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► **To cite this version:**

Zhongzhi Shi. Mind Modeling in Intelligence Science. 4th International Conference on Intelligence Science (ICIS), Feb 2021, Durgapur, India. pp.3-12, 10.1007/978-3-030-74826-5_1 . hal-03741716

HAL Id: hal-03741716

<https://inria.hal.science/hal-03741716v1>

Submitted on 1 Aug 2022

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Mind Modeling In Intelligence Science

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Abstract. Intelligence Science is an interdisciplinary subject which dedicates to joint research on basic theory and technology of intelligence by brain science, cognitive science, artificial intelligence and others. Mind modeling is the core of intelligence science. Here mind means a series of cognitive abilities, which enable individuals to have consciousness, sense the outside world, think, make judgment, and remember things. The mind model consciousness and memory (CAM) is proposed by the Intelligence Science Laboratory. The CAM model is a framework for artificial general intelligence and will lead the development of a new generation of artificial intelligence. This paper will outline the age of intelligence, mind model CAM, brain computer integration.

Keywords: intelligence science, age of intelligence, mind modeling, CAM, ABGP agent.

1 The Age of Intelligence

In the summer of 1956, John McCarthy, a young assistant professor at Dartmouth University, Minsky at Harvard University, Shannon at Bell Labs and Rochester, the information research center of IBM, initiated the conference. They invited Newell and Simon from Carnegie Mellon University, Selfridge and Solomon from MIT, and Samuel and More from IBM. Their research majors include mathematics, psychology, neurophysiology, information theory and computer science. They are interdisciplinary and discuss the possibility of artificial intelligence from different perspectives. McCarthy first introduced the term of artificial intelligence (AI) in the proposal for the Dartmouth summer research project on artificial intelligence. He defined AI as "making a machine's response way like the intelligence on which a person acts". Dartmouth conference marks the official birth of artificial intelligence.

For more than 60 years, the heuristic search and non-monotonic reasoning put forward by AI scholars have enriched the methods of problem solving. The research of big data, deep learning, knowledge discovery and so on has promoted the development of intelligent systems and achieved practical benefits. The progress of pattern recognition has enabled the computer to have the ability of listening, speaking, reading and seeing to a certain extent.

On February 14-16, 2011, Watson, the IBM artificial intelligence system, defeated two "Ever Victorious generals" Jennings and Rutter in the famous American quiz show jeopardy. From March 9 to 15, 2016, AlphaGo of Google DeepMind adopted deep reinforcement learning and Monte Carlo search algorithm to beat the Korean go

champion Li Shisha 4:1.

After a continuous dialogue with other Silicon Valley technology tycoons in 2015, Elon Musk decided to jointly create OpenAI, hoping to prevent the catastrophic impact of AI and promote AI to play a positive role. On December 12, 2015, OpenAI, a non-profit artificial intelligence project, was officially launched. OpenAI put forward GPT model in improving language understanding by generative pre training. GPT-2, announced in February 2019, is an unsupervised translational language model trained on 8 million documents with a total of 40Gb of text.

In May 2020, OpenAI released GPT-3, which contains 175 billion parameters more two orders of magnitude parameters than GPT-2 with 1.5 billion parameters, which is a great improvement over GPT-2. GPT-3 has achieved strong performance on many NLP datasets, including translation, question answering and cloze tasks, as well as tasks requiring immediate reasoning or domain adaptation, such as using a new word in a sentence or performing 3-digit operations. GPT-3 can generate news article samples that are difficult for human evaluators to distinguish. For GPT-3, its biggest value is the ability of self-learning without supervision, and the performance improvement can be achieved by simply expanding the scale.

In 1972, Dr. Christian Anfinsen, the Nobel Prize winner in chemistry, said that theoretically, the amino acid sequence of a protein should be able to completely determine its 3D structure. This hypothesis has inspired 50 years of research on protein 3D structure prediction based on amino acid sequence. International protein structure prediction competition (CASP) selects the protein structures that have been analyzed experimentally, but not yet published, as targets, and let research teams around the world use their own computational methods to predict their structures. In this year's CASP, the AlphaFold system predicted a median GDT score of 92.4 for all protein targets. Even for the most difficult protein targets, AlphaFold had a median GDT score of 87.0. Among the nearly 100 protein targets tested, AlphaFold predicted two-thirds of the protein targets with the same predicted structure as the experimental results.

From above major events we can see that the arrival of the age of intelligence. Intelligence science is an interdisciplinary subject which is jointly studied by brain science, cognitive science, artificial intelligence and others. Intelligence science not only to conduct functional simulation of intelligent behavior, but also should explore on the mechanism to explore new theory of intelligence, new technologies. It has penetrated into all fields of society and aroused extensive concern and research.

2 Mind Modeling

Mind is all of human being spiritual activities, including emotion, will, feeling, perception, image, learning, memory, thought, intuition and so on. It is frequent to utilize modern scientific method to study the form, process and law of human irrational psychology and rational cognition's integration. The technology of establishing mind model is often called the mind modeling, with purpose of exploring and studying the mechanism of human's thought in some ways, especially the human information processing mechanism, which also provides the design of corresponding artificial intelligence system with new architecture and technology [1].

Mind problem is a very complex nonlinear problem, and mind world must be studied by modern scientific method. Intelligence science is researching on a psychological or

mind process, but it is not a traditional psychological science. It must look for the evidence of neurobiology and brain science, so as to provide a certainty basis for the mind problems. The mind world is different from the world described by modern logic and mathematics: the latter is a world without contradiction, while the mind world is full of contradiction. Logic and mathematics can only use deductive reasoning and analytical method to understand and grasp possible world, while human's mind can master the world in many ways such as deduction, induction, analogy, analysis, synthesis, abstraction, generalization, association and intuition. So mind world is more complex than the latter. So, from the poor, non-contradictory, deductive and relatively simple possible world, how can we enter the infinite, contradictory, using multiple logic and cognitive approach, more complex mind world? This is one of the basic issues of intelligence science.

Generally, models are used to express how mind works and understand the working mechanism of mind. In 1980, Newell first proposed the standard of mind modeling [2]. In 1990, Newell described human mind as a set of functional constraints and proposed 13 criteria for mind [3]. In 2003, on the basis of Newell's 13 criteria, Anderson et al. Put forward Newell test [4] to judge the criteria to be met by human mind model and the conditions needed for better work. In 2013, the literature [5] analyzed the standards of mind models. In order to construct mind model better, the paper proposed the criteria of mind modeling:

- Behave Flexibly
- Adaptive Behavior
- Real Time
- Large-Scale Knowledge Base
- Dynamic Behavior
- Knowledge Integration
- Use Language
- Consciousness
- Learning
- Development
- Evolution
- Brain

So far, there are many mind modeling methods, including symbolic based modeling, neural network based on connectionism mind modeling, agent based mind modeling, math based mind modeling, computer simulation based mind modeling, hybrid mind modeling. Here we only introduce symbolic mind model, connectionist mind model and hybrid mind model.

2.1 Symbolic mind model

The 1975 ACM Turing Award was presented jointly to Allen Newell and Herbert A. Simon at the ACM Annual Conference in Minneapolis, October 20, 1976. They gave Ten Turing Lecture entitled "Computer science as empirical inquiry: symbols and search". At this lecture they presented a general scientific hypothesis—a law of qualitative structure for symbol systems: the Physical Symbol System Hypothesis [6]. A

physical symbol system has the necessary and sufficient means for general intelligent action. By "necessary" it means that any system that exhibits general intelligence will prove upon analysis to be a physical symbol system. By "sufficient" it means that any physical symbol system of sufficient size can be organized further to exhibit general intelligence. By "general intelligent action" it wishes to indicate the same scope of intelligence as we see in human action: that in any real situation behavior appropriate to the ends of the system and adaptive to the demands of the environment can occur, within some limits of speed and complexity. The Physical Symbol System Hypothesis clearly is a law of qualitative structure. It specifies a general class of systems within which one will find those capable of intelligent action.

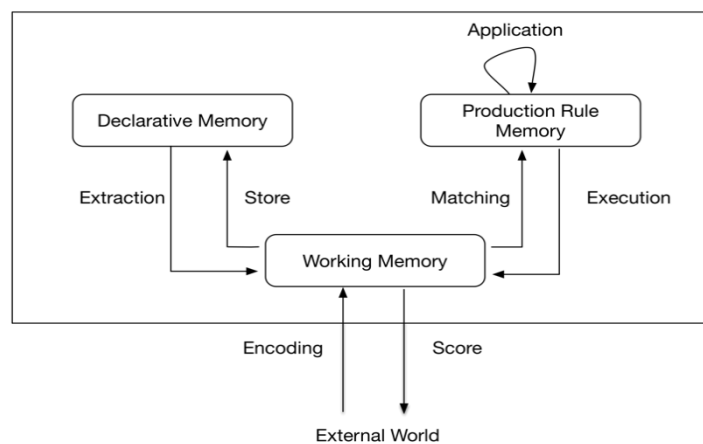


Fig. 1. Architecture of ACT

In 1983, Anderson elaborated the basic theory of ACT-R from every aspect of psychological processing activities in the book "cognitive structure". The general framework of ACT consists of three memory components: working memory, declarative memory and procedural memory in Figure 1 [7].

- declarative memory, which is semantic network composed by interconnected concepts with different active intensities.
- procedural memory, a series of production rules of procedural memory.
- working memory, which contains the information that is currently active.

Declarative knowledge is represented by chunks. Chunk is similar to graph structure. Each chunk can encode a group of knowledge. Declarative knowledge is able to be reported, and not closely associated with the context. However, procedural knowledge usually cannot be expressed. It is automatically used and is targeted to be applied to specific context. It was tested that a variety of methods can be used to store information in declarative memory and then extract the stored information. The matching process is to find the correspondence between the information in working memory and conditions of production rules. The execution process is to put the actions generated by successfully matched production rules to the working memory. Matching all production activities before execution is also known as production applications. The last operation is done by the working memory. Then the rule execution is achieved. Through the "application process", the procedure knowledge can be applied to its own processing. By checking existing production rules, new production rules can be learned. To the greatest extent, Anderson explained skill acquisitions as knowledge compilation. It is the realization of

transformation of declarative knowledge to procedural knowledge. Knowledge compilation has two sub-processes: the procedure programming and synthesis.

Procedure programming refers to the process of transforming declarative knowledge into procedural knowledge or production rules. Problem solvers initially solve the problem, such as mathematics or programming, according to knowledge obtained from books. In process of problem solving, the novice will combine weak problem solving methods, such as hill-climbing method or the method-goal analysis, to produce many sub-goals, and produce declarative knowledge. When repeatedly solve an event in the problem, some special declarative knowledge will be extracted repeatedly. At this moment, a new production rule is generated. While an application can learn new production rules indicates that according to ACT theory the process of learning is "learning from doing". Program knowledge can be described as a mode (IF part of production rule), and the action to be performed is described as an action (THEN part of production rule). This declarative knowledge to procedural knowledge transformation process, will also lead to reduction of processing on test speech. Related to this, the degree of automation on problem-solving will be increased.

In ACT-R, the Learning is realized by the growth and adjustment of micro knowledge units. This knowledge can be combined to produce complex cognitive processes. In the learning process, the environment plays an important role, because it established the structural problem object. This structure can assist chunk learning, and promote the formation of production rules. The importance of this step is that it re-emphasizes the importance of the essential characteristics in analytical environment for understanding human cognition. However, since the demise of behaviorism, cognitive revolution rise, this point was neglected.

2.2 Connectionist mind model

Adaptive Resonance Theory (ART) was proposed by S. Grossberg of Boston University in 1976 [8]. There are many versions of ART. ART1 is the earliest version. ART1 contains a master-slave algorithm with parallel architecture. It uses set operation in the activation and matching functions of the algorithm. It mainly deals with the problem of image recognition (i.e. black and white) with only 0 and 1. ART2 can process gray scale (i.e. analog value) input. ART3 has a multi-level search architecture, which integrates the functions of the first two structures and expands the two-layer neural network to any multi-layer neural network. Since ART3 incorporated the bio electrochemical reaction mechanism of neurons into the operation model of neurons, its function and ability were further expanded.

The basic architecture of ART1 is shown in Figure 2. It consists of three parts: attention subsystem, adjustment subsystem and gain control. Attention subsystem and adjustment subsystem are complementary. ART model deals with familiar or unfamiliar events through the interaction between these two subsystems and control mechanism. In the attention subsystem, there are F_1 and F_2 , which are composed of short-term memory units, namely STM- F_1 and STM- F_2 . The connecting channel between F_1 and F_2 is long-term memory LTM. Gain control has two functions: one is used to distinguish bottom-up and top-down signals in F_1 ; the other is that F_2 can play a threshold role for signals from F_1 when input signals enter the system. The adjustment subsystem consists of A and STM reset wave channels.

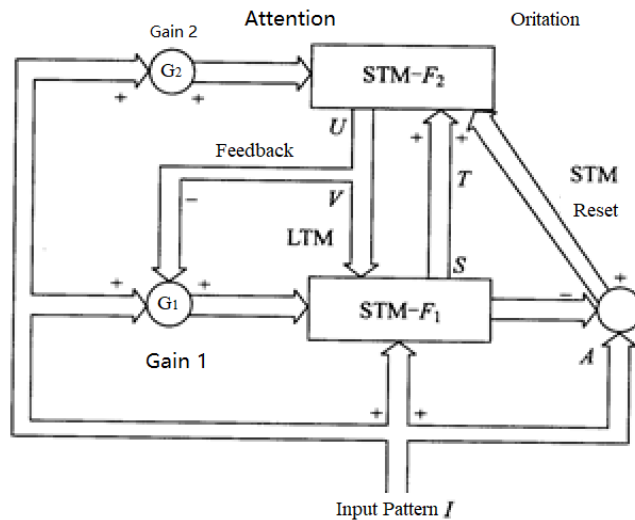


Fig. 2 ART basic architecture

In ART model, its working process adopts 2/3 rule. The so-called 2/3 rule is that in ART network, two of the three input signals must work to make neurons produce output signals. When double input from bottom up, among the three input signal sources of F_1 , there is input signal I for input and input to F_1 generated after I passes gain control 1. because these two input signals work, neurons in F_1 are activated and F_1 can generate signal output.

In 2008, Grossberg and Massimiliano put forward SMART (synchronous matching adaptive resonance theory) model [9], in which the brain coordinates a multi-stage thalamus and cortex learn process and stabilizes important information out of memory. SMART model shows bottom-up and top-down paths that work together and through coordinating the several processes of learning expectations, focus, resonance and synchronize to complete the above objectives. In particular, SMART model explains how to achieve needs about concentrating on learning through the brain subtle loop, especially the cell hierarchical organization in the new cortex loop.

The SMART model made different vibration frequencies associated with the spike timing-dependent plasticity (STDP) together. If the average incentive of presynaptic and postsynaptic cells is 10~20ms, in other word, in STDP learning window, learning scenarios will be more easily to be restricted to the matching conditions. This model predicts STDP will further strengthen sync excitement in the regions of the related cortical and subcortical, and the long-term memory weights can be matched synchronous resonance to prevent or quickly reversed in fast learning rules. In the matched condition, the amplified γ vibration made the presynaptic excitement compress into a narrow time-domain window, which will help excitement to spread over the cortex hierarchical structure. The prediction is consistent with the rapid reduction of effects, postsynaptic excitatory of the observed lateral geniculate nucleus.

2.3 Hybrid mind model

In the mind activities, memory and consciousness play the most important role. Memory stores various important information and knowledge. Consciousness make human having the concept of self, according to the needs, preferences based goals, and do all kinds of cognitive activity according to memory information. Therefore, the main emphasis on mind model CAM are memory functions and consciousness functions [10]. Figure 3 shows the architecture of the mind model CAM, which includes 5 main modules: memory, consciousness, high-level cognitive functions, perception and effectors.

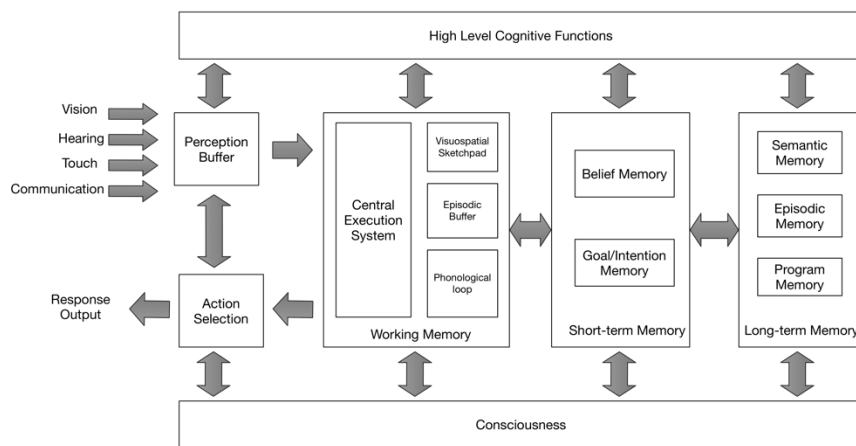


Fig. 3 Architecture of mind model CAM

3 Brain Computer Integration

Brain computer integration is a new form of intelligence, which is different from human intelligence and artificial intelligence. It is a new generation of intelligence science system which combines physics and biology. The brain computer integration intelligence is different from human intelligence and artificial intelligence in the following three aspects: (a) at the intelligent input, the idea of brain computer integration intelligence not only depends on the objective data collected by hardware sensors or the subjective information sensed by human facial features, but also combines the two effectively, and forms a new input mode with the prior knowledge of person; (b) in the stage of information processing, which is also an important stage of intelligence generation, a new way of understanding is constructed by integrating the cognitive mode of human beings with the computing ability of computer advantages. (c) at the output end of intelligence, the value effect of human beings in decision-making is added into the algorithm of gradual iteration of computer to match each other, forming an organic and probabilistic coordination optimize

judgment. In the continuous adaptation of human computer integration, people will consciously think about inertia common sense behavior, and machines will also find the difference of value weight from the decision-making under different conditions of people.

Brain computer integration adopts a hierarchical architecture. Human beings analyze and perceive the external environment through the acquired perfect cognitive ability. The cognitive process can be divided into perception and behavior layer, decision-making layer, memory and intention layer, forming mental thinking. The machine perceives and analyzes the external environment through detecting data, and the cognitive process can be divided into awareness and actuator layer, planning layer, belief and motivation layer, forming formal thinking. The same architecture indicates that humans and machines can merge at the same level, and cause and effect relationships can also be generated at different levels. **Figure 4** is the cognitive model of brain computer integration [11]. In this model the left part is simulated human brain in terms of CAM mind model; the right part is computer based on ABGP agent.

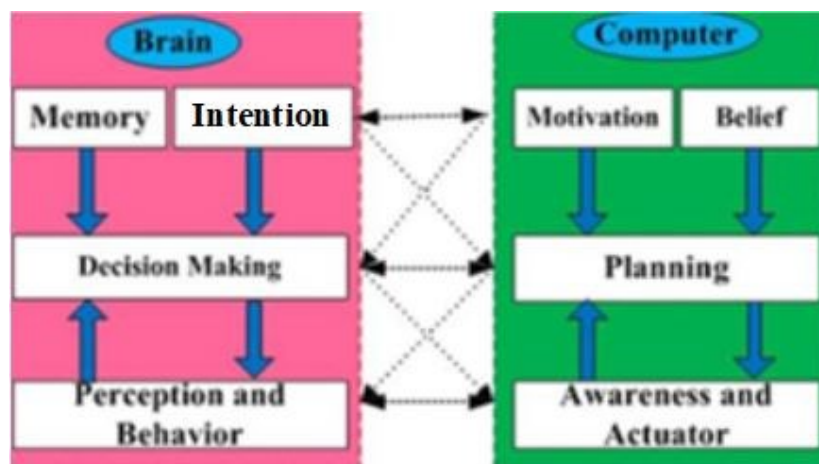


Fig. 4 Cognitive model of brain computer integration

In brain computer integration, each brain and computer can be viewed as an agent playing special role and work together for a sharing goal. The agent cognitive model is illustrated in **Figure 5** [12], which agents deliberate the external perception and the internal mental state for decision-making. The model is represented as a 4-tuple: <Awareness, Belief, Goal, Plan>. Awareness has four basic characteristics:

- (a) Awareness is knowledge about the state of a particular environment.
- (b) Environments change over time, so awareness must be kept up to date.
- (c) People maintain their awareness by interacting with the environment.

(d) Awareness is usually a secondary goal—that is, the overall goal is not simply. Awareness is described by the basic elements and relationships related to the agent’s setting.

Belief can be viewed as the agent’s knowledge about its environment and itself. Goal represents the concrete motivations that influence an agent’s behaviors. Plan is used to achieve the agent’s goals. Moreover, an important module motivation-driven intention is used to drive the collaboration of cyborg intelligent system.

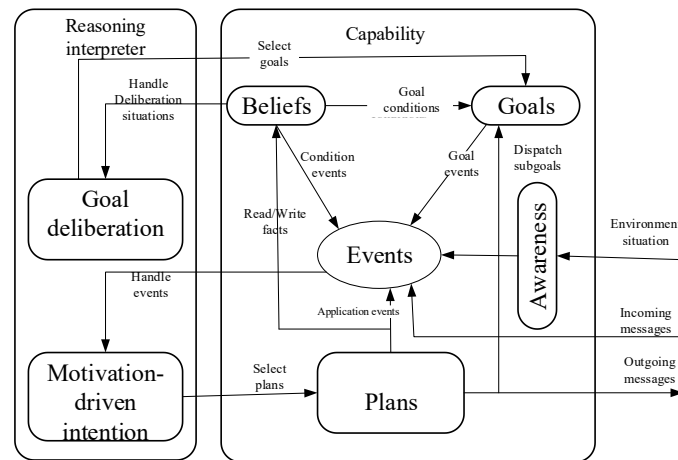


Fig. 5 Agent cognitive model

4 Conclusions

Mind modeling is the core of intelligence science. This paper described the symbolic mind model ACT-R, connectionist mind model SMART, hybrid mind model CAM. The mind model consciousness and memory (CAM) is proposed by the Intelligence Science Laboratory. The CAM model is a framework for artificial general intelligence and will lead the development of a new generation of artificial intelligence. This paper took brain computer integration as an application example of mind model CAM.

Intelligence science is an interdisciplinary subject which is jointly studied by brain science, cognitive science, artificial intelligence and others. Intelligence science not only to conduct functional simulation of intelligent behavior, but also should research on the mechanism to explore new theory and technologies for promoting the development of intelligence age.

Acknowledgements

This work is supported by the National Program on Key Basic Research Project (973) (No. 2013CB329502), National Natural Science Foundation of China (No. 61035003), National Science and Technology Support Program (2012BA107B02).

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