ABSTRACT

An attempt was made in the article to propose a new approach to the intelligence research, namely the cognitive approach that tries to explore in depth the core mechanism of intelligence formation of intelligent systems from the cognitive viewpoint. It is discovered, as result, that the mechanism of intelligence formation in general case is implemented by a sequence of transformations conversing the information to knowledge and further to intelligence (i.e., the intelligent strategy, the embodiment of intelligence in a narrower sense). It is also discovered that the three major approaches to AI that exist, the structural simulation approach, the functional simulation approach, and the behavior simulation approach, can all be harmoniously unified within the framework of the cognitive approach. These two discoveries, as well as the related background, will be reported here in the article.

Keywords:  core mechanism of intelligence formation; information theory; information-knowledge-intelligence transformation; intelligence theory; knowledge theory

INTRODUCTION

Artificial intelligence is a branch of modern science and technology aiming at the exploration of the secrets of human intelligence on one hand and the transplantation of human intelligence to machines on the other hand, so that machines are able to perform functions as intelligently as they can. What is the essence of intelligence, as we should understand it in the scientific context, then? What are the parts of human intelligence that can technically be feasible for transplanting to machines? In what ways would humans be able to make machines really intelligent? These are some of the major issues we should make clear in AI research.

Due to the high complexity of the issues, there have been many approaches proposed in history to the research of these secrets. The three dominant approaches are: (1) the structural simulation approach, whose typical representative is neural networks, (2) the functional simulation approach, whose typical representative is expert systems, and (3) the behavior simulation approach, whose typical representative is sensory-motor systems. They study the intelligence, respectively, from different angles of views: (1) the views of the biological neural networks structure in human brain, (2) the views of its logical reasoning processes, and (3) the views of its input-output behavior. They are good approaches to the intelligence research, and therefore have all made certain progresses so far.
Some of the technically well-known contributors of the three approaches to AI can be briefly listed as the following.

A great number of artificial neural network models, algorithms, and applications have been developed in the line of the first approach. The well-known contributions can be seen from, for example, McCulloch and Pitts (1943), Rosenblatt (1958), Hopfield (1982), Rumelhart et al. (1990), and Ruan (2006). Various results in symbolic logic and expert systems with applications in wide areas have been presented in the stream of the second approach. The impressive achievements can be found from, for instance, Feigenbaum and Feldman (1963), Simon (1969), Newell and Simon (1972), Barr et al. (1982), Russell and Norvig (2006), and many more. Quite extractive sensory-motor systems have been designed in the thought of the third approach. The outstanding examples can be seen from Brooks (1990, 1991). Note that the neural networks approach (also called connectionism approach), has been renamed the computational intelligence since the early 1990s through the process of combining fuzzy logic and genetic algorithms.

On the other hand, however, each of the three approaches has also been confronted with respective and critical difficulties.

The neural networks approach faces the dilemma in dealing with the relationship between the structural complexity and the intelligent performance of neural networks. The number of neurons in the human brain is as large as $10^{10}$, and the total number of connections among the neurons is in the order of $10^{14}$, and the huge number of connections gives the guarantee of high intelligence to the human brain. This scale would be impossible, nevertheless, for artificial neural networks to reach based on industrial capability in modern technology. If the number of neurons and connections in artificial neural networks are reduced to the feasible order for industrial implementation, the performance in intelligence will be severely reduced, too. It is very difficult, even for today and the near future, to find a satisfactory compromise between the complexity in structure and the performance in intelligence.

The expert systems approach is confronted with the difficulty in such issues as knowledge acquisition, representation, and inference. Knowledge is one of the most crucial bases for any expert system, and nonetheless, most of the knowledge bases have been basically built up manually relying on the system designers. It is, of course, hard work with low efficiency. At the same time, the power of the means of knowledge representation and inference based on mathematical logic are also rather limited in expression and operation. This leads to another problem, severe limitation in practical applications. The low efficiencies, as a bottleneck, in knowledge acquisition, representation, and inference make the expert systems approach far from as promising as it was announced and expected in the early days of AI history.

Because the sensory-motor approach does neither simulate the biological neural networks of human brain, nor simulate the process of symbolic manipulation, it therefore does not need knowledge bases as that in expert systems, nor does it suffer from the structural dilemma mentioned before. It seems that it is able to totally avoid such difficulties as that seen either in neural networks or in the expert systems approach. This may be true to a certain extent. However, the sensory-motor approach suffers from another difficulty, the difficulty of having higher-level intelligence. The performance the sensory-motor systems can achieve is relatively simple in general, although useful. It is really difficult for the sensory-motor approach to implement the high level intelligence like thinking, reasoning, and many other complicated features in intelligence.

Moreover, while facing certain critical difficulties, the three approaches seemed not quite harmonious to each other in the history of their development, and it is still difficult to work with them together nowadays. People from the three disciplines sometimes even argued among one another as to which one among the three is the best. This makes researchers re-evaluate the approaches to AI and find some new and