stable form, and can be used for communicating, which is the highest level of RR.

As shown in the figure below, when a concept is mastered in a higher grade, the relation of the concept expands gradually. This expansion happens as well in human's mind. The concepts cover a wider range in his concept system.

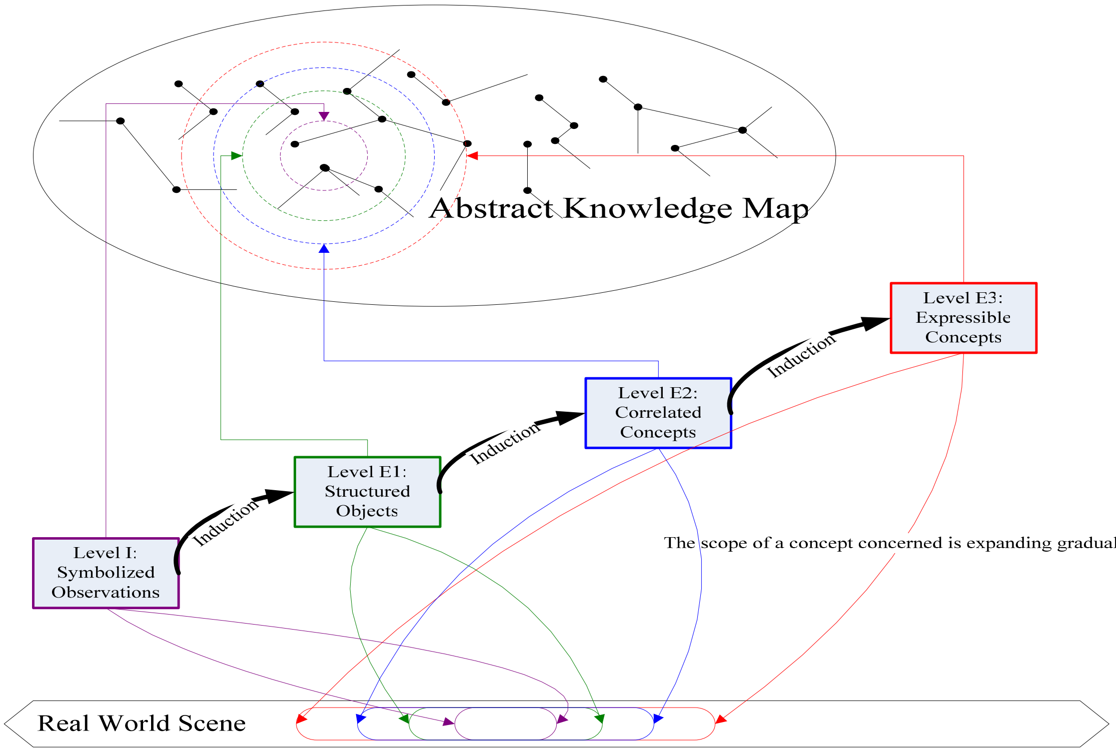

Figure1 The representation redescription process

RR hypothesis provides a new idea for constructing knowledge-based system. It illustrates the development of acquiring concept and using concept from the aspect of representation evolution.

3.2. Learning the concept of round as an example

Let's take children's learning the concept of round as an example. The process shows how round is mastered as a concept. In the experiment, children gain the concept "round" from some circles and other figures drawn on the papers first. Then, they can touch more round thing such as balls, wheels and rings freely and tell the distinction between them and other things.

Table1 shows the children's ability and behaviors in different stage of comprehension.

Stage	Behaviors	Possible inner explanations
Implicit	Children only learn some typical instances of circles. They can recognize instances they have learnt.	Instances of events are saved independently, similar instances don't share representational components, and they are not abstracted to concepts. Representation is composed of a series of basic atomic operations. It is only a reaction response to the specific situation or problem.
Explicit 1	Children can determine whether a figure on the paper is round. Not only the instances have they learnt.	By summarizing and inducing examples, children discovered the common features and formed the common representation. The representation has an independent module with relatively single function, which is considered as the core of new concept.
Explicit 2	Things such as balls and wheels can be regarded as round things. Children can grasp some features of round things such as the ability of rolling.	The representation is more abstract, can adapt to more problem solving, the external visibility and the share ability were improved. Some operations in the representation can be used by requirement
Explicit 3	Children can tell which part of an object is round and tell the functions of these parts. They can recognize more features of round things and can apply them in different situations.	The concepts are related to other concepts tightly. The representation is highly abstracted and tends to be stored for a long time. In this stage, representation can be easily interpreted to another form, such as language.

Table1 The behaviors and Possible inner explanations to a new concept in different stages

3.3. The relation between representation redescription and knowledge system building

RR hypothesis illustrates the process of acquiring concepts from the aspect of representation evolution. It described the process of concept development reasonably, that is, use the change of representation to indicate the improvement of knowledge acquisition. It plays an important role in simulating people's cognitive structure from the aspect of algorithm.

The core of RR is the distinction between implicit knowledge and explicit knowledge[3]. However, the RR hypothesis does not elaborate on the specific form of the knowledge in each level. The other problem worthy of note is that the standard used by RR is very vague. What is the representation of each explicit level? What is the distinction between them? RR hypothesis did not give a detailed description. Moreover, RR model includes four representational levels and three change phases, so there must be a complex mechanism to control the process of RR. But all these details are not involved in RR hypothesis.

4. Representation of RR process based on Object-Oriented standard

4.1. Why object-oriented method?

In this paper, we use the object-oriented approach to represent knowledge. It's a good idea that using objects to describe the attributes and behaviors of things. Object-oriented technology is a matured technology. It is a good method to represent knowledge for its rich and stable semantic. It has a lot of good features, such as modularity, maintainability, extensibility, inheritability and so on. This is why we combine the object-oriented technology with the knowledge representation. Moreover, object-oriented technology is a good tool, which can describe the physical world. It has reliable guarantee in theory and methods. Take learning the concept "round" as example, this paper illustrates the RR process of acquiring the concept "counting" in the following part. It uses the change in attributes and behaviors of object to realize the evolution of mastering concept, and to explain the development of cognition.

4.2. Object-oriented representation of learning the concept of round

At the implicit level，children merely recognize instances they have learnt such as figures on a paper. The representation related to round in their mind can be like figure 2:

```
RoundFigure1 {Isinstance=Ture;Isround=True;}
RoundFigure2 {Isinstance=False;Isround=False;}
TriangleFigure1{Isinstance=Ture;Isround= False;}
Ball1{Isinstance=False;Isround=False;}
```

Figure2 Object-oriented representation of RR Level I

At the explicit 1 level，children can recognize all round figures on the paper, but can not recognize round in other forms. The concept of round begins to take shape in the children's mind. Some features of the concept are acquired from the study of instances. The representation can be like figure 3:

```
Class Round {Symmetric=True;}
Round RoundFigure1{Isinstance=Ture;Isround=True;Symmetric=True;}
Round RoundFigure2{Isinstance=False;Isround=True;Symmetric=True;}
TriangleFigure1{Isinstance=Ture;Isround= False;}
Ball1{Isinstance=False;Isround=False;}
```

Figure3 Object-oriented representation of RR Level E1

At the explicit 2 level，children can recognize round things in almost any forms. Some features and methods of round are grasped as well. Children can grasp relations such as inheritance and so on. The representation can be like figure 4:

```
Class Round{Symmetric=True;Roll(){Being pshed, round things can rotate.}}
Round RoundFigure1{Isinstance=Ture;Isround=True;Symmetric=True;}
Round RoundFigure2{Isinstance=False;Isround=True;Symmetric=True;}
TriangleFigure1{Isinstance=Ture;Isround= False;}
Ball1{Isinstance=False;Isround=False;Symmetric=True;Roll();}
```

Figure4 Object-oriented representation of RR Level E2

At the explicit 3 level，children can not only recognize round things but also grasp their essence. It's a complicated representation of the concept of round with the relationship to many other concepts and impossible to be drawn on a paper.

5. Algorithm

5.1. Three actions in RR process

From the example, we can see there are three actions in the RR process.

The first action is inducing, children induced the new concept can be related to many objects rather than the ones they learned by this way step by step. The second is splitting, by observing what can be adhered to many types of objects, new concept was recognized. The third is feature gaining. By this action, children know many other features about the new concept which can not be gained merely through the simple training. This is also a quite complex action.

We can construct the algorithm of concept acquisition according to these actions.

5.2. Process and algorithm

We observe information from samples. In the implicit stage, instances are saved in our mind as what they are. Then, useful information is extracted and higher-levelled representation is constructed. The process can be represented by figure 5.

Concept gaining in natural world is too complicated, so we merely pose the algorithm based on symbol systems. As shown in figure 2, information are extracted and clustered from samples in the real world. First, the objects obtained from observed samples and events are blended to object groups use structured-mining (if there exists a knowledge-base, it should be applied). Then, new concepts can be induced from the object groups according the classification hierarchies. New concepts' attributes and methods can be gained in further training. After that, new concepts should be represented using various forms such as formal language or insert into database for applications and problem solving.

In this algorithm, structured-mine is a complicated operation, normally include the application of knowledge base and a structured cluster operation which finally divides observed events into object groups. If knowledge base is empty, we needn't apply it to the scenarios. If the objects are recognized by the application of knowledge base, cluster is only an operation that adhere events to objects according the structure such as syntax, space and temporal information.While iterating of the algorithm, more and more information about concepts are acquired. Relations between concepts become more and more complicated and clear.

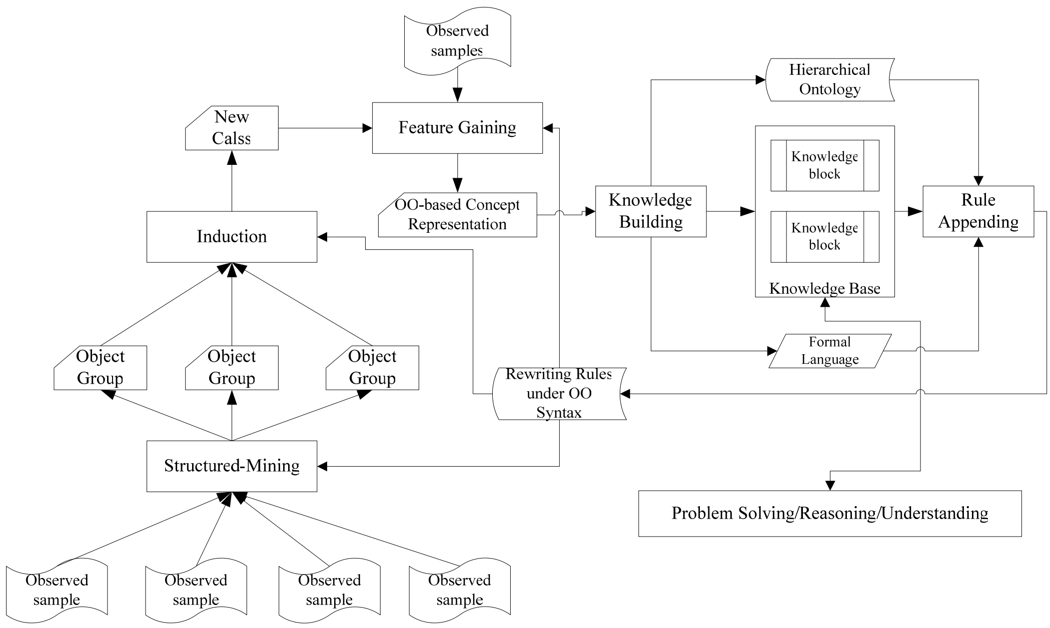

Figure5 RR based machine-learning process

6. Conclusion

In summary, this research puts forward a new method of constructing concept system, which is based on RR, which takes an important step on the road of solving unrestrictive problems. The research is considered as a knowledge acquisition module rather than a cognitive module; it helps us to know more about the representational form and using principle of concept system in detail. However, RR model includes four representational levels and three changing phases, so there must be a complex mechanism to control the RR process. But all these details are not involved in RR hypothesis. Therefore, it is difficult to realize the algorithm of representational evolution, and it is also an important direction that we have to study.

7. Acknowledgements

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