Cognition and Approaches

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Directions of cognition studies changed over time. The advances of science and technology uncovered new possibilities of studying nervous system and enabled novel discoveries and theories by observing the animal and human behavior. Simulation of cognitive process would yield many benefits as for science so for industry in designing devices for instance. Science would obtain answers that were hankered after for a long time.

This paper attempts to compare some of traditional approaches to understanding and modeling of cognition with some newer views on the subject.

Brain, Body, Environment

Earlier, traditional approach to modeling cognitive processes or more precisely cognitive robots[1] used to put accent on the role of the central nervous system. Even though processing of the input information is important, crucial is the ability to create a plan of action, including the way of executing the plan. The plan is represented by symbolic expressions. In the beginning, the plan was usually created using the logical deduction. Later, new improved methods of logical reasoning were proposed like nonmonotonic reasoning, fuzzy logic etc. which overcome some of the deficiencies of classical logic reasoning, but still have some drawbacks of their own.

Some of the advantages of the mentioned approach are that the way of reasoning is precisely defined, mathematically formal, it is simple for manipulation, and its correctness can be proved or disapproved easily[2]. They are derived from logic principles based on human reasoning. Its disadvantage would be quite substantial complexity of evaluation in some cases, moreover the analysis of facts and plan creating can be quite time demanding. The other important disadvantage is the usage of symbols, which for example brings problems in learning and adaptation processes of cognitive robots, the question of defining new objects or concepts, or the necessity of having the inputs that have the certain acceptable (coded) form. We need to transform our analogue input into information that is discrete and can be then used and symbolically manipulated by the central nervous system (in cognitive robots it could be a processor).

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[1] Robots that show “intelligent behavior”, although the meaning of intelligence is still not defined precisely defined

[2] Easily in the sense that the symbolic representation is appropriate for scientific observations and studying and not with the meaning of simple manipulation.

New approach tries to solve the problem of cognition on different level, by understanding the functioning of the brain and living beings in general, in contrast with the first approach, which is more based on psychological and philosophical view of cognition processes. Researches in biology and neuroscience show that for low level cognition body and environment play the same important roles as central nervous system. This was not the case in the first approach. Under the expression low level cognition I mean cognitive processes that need constant information from the environment and does not require linguistic and semantic capability, like for example walking, dressing etc.

It is possible to find many examples from real life that can demonstrate how cognition depends on body, i.e. different body would lead to different cognitive processes. Different animals have different brain structures. Over the time, the body and the brain of an animal co-evolved and co-developed. Experiments with animals that had two fingers bound showed that this binding led to changes in the nervous system. The information that central nervous system receives largely depends on the body structure, which receive the signals, and on the other side the motor output from the body is also determined by structure of the body. This is a result of the fact that brain is embedded within the body.

Second approach emphasizes the interactive behavior, i.e. on-line cognition where the body including the nervous system is in constant interaction with environment. This can be also observed in animal world. For example the hydrodynamics of the water plays important role for swimming of lamprey[3]. Removing the lamprey from the water and stimulating it to swim lead to generation of completely inappropriate movements of lamprey. This verifies the importance of the feedback from the environment to adaptive behavior.

The following simple experiment with a robot illustrates the interactions of three equally important “players” of adaptive behavior: the brain, the body and the environment. The robot was placed in dark, closed, rectangular field with white triangle and white rectangle, which it should distinguish, by going to the triangle. Evolutionary algorithm was used to develop the position of two visual sensors and the robot “brain”, which consisted of artificial neural network. The evolved solution had two sensors placed vertically, one above the other, and the strategy of robot’s behavior was as follows: when it registered the edges of triangle it went forward, else the robot circled. Sometimes the sensor input of the edges of rectangle the robot confused with the edges of triangle, but after coming closer to the rectangle, it “realized the mistake” started to rotate, found the triangle and moved towards it. In the previous illustration is obvious the need of constant sensor input which helps robot find the right object and correcting its behavior after the mistake. Another issue is the position of sensors, which also determine the robot behavior, if the different positioning of sensors was chosen it could lead to different input

[3] Species of primitive, jawless fishes, eel-like, scaleless animals

information and so to different behavior and in some cases even new strategy. If the environment was changed so that for example there were many objects that could “remind” the robot of triangle edges, then it could undoubtedly happen that the strategy that was successful in previous environment fails in the new situation.

Representational vs. Nonrepresentational Memory

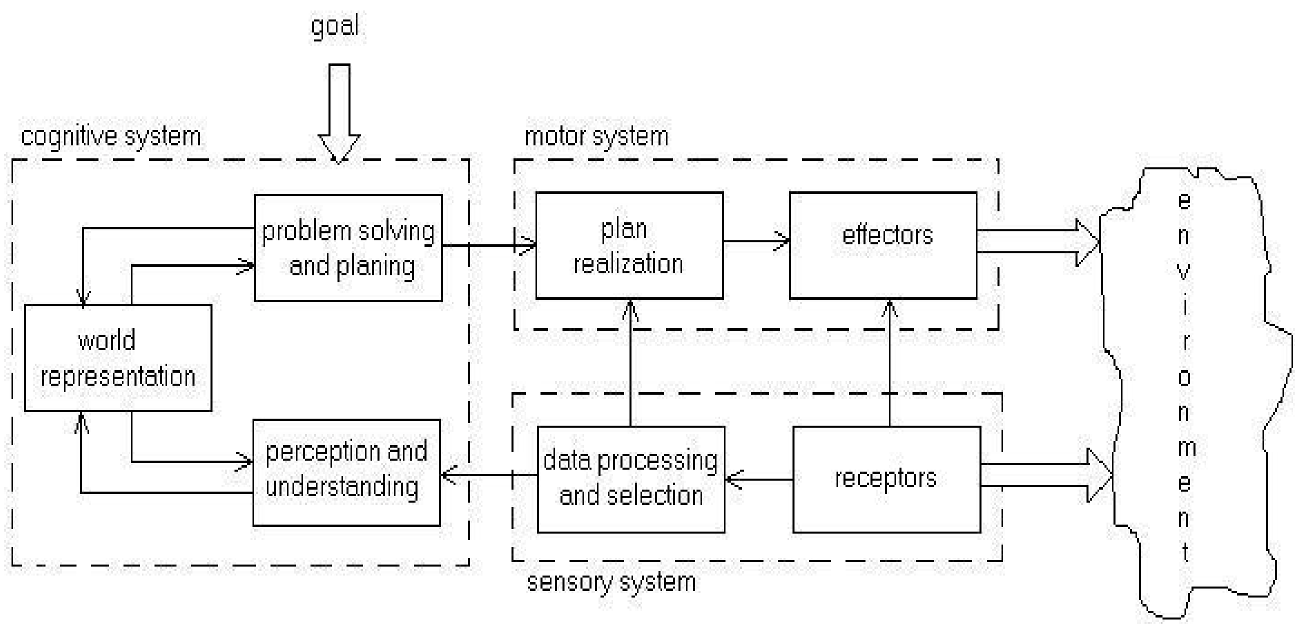
Traditional view of memory is naturally representational. Partial explanation can be found in standard computer systems that have representational memory in the form of hard disks for instance. Since for the modeling of cognitive processes were used computers, the fact that symbolic representation was chosen seems reasonable enough. Moreover, taking the psychological view of memory into account the usage of representational memory can be justified. As mentioned before, symbolic representation can be easily manipulated based on the laws of logic or improved logic theories, but reveal limitations in modeling adaptive behavior and learning. Symbolic representation has problems with ambiguous input, which is very common in reality, for instance a real scene, instead it requires a coded input. Another intriguing question is the possibility of storing all the possible combinations of codes, which seems unmanageable task even for such a complex structure like the brain is. This fact actually suggests that the memory of living beings is not symbolically represented.

Studies of neuroscience bring new views on the old subject of cognition, they suggest that the memory is nonrepresentational. Owing to the fact that the brain is a very complex and still unexplored system, the advances of science provide the possibility of deeper and more thorough studying of nervous system. The approach proposes that the key concepts are categorization and concept. Memory is just changing of dynamics of the brain. Essential are synaptic changes that occur in the brain, which are results of processes of reentry and value systems. Reentry would be synchronization of the activity of group of neurons in different brain maps making a circuit that could give a certain output of the system. Value systems on the other hand influence whether during some neural activity the strengthening or the weakening of synapses will take place. For example if something important happens to us we tend to remember the situation more intensively. Memory is the result of distributed activity of neurons, input from the environment, the body and the brain. The changes in synapses will have effect on the future outputs from the brain given the similar or dissimilar inputs.

As mentioned earlier, the cognition could be divided in the lower level and the higher level cognition. Higher level cognition is common for humans, where important role would have semantic and linguistic capability. Cognitive processes that do not require continual input or does not require input at all still justify the existence of symbolic representation and reasoning. Such processes might be for instance deep thinking, playing chess, solving mathematical problems etc. On the other hand, for the lower level cognition, which is besides being common for humans especially common for animal species, appears that nonrepresentational memory is the more suitable choice.

Parallel vs. Sequential

Another question about cognitive processes is whether they are parallel or sequential. If we consider the human thinking, at one time we can only have “in mind” one thought. Why we should not believe that the cognitive process is sequential? The traditional view on the subject did accept sequential approach. Detailed scheme of a cognitive robot is shown on the Picture1.



Picture 1. Elementary block scheme of a robot

This approach was designed having in mind representational memory. Information is processed by one unit and sent to another for processing.

On the contrary, from the studies of the nervous system emerged that functional areas[4] can be recognized in the brain. Between these areas in the central nervous system occurs parallel activity. Furthermore, how should be explained the speed of information processing in the brain? Interesting example of driving the car illustrates how the continuous input is successfully handled by the nervous system. A solution could give the parallel, distributed nervous system divided into groups of neurons that create functional clusters.

[4] A group of neurons that interact among themselves much more then they interact with surrounding neurons

Instructional vs. Adaptive

Having in mind computer algorithms, cognitive processes simulated by computers were designed, as might have been expected, in the form of procedure. Taking into consideration an animal, no matter how simple is the animal's behavior it can hardly be represented as a procedure that never changes in time. If we agree that animal can not have representational memory or internal representation of the world, due to the facts discussed earlier, it yields that "procedure" of behavior should be changed during time. Animal will act adaptively, so in this case we can not talk about procedure. The new experience will be built in the nervous system of an animal.

Instructional behavior might have its justification in some higher level cognition having a representational memory for example.

Unanswered Questions

The true problem is that we still do not know how exactly nervous system works. Is it enough to record the activity of neurons to answer the question? Are we able to tell from that what an animal or person is thinking about? Do we need to know this? On which level should we study the nervous system?

Method of solving the problem, in this case the problem of cognition, does not necessarily need to imitate into the smallest detail the method that use animals or humans. Exactly the same is very probably absolutely impossible. Similarly like construction of today's airplanes, it is not mimicked the flight of the birds. The actual problem that stands in the way is exact definition of concepts like intelligence or cognition. Anyway, research on all levels of cognition may yield results that could be utilized in further studies and open the way to successful theory and explanation.

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