Ecological Methodology and Mechanism Approach

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-- New perspective to Intelligence Science

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Abstract. What would strongly appeal in the paper is that the ecological methodology and the mechanism approach, both are newly proposed by the author of the paper, be employed for the study of intelligence science. As presented, the unified theory of intelligence science is discovered and established due to the methodology and approach being adopted.

Keywords: Ecological Methodology, Mechanism Approach, Unified Theory of Intelligence

1 Introduction

The research on artificial intelligence, AI for short, has made a number of splendid progresses recently while also confronted with severe controversies. Some researchers declare that the great breakthrough in AI is coming in few decades and AI machines will take the domination over human beings. Other group of researchers, however, insists on the existence of huge difficulties in AI research in which many fundamental issues related to intelligence are still remained unclear, or even almost unknown [1]. This situation led the theme of intelligence science, instead of intelligence technology (or AI), to receive more and more attentions from academic circles worldwide.

It is well accepted that the first important issue one should take care in mind in the academic research is the question of whether the scientific methodology being adopted is appropriate or not. This is because of the fact that scientific methodology is the macroscopic guideline for research that will inspire the proper approach to the specific field of research. Therefore, whether or not the methodology is suitable for intelligence study will determine whether or not the research can be successful [2].

According to the principles mentioned above, we have noted that the methodology adopted in intelligence research has long been the reductionism featured with "divide and conquer" which had been an extremely powerful, and also successful, methodology in classical physics in modern times. This led AI research to the situation where a number of different, and mutually isolated, approaches being employed, namely the structuralism, the functionalism, and the behaviorism all in parallel and separate. As result, researchers employing different approaches have different understanding on what AI

should be. In other words, reductionism is the major root that generates the controversies in AI [3].

In order to effectively improve the situation, we have carried out a long term investigations based on which we have summed up and would now like to propose a new methodology, named ecological methodology, for the intelligence science study from which a new approach to the intelligence research, termed mechanism approach, is also inspired [4].

The concepts of ecological methodology will be introduced in section 2 and then the basic model of the typical intelligence process, based on ecological methodology, will be presented in section 3. The mechanism approach to the study of intelligence science will be explained and compared with the other approaches in section 4. The major results due to the new methodology and approach will be exposited in section 5. Some conclusions will be given in the final section

2 Ecological Methodology vs. Reductionism Methodology

2.1 Definition 1 Methodology

Methodology, scientific methodology more precisely, is not methods for dealing with specific problems but is a general term that refers to the general criterion, or the general guideline, for the proper selection of the specific methods to a field of study.

Therefore, the first, and also the most important, issue among other any things for scientific study should be making an effort in doing an assessment on whether the methodology to be employed is appropriate or not. Only the proper methodology employed could give guarantee to the success of the research.

One of the most influential, and also the most successful, methodologies in the history of natural sciences development is the "reductionism". It says that, a complex system can be divided into a number of sub-systems, which must be simpler and easier to handle, and that the solution for the system can then be obtained by summing up the ones of all sub-systems. So, this methodology can well be characterized as "divide and conquer".

Reductionism as a methodology has achieved numerous successes, particularly in the physical science study, or mechanical science study in modern times. The major characteristic for performing the reductionism, as was mentioned above, is that the complex problem must first be divided into a number of simpler, and mutually isolated, sub-problems and then each of the sub-problem be individually solved and finally all the sub-solutions are summed up. This caused no problem in classical physical science study.

However, if the system in consideration is a kind of information systems, the performing of reductionism will certainly cause serious problem. This is because of the fact that there exist complex information links among the sub-systems of the system and between the system and its environment and that all the information links are the 'life lines' of the information system. The 'life lines' of the information system may be cut-off when improperly dividing the system, hence leading the information system being "dead system".

Therefore, when dealing with the problems in information systems, intelligence systems in particular, which are usually complex systems, one should be very much careful on how to properly dividing on one hand and, on the other hand, should carefully seek for the new, and appropriate, methodology for recovering the life lines of the system.

2.2 Definition 2 Ecology and Ecosystem

As a kind of methodology, ecology is referred to the general guideline that emphasizes the study of interrelationships among the organisms of the system and between the system and their environment. All the interrelated organisms constitute the ecosystem.

Obviously, the methodology of ecology, or more conveniently the ecological methodology, is the methodology that is exactly what needed for the study of complex information systems, through which the life lines, or the interrelations, among all the parts of the ecosystem and between the ecosystem and its environment can hopefully be recovered. Consequently, the global properties and laws governing the complex information system can hence be recovered and studied.

It is known that intelligence is derived out from knowledge which in turn is from information. In other words, there will be no intelligence at all if there is no information provided.

Therefore, intelligence systems in all cases are complex information systems, or equivalently information processing systems, in nature. In other words, ecological methodology is the one needed, and suitable, for the study of intelligence science.

3 The Model of Intelligence Process in Perspective of Ecological Methodology

In accordance with the definition of ecological methodology and the investigation of various kinds of intelligence activities, it is found that the most typical intelligence process can be abstracted as the model in Fig.1.

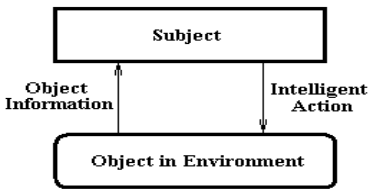

Fig. 1. Abstract Model of Typical Intelligence Process

As can be seen from Fig.1 that the intelligence process must be within the framework of the subject-object interaction: First, the object in environment presents its object information to the subject. And then the subject handles the object information and produces, based on the results of the handling, an intelligence action that acts on the object in environment. The action must be intelligent enough. Otherwise the subject may suffer from risks of danger.

The process of producing intelligent action in Fig.1 can be expressed in more detail. This leads to the model in Fig.2.

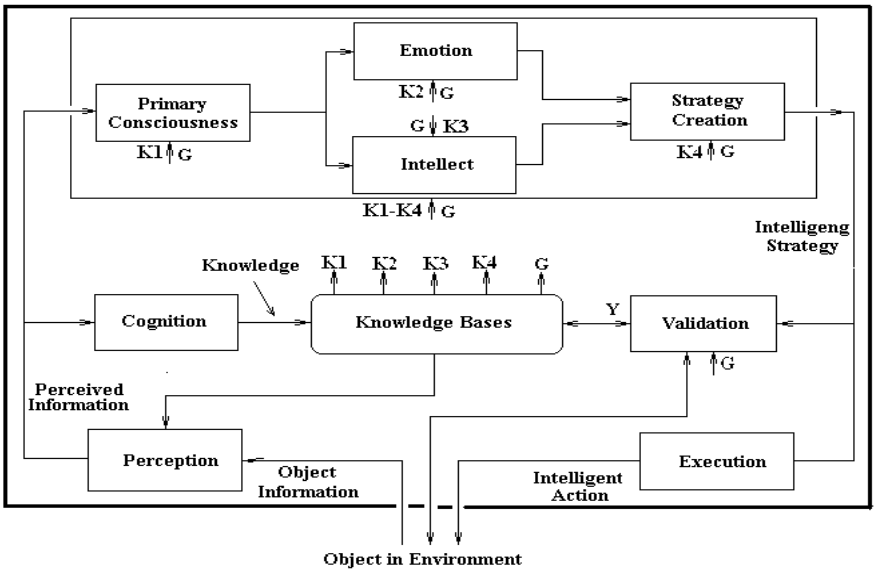

Fig. 2. The Detailed Version of Fig.1

The entirety within the thick-line-box in Fig.2 represents the subject who performs all the functions of intelligence: perception, cognition, strategy creation and strategy execution. The attributes that characterize the subject include various kinds of knowledge, K1 (innate and commonsense knowledge), K2 (empirical knowledge), K3 (regular knowledge), K4 (Art and other knowledge needed for strategy creation), and the goal for problem solving, G, all stored in the knowledge base at the center.

As can be seen from Fig.2 that there exist various kinds of interrelations among the units of the subject and between the subject and the environment. The studies of the interrelations meet the requirements of ecological methodology.

More specifically, the major interrelations that the ecological methodology concerns the most include the followings (see in Fig.2):

(1) The interrelation between the object in environment and the subject's unit of perception,

(2) The interrelation between the unit of perception and the unit of cognition,

(3) The interrelation between the unit of cognition and the unit of intelligence the latter of which consists of the unit of primary consciousness, the unit of emotion, the unit of intellect, and the unit of strategy creation,

(4) The interrelation between the unit of intelligence and the unit of execution, and

(5) The interrelation between the unit of execution and the object in environment.

4 Mechanism Approach vs. Other Approaches

The next issue is to develop the proper approach to the study of intelligence science based on the general guideline from the ecological methodology and the associated model. That means that we should understand and study these interrelations among the units of the system and their environment so that the laws and rules that govern the intelligence processes and activities can be established.

There have been many different approaches existed in history. Particularly in AI research, there are structuralism approach for dealing with neural networks, functionalism approach for dealing with physical symbol systems and expert systems, and behaviorism approach for dealing with sensor-motor systems. As mentioned above, these approaches are resulted from the reductionism methodology and can only explore some of the partial knowledge of the intelligence process.

Note that the mainstay in intelligence system is the series of interrelations among the units and their environment and that all the units of the subject cannot be treated separately from each other as mutually isolated ones. We should explore and discover the inherent mechanism that reasonably organizes all the units to fulfill the task of generating intelligence. This leads to the mechanism approach to intelligence science study.

To investigate the mechanism approach, Let's look back the model in Fig.2:

The function of interrelation (1) is to converse object information to perceived information; The function of interrelation (2) is to converse perceived information to knowledge; The function of interrelation (3) is to converse perceived information to intelligent strategy; The function of interrelation (4) is to converse the intelligent strategy to intelligent action; and The function of interrelation (5) is to apply intelligent action to the object in environment.

This can briefly be expressed as a series of conversion, that is,

(1) The conversion: object information → perceived information,

(2) The conversion: perceived information → knowledge,

(3) The conversion: knowledge → intelligent strategy,

(4) The conversion: intelligent strategy → intelligent action, and

(5) The conversion: intelligent action → object.

The series of conversion above can be expressed as "information → knowledge → intelligence", in which "object information" and "perceived information" are abstracted as "information" and similarly, "intelligent strategy" and "intelligent action" are abstracted as "intelligence".

Therefore, the most compact expression for the mechanism approach to intelligence science is the series of conversion:

$$\text{information} \rightarrow \text{knowledge} \rightarrow \text{intelligence} \qquad (4.1)$$

The formula (4.1) means that, by employing mechanism approach to the study of intelligence science, the most important thing should be to have the information needed for the problem solving and to handle the series of the conversion from information to knowledge and further to intelligence, instead of the specific structure, functions, and behaviors of the system.

The formula (4.1) is the most important and significant result because of the fact that the system's structure, functions and behaviors must be determined by the mechanism of the intelligence system. In other words, mechanism of intelligence generation is the only dominating factor in the study of intelligence science whereas the system's structure, functions, and behaviors are the dominated factors.

5 Major Results Due to the Mechanism Approach

It is easy to see from the formula (4.1) that the essence of the mechanism approach can be named as "Information Conversion and intelligence Creation" provided that the following three conditions are given beforehand: (1) The object information that represents the problem to be solved, (2) The goal that indicates the final state for the problem solved, and (3) The knowledge that is needed for solving the problem in hand. This can also be clearly expressed in Fig.3 below [4].

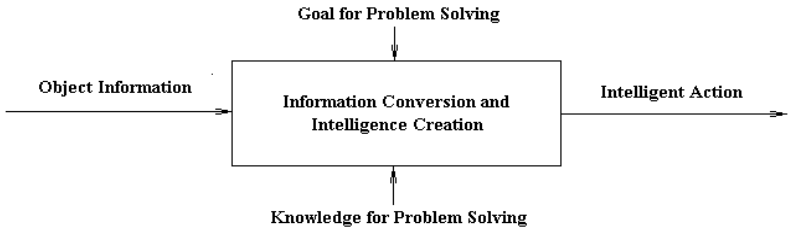

Fig. 3. Another Expression for the Formula (4.1)

The meaning one can see from Fig.3 can be expressed in words that, as long as the three conditions are provided, the study of intelligence science is to perform the function of (4.1), the function of information conversion and intelligence creation, with the intelligent action being produced and executed.

If the result of the intelligent action is satisfied the problem is satisfactorily solved. Otherwise the error between the actual state and the goal state, as a kind of new information, should be feedback to the input of the system and the new knowledge should be learned and added for producing a new, and better, strategy. This "feedback-leaning-optimization" loop may be carried on a certain number of times until the result is satisfied.

This is the universal law as well as the unified theory of intelligence science.

6 Conclusions

(1) Scientific methodology is the first, and the most important, issue in scientific research. The reductionism methodology employed in intelligence research the past is not sufficient. The scientific methodology appropriate to the study of intelligence science should be the one of ecology, or more precisely the **methodology of information ecology**.

(2) The secondly important issue in any scientific research is to, under the guideline of the methodology employed, formulate an appropriate model representing the research. The model applied in AI in the past has been much too narrowly isolated. The appropriate models of typical intelligence process should be **the model of subject-object interaction** expressed in Fig.1 and Fig.2 respectively, instead of the model of brain only.

(3) The thirdly important issue in any scientific research is the approach selection, under the general guideline of the methodology employed and also based on the model selected. The structural approach, the functionalism approach, and the behaviorism approach applied in AI in the past are locally and shallowly valid. The universal approach to the study of intelligence science is the **mechanism approach expressed in the formula (4.1)**.

(4) The mechanism approach to intelligence science study has been identified as the series of conversion: "object information → perceived information → knowledge → intelligent strategy → intelligent action", or more briefly "**information → knowledge → intelligence**" in which the conversions need to be supported by new logic [5] and new mathematics [6].

(5) The most interesting, and also most significant, result is the universal law governing the intelligence science that is the **Law of Information Conversion for Intelligence Creation** expressed in Fig.3 and Fig.2 which is derived from the methodology of information ecology, ecological model of intelligence process, and the mechanism approach. The law is universally valid, that is whenever the three conditions (the object information about the problem to be handled, the goal for the problem solving, and the knowledge needed for the problem solving) are provided, the task of intelligence science study is to perform the mechanism approach.

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