

# Research on Knowledge Representation based on AORBCO Model

Liangshun Xiao, Junmin Luo, and Wuqi Gao

College of Computer Science and Engineering, Xi'an Technology University, Xi'an 710021,  
China

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## Abstract

Knowledge representation is as the foundation of artificial intelligence and plays a crucial role in the function of intelligent models. In this paper, through the study of existing knowledge representation methods, we find that these knowledge representations only model a single domain, but human intelligence is comprehensive and is capable of solving complex problems across domains, and these knowledge representations are incomplete in their definition and representation of knowledge. Based on this, this paper provides a clear definition of knowledge from the theory of consciousness-only, and analyzes and compares the existing knowledge representation methods from three completely new perspectives: composition, role, and characteristics of knowledge. Through the comparative analysis, it is found that the AORBCO model has advantages over other models in completeness and intelligence of knowledge representation, and can better represent intelligence and more complete and comprehensive representation of different knowledge.

## Keywords

Intelligence; Knowledge; Artificial Intelligence; Knowledge Representation.

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## 1. Introduction

The emergence of computers has facilitated the dissemination of knowledge, and at the same time many definitions of knowledge have emerged, for example, the literature [1] considers that knowledge is formed through processing and transformation and is the resultant form of the human cognitive process. Knowledge engineering [2] considers that the sources of knowledge include: experts, books, sensors and files in computers, etc., and that knowledge is a procedure used to solve a specific domain or problem. These definitions of knowledge are very vague and fail to give the essence of what knowledge is.

In addition, a variety of existing knowledge representation methods do not have a deep enough understanding of knowledge, but only one-sided representation, and they sever intelligence from knowledge, for example, first-order predicate logic [3] represents the properties and relations of things through predicate formulas, and does not have affective knowledge; knowledge graph [4] represents the state of things through nodes and edges, but does not have process knowledge; object-oriented simply treats all things object-oriented simply treats all things as objects without distinguishing subjects and objects; distributed knowledge representation [5] can only describe the states and relationships of things.

For this reason, this paper gives a definition of knowledge with the help of concepts in theory of consciousness-only psychology and gives a representation of knowledge in the AORBCO model. It also analyzes and compares the existing forms of knowledge representation from three new perspectives: composition, role and characteristics of knowledge, and concludes that the AORBCO model can better represent knowledge.

For this reason, this paper gives the definition of knowledge by comparing the relevant knowledge representations and analyzes the relationship between the three of information, data and knowledge, and analyzes and compares the common forms of knowledge representation.

## 2. Knowledge Definition and AORBCO Model

Knowledge and intelligence often appear together, regarding what is intelligence? Knowledge threshold theory [6] considers the amount of knowledge and the level of generalization as intelligence. In psychology [7], intelligence consists of intelligence and competence, with intelligence being the process from sensation to memory to thought, behavior and language being the products of intelligence, and "competence" being the process of performance of behavior and language. These definitions analyze intelligence in terms of determinants and components, respectively, but they separate intelligence from knowledge and describe it in an incomplete way.

Since the study of human intelligence in the psychology of consciousness only is deeper, the definition of knowledge is given here: knowledge is the understanding and description of "knowledge", that is, the whole world. In knowledge-only psychology, the subject of knowledge consists of eight consciousnesses: eye, ear, nose, tongue, body, consciousness, mantra, and arya. The object of knowledge of the first five senses is the real world, and the object of knowledge of the last three senses is the abstract world. With knowledge in order to manifest intelligence, the manifestation of intelligence is also knowledge, so we think that intelligence and knowledge are actually equivalent. The AORBCO model [8] provides a concrete representation of our defined knowledge by adopting the idea of "one person, one world" and simulating the real world by studying the nature, structure, composition and society of the human mind to build a knowledge base of Ego (self), which perceives, understands, plans, executes and communicates with acquaintances to solve problems and learn. execution, and communication with acquaintances to solve problems and learn. The model contains the individual knowledge components and their intertransformations and interconnections.

As shown in Figure 1, the structure of the model description language is as follows.

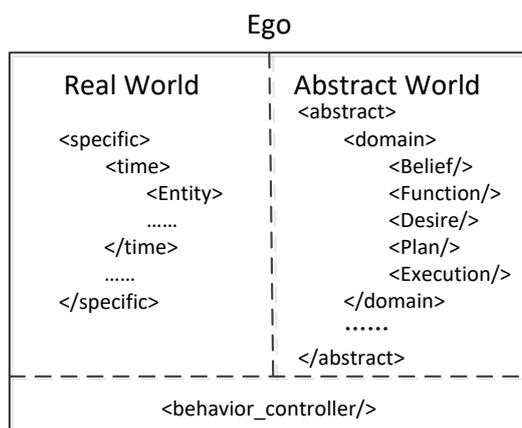


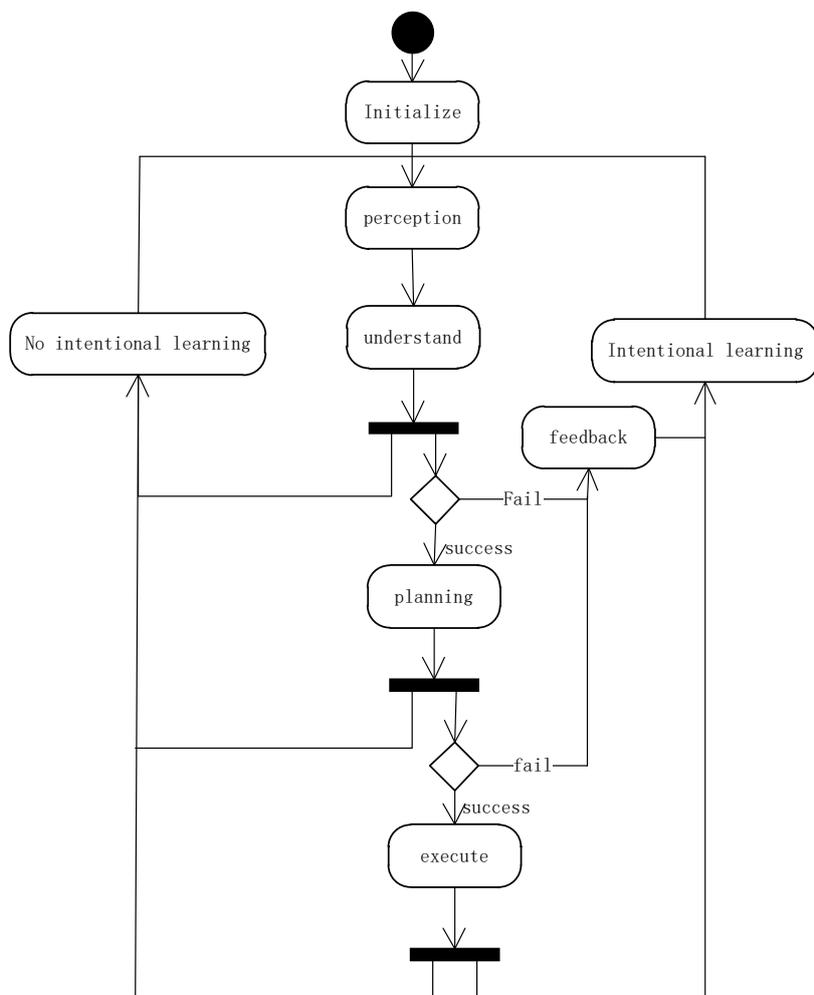
Figure 1. AORBCO Model description language

The tag <specific> represents the real world. The tag <abstract> represents the abstract world. The tag <time> indicates the state of the real world at a given time. The tag <Entity> represents the state of something in the real world at a certain time. The tag <domain> represents multiple domains of the abstract world. The tag <Belief> represents a Belief. The tag <Function> indicates capability. The tag <Desire> indicates a wish. The label <Plan> indicates the Plan. The tag <Execution> indicates Execution. The tag indicates the behavior control mechanism.

Beliefs are descriptions of entities and their relationships that Ego knows, including acquaintances, objects, and relationships between them. Capabilities are the set of operations that make things change

from one state to another. Aspiration is the description of the goal that Ego wants to achieve, i.e., the goal state. Planning is the decomposition of aspirations in order to accomplish them. Execution is the running of the planned sequence of operations.

The behavior control mechanism then makes the controller in the Ego. As shown in Figure 2, the model divides the process of Ego knowing the world into five steps: perceiving, understanding, planning, executing, and learning. First is the initialization of the model: including the initialization of beliefs, abilities, and wishes; perception: processing the information perceived by Ego, including acquiring and filtering knowledge; understanding indicates the connection between the knowledge perceived by Ego and the knowledge of the abstract world, and generating wishes according to the actual needs; planning indicates the decomposition of wishes made to realize the wishes, which is used in the AORBCO model. The idea of "divide and conquer" is used in the AORBCO model to decompose the wishes and solve them one by one; execution indicates the operation of the actions generated by planning; learning is the summary of Ego's experience, including unintentional learning and intentional learning; unintentional learning refers to the habitual change of Ego's proficiency in understanding the world; intentional learning indicates that Ego learns a new problem from a familiar person when encountering a new problems, learning new abilities from acquaintances.



**Figure 2.** Execution process of behavior control mechanism

Knowledge representation is the mapping of things in the real world into symbols in the computer, and the processing of symbols to represent the relationships and changes among things. In the next parts 2, 3 and 4, the existing knowledge representation methods are comparatively analyzed from

three completely new perspectives: composition of knowledge from the perspective of the knower and the known, and from the perspective of completeness and structure; the role of knowledge is analyzed according to the usefulness of various kinds of knowledge, i.e., from the perspective of functionality; and the characteristics of knowledge are analyzed from the perspective of intelligence.

### 3. Representation of Knowledge Composition in the AORBCO Model

According to the composition of knowledge, it can be divided into: subject, ability, object, and purpose, as shown in Figure 3. The subject, i.e., the knower, is distinguished from the object and is able to know the world. Object indicates the thing to be known. Purpose is the goal of the subject to know the object, i.e., why the subject wants to know the object. Ability is the process of how the subject knows the object. Among them, the object of knowing is a kind of knowledge in a narrow sense, and many existing researches are studied from the perspective of the object, and the object of knowing is inseparable from the subject, because without the subject of knowing there would be no object of knowing.

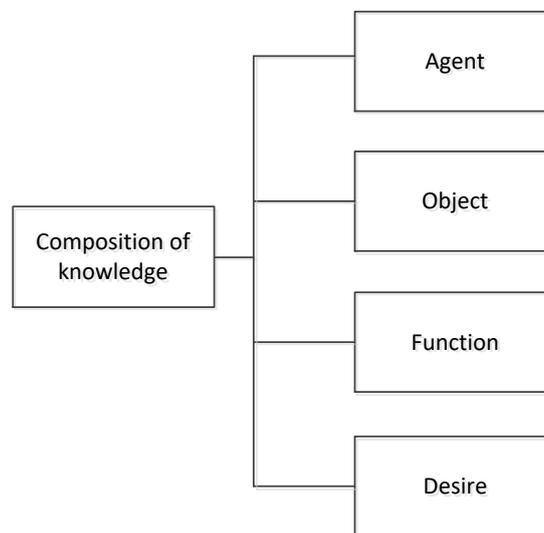


Figure 3. The composition of knowledge

The existing knowledge representation methods are analyzed by the composition of knowledge, as shown in Table 1, where - is not discussed or cannot be represented. Among the existing knowledge representation methods, only the concept of subject is talked about in object-oriented and multi-agent systems, where the subject in object-oriented is an object and the subject in multi-agent systems is each Agent, but it is not completely based on self-modeling. Different knowledge representation methods are based on their respective domains, in order to solve a domain problem or task, and are not a domain-wide representation method.

The subject in AORBCO model is Ego, and the result of recognition is from Ego, and the result of recognition can be different even if different subjects perceive the same thing. The result depends on the subject of awareness. The object of recognition is the different media such as character, picture, audio, etc., which are perceived by the input device. Ability is the operation that Ego has, for example, subject A has the ability to analyze decimal values, and subject B has the ability to analyze binary. Purpose is the Ego desire, which is the driving force that drives the subject to learn and evolve, and is achieved through the behavior control mechanism. And the purpose here is not just to solve a single domain problem, but a domain-wide problem, e.g. to calculate the friction force when an object is in motion is a calculation method involving the domain of physics and a specific calculation in the domain of mathematics.

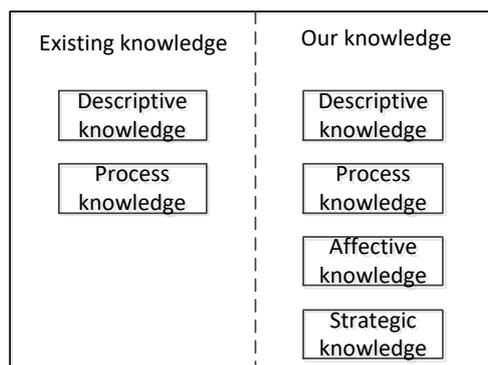
**Table 1.** Analysis of the components of knowledge

	Agent	Object	Function	Desire
First-order predicate logic	-	Predicates	Predicates	single field
Production representation	-	Global database	Post-condition	single field
object-oriented	object	Object and class	methods	single field
Knowledge Graph	-	triple	-	single field
Distributed representation	-	vector	-	single field
Neural networks	-	Nodes, links, and weights	Back propagation (training phase)	single field
Multi-Agent System	Agent	belief	Desire generation, screening	single field
AORBCO	Ego	Belief, desire	Function,execute, behavioral control mechanisms	all field

#### 4. Representation of the Role of Knowledge in the AORBCO Model

According to the different roles of knowledge, knowledge is classified here as: descriptive knowledge, process knowledge, affective knowledge, and strategic knowledge. As shown in Figure 4, the existing classification of knowledge in the field of artificial intelligence contains only descriptive and process knowledge, and the representation and classification of affective and strategic knowledge have not been explicitly proposed. Descriptive knowledge is the knowledge that describes the state of things. Process knowledge is the operations that make the state of things change. Affective knowledge is the knowledge that makes value judgments about the current state of an entity and is a reference for making choices. Strategic knowledge is the knowledge that makes use of descriptive knowledge and emotional knowledge for the selection of process knowledge. The formal representation of strategic knowledge  $S$  is shown in formula (1), where  $B$  denotes descriptive knowledge,  $E$  denotes emotional knowledge, and  $F$  denotes process knowledge, indicating that the operation of  $F$  can be performed under the conditions of  $B$  and  $E$ . Various kinds of knowledge call and transform each other to form a complete knowledge system.

$$(B) \stackrel{E}{\Rightarrow} (F) \tag{1}$$



**Figure 4.** The role of knowledge

The existing knowledge representations were analyzed by the role of knowledge, as shown in Table 2.

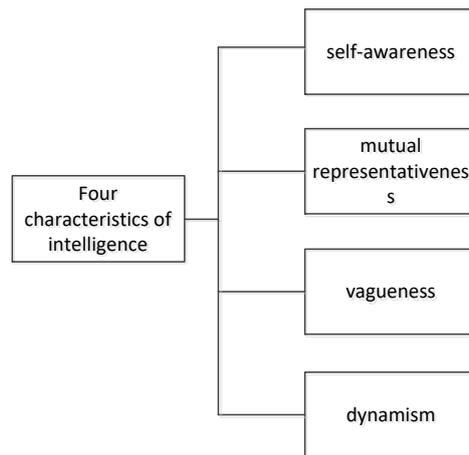
**Table 2.** Analysis of the role of knowledge

	Descriptive knowledge	Process knowledge	Affective knowledge	Strategic knowledge
First-order predicate logic	Predicates	Predicates	Implied truth and falsehood	Equivalences
Production representation	Global database	Post-condition	Pre-condition	rules
object-oriented	Object and class	methods	-	methods
Knowledge Graph	triple	-	-	-
Distributed representation	vector	-	-	-
Neural networks	Nodes, links, and weights	Back propagation (training phase)	weight	-
Multi-Agent System	belief	Desire generation, screening	-	Consultation, planning
AORBCO	Belief, desire	Function, execute, behavioral control	weight	planning

In the AORBCO model, descriptive knowledge is represented as: beliefs, desires, for example, Ego has a description of peony in its beliefs: plant kingdom, angiosperm phylum, dicotyledonous phylum. Process knowledge is expressed as: ability, execution, and behavior control mechanism, for example, Ego has the ability to sort arrays, which will correspond to a source file that can be executed. Affective knowledge is expressed as the change of intimacy between subjects and the weights of objects, for example, Ego's intimacy to acquaintance A is 0.6, and will increase to 0.65 as the number of cooperative problem solving between them increases, then the next time it encounters a similar problem, Ego will be more inclined to ask acquaintance A for help. Strategic knowledge is expressed as planning, and the ability will be selected according to the specific state and emotion in solving the problem.

## 5. Representation of Knowledge Characteristics in the AORBCO Model

In the literature [9-12] through the study of human intelligence by general psychology, reflective psychology, cognitive psychology and mereological psychology, it was found that mereological psychology has studied the nature, composition and function of human intelligence more thoroughly, and concluded that human intelligence has four major characteristics such as self-awareness, mutual representativeness, ambiguity and dynamism. As shown in Figure 5, self-awareness, indicates that individuals are aware of their own states, emotions, and thoughts, and each person has his or her own independent world, and understands acquaintances through interaction with them. Mutual representativeness, which indicates that nothing is isolated and depends on other things to exist. Ambiguity, indicating that things are related to each other with distinctions of closeness and distance, and are not clearly classified. Dynamism, indicating that the state and relationship of things are changing with the environment.



**Figure 5.** The four characteristics of intelligence

Similarly, like intelligence, knowledge has four main characteristics, the subject of knowledge is also human, knowledge is also established by mutual representation, the relationship between knowledge has different degrees of closeness, and knowledge can be changed by the subject's awareness. The existing knowledge representation methods are analyzed through knowledge characteristics, and Table 3 compares different knowledge representations in the dimensions of the four characteristics of intelligence.

**Table 3.** Analysis of four characteristics of knowledge

	self-awareness	mutual representativeness	vagueness	dynamism
First-order predicate logic	-	Predicates and implications	-	-
Production representation	-	Global database and production	-	reasoning
object-oriented	-	attribute	attribute	-
Knowledge Graph	-	Relationships and properties between nodes	-	reasoning
Distributed representation	-	The value of a dimension in a vector	the value of the integration vector	-
Neural networks	-	Each node and its neighbor	Weights between nodes	Back propagation
Multi-Agent System	Agent	belief	Desire generation, screening	single field
AORBCO	view of the Ego	The relationship between Ego and acquaintances and objects	weight	Renewal of beliefs, abilities, desires

The AORBCO model describes the real world from the perspective of an individual, and the knowledge is all knowledge from Ego's perspective, and the mapping of acquaintances is established in Ego by interacting with acquaintances, so the model is completely based on self-awareness, for example, the integrity of acquaintance A is in Ego's belief is 0.8, but it is really 0.6 in another subject's

view. the existence of self in Ego's belief with acquaintances and The connection of the object is the mutual representativeness in the AORBCO model. the weights between the intimacy of the acquaintance and the object in Ego's beliefs are weights from 0 to 1, rather than explicit 0 or 1, because the weights change with Ego's awareness as a way to represent the ambiguity of knowledge. In addition Ego will realize the update of acquaintance, object, and relationship, as well as the update of ability and desire with its own awareness and interaction with acquaintance, thus indicating the dynamic nature of knowledge, for example, Ego learns how to sort the array through the interaction with acquaintance A, and the weight between them increases.

## 6. Conclusion

In this paper, we analyze the existing knowledge representation methods, out the definition of knowledge, and compare the existing knowledge representation methods through the three perspectives of composition, role and characteristics of knowledge, and the results show that AORBCO model can better represent knowledge. The subsequent research is based on the knowledge fusion research in the AORBCO model, which is to map the information in the real world into the abstract world of Ego to form an understanding of things.

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