On Intelligence Science

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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. Brain science explores the essence of brain, research on the principle and model of natural intelligence in molecular, cell and behavior level. Cognitive science studies human mental activity, such as perception, learning, memory, thinking, consciousness etc. In order to implement machine intelligence, artificial intelligence attempts simulation, extension and expansion of human intelligence using artificial methodology and technology. Research scientists coming from above three disciplines work together to explore new concept, new theory, new methodology. It will be successful and create a brilliant future in 21 century.

The paper will outline the framework of intelligence science and present the ten big issues. Research approaches will be pointed out. Finally the paper gives perspective for the future.

Keywords: Intelligence science; brain science; cognitive science; artificial intelligence; computational intelligence.

1. Introduction

There are three revolutions with impact in the human history, the tool-making revolution, agricultural revolution and industrial revolution. Accompanying these revolutions, the situation of society, economy and civilization have transformed from one to another. What is the next revolution? It is the intelligence revolution with the goal of replacing work performed by human brain work with machine intelligence.

Intelligence is the ability to think and learn. How to create the intelligence from matter? It is a valuable and extractive problem, but it is also a tough problem. Since 1956 artificial intelligence is formally found and has enjoyed tremendous success over the past fifty years. Its achievements and techniques are in the mainstream of computer science and at the core of so many systems. For example, the computer beats the world’s chess champ, commercial systems are exploiting voice and speech capabilities, there are robots running around the surface of Mars and so on. We have made significant headway in solving fundamental problems in knowledge rep-
representing, symbolic reasoning, machine learning, and more.

During the past fifty years, the Turing test and physical symbolic system hypothesis play important roles to push research on artificial intelligence. Alan Turing claimed that it was too difficult to define intelligence. Instead he proposed Turing test in 1950.\textsuperscript{1} But the Turing test does not constitute an appropriate or useful criterion for human-level artificial intelligence. Nilsson suggested we replace the Turing test by the “employment test.”\textsuperscript{2} To pass the employment test, AI programs must be able to perform the jobs ordinarily performed by humans. Systems with true human-level intelligence should be able to perform the tasks for which humans get paid. One can hope that the skills and knowledge gained by a system’s education and experience and the habilie-system approach toward human-level AI can be entered at whatever level.

The 1975 ACM Turing Award was presented jointly to Allen Newell and Herbert A. Simon at the ACM Annual Conference in Minneapolis, October 20. They delivered the 1975 ACM Turing Award Lecture and proposed physical symbolic system hypothesis: “A physical symbol system has the necessary and sufficient means for intelligent action.”.\textsuperscript{3} A physical symbol system “consists of a set of entities, called symbols, which are physical patterns that can occur as components of another type of entity called an expression.” Traditional artificial intelligence follows the principle of physical symbolic system hypothesis to get great successes, particular in knowledge engineering.

During the 1980’s Japan proposed the fifth generation computer system (FGCS) which is knowledge information processing forming the main part of applied artificial intelligence was expected to be an important fields in 1990s information processing. The key technologies for the Fifth Generation Computer System seem to be VLSI architecture, parallel processing such as data flow control, logic programming, knowledge base based on relational database, applied artificial intelligence and pattern processing. Inference machines and relational algebra machines are typical of the core processors which constitute FGCS. After ten years research and development FGCS project did not reach the expected goal and caused many to reflect over the strategy and methodology of artificial intelligence.

In 1991, Kirsh pointed out five foundational issues for AI: (1) Core AI is the study of conceptualization and should begin with knowledge level theories. (2) Cognition can be studied as a disembodied process without solving the symbol grounding problem. (3) Cognition is nicely described in propositional terms. (4) We can study cognition separately from learning. (5) There is a single architecture underlying virtually all cognition.\textsuperscript{4} Minsky has argued that intelligence is the product of hundreds, probably thousands of specialized computational mechanisms he terms agents in Society of Mind.\textsuperscript{5} There is no homogenous underlying architecture. In the society of mind theory, mental activity is the product of many agents of varying complexity interacting in hundreds of ways. The purpose of the theory is to display the variety of mechanisms that are likely to be useful in a mind-like system, and to advocate the need for diversity. There is no quick way to justify the assumption of
architecture homogeneity.

Humans are the best example of human-level intelligence. McCarthy declared the long-term goal of AI is human-level AI.\textsuperscript{6} Recent works in multiple disciplines of cognitive and neuroscience motivate new computational approaches to achieving human-level AI. In the book On Intelligence, Hawkins proposed machine intelligence meets neuroscience.\textsuperscript{7} Granger presented a framework for integrating the benefits of parallel neural hardware with more serial and symbolic processing which motivated by recent discoveries in neuroscience.\textsuperscript{8} Langley proposed a cognitive architecture ICARUS which uses means-ends analysis to direct learning and stores complex skills in a hierarchical manner.\textsuperscript{9} Sycara proposed the multi-agent systems framework which one develops distinct modules for different facets of an intelligent system.\textsuperscript{10} Cassimatis and his colleagues investigate Polyscheme which is a cognitive architecture designed to model and achieve human-level intelligence by integrating multiple methods of representation, reasoning and problem solving.\textsuperscript{11}

Through more than ten years investigation, particular encouraged by bioinformatics which is a paragon combining biological science and information science in the end of 20 century, I think artificial intelligence should change the research paradigm and learn from natural intelligence. The interdisciplinary subject entitled Intelligence Science is promoted. In 2002 the special Web site called Intelligence Science and Artificial Intelligence has been appeared on Internet, which is constructed by Intelligence Science Lab of Institute of Computing Technology, Chinese Academy of Sciences. A special bibliography entitled Intelligence Science written by author was published by Tsinghua University Press in 2006.\textsuperscript{12} The book shows a framework of intelligence science and points out research topics in related subject. In order to resolve the current challenge issue in information science and technology, that is, high performance computer and its intelligence level is extremely low, scientists research on brain-like computer. IBM has received a $4.9 million grant from DARPA to lead an ambitious, cross-disciplinary research project to create a new computing platform: electronic circuits that operate like a brain. Along with IBM Almaden Research Center and IBM T. J. Watson Research Center, Stanford University, University of Wisconsin-Madison, Cornell University, Columbia University Medical Center, and University of California-Merced are participating in the project. Henry Markram who is Director of the Center for Neuroscience Technology and co-Director of EPFL’s Brain Mind Institute involves to unravel the blueprint of the neocortical column, chemical imaging and gene expression.

2. A Framework of Intelligence Science

Intelligence science is an interdisciplinary subject mainly including brain science, cognitive science, artificial intelligence and others. Brain science explores the essence of brain, research on the principle and model of natural intelligence in molecular, cell and behavior level. Cognitive science studies human mental activity, such as perception, learning, memory, thinking, consciousness etc. In order to implement
machine intelligence, Artificial intelligence attempts simulation, extension and expansion of human intelligence using artificial methodology and technology.\textsuperscript{12}

Brain can perceive the outside world through our senses, such as eye, ear, nose, skin, each of which sends patterns corresponding to the real-time environment. Sensory input provides abundant information about certain physical properties in the surrounding world, and the reception, processing, and transmission of such information are often framed as a neural bottom-up process. The neural correlates of each can be studied in their own right by suitable experimental paradigms, and functional magnetic resonance imaging (fMRI) has proven very valuable in humans.

The brain has trillions of neurons, with complicated branching dendrites, and dozens of different types of ion-selective channels. Brain science, particular computational neuroscience focuses on making detailed biologically realistic models which can be simulated by computer. Brain science points out that perceptive lobes have special function separately, the occipital lobe processes the visual information, the temporal lobe processes auditory information, the parietal lobe processes the information from the somatic sensors. All of three lobes deal with information perceived from the physical world. Each lobe is covered with cortex where the bodies of neurons are located. Cortex consists of primary, intermediate and advanced areas at least. Information is processed in the primary area first, then is passed to intermediate and advanced area.

Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. Cognitive scientists study the nature of intelligence from a psychological point of view, mostly building computer models that help elucidate what happens in our brains during problem solving, remembering, perceiving, and other psychological processes. Most centrally, cognitive science is the study of how the mind works, both in its conceptual organization and in its computational and neural infrastructure. The mind contains perception, rational, consciousness and emotion.

Comparing with computer system, the neural networks in brain is same as hardware and the mind looks like software. Most work in cognitive science assumes that the mind has mental representations analogous to computer data structures, and computational procedures similar to computational algorithms. Connectionists have proposed novel ideas to use neurons and their connections as inspirations for data structures, and neuron firing and spreading activation as inspirations for algorithms. Cognitive science then works with a complex 3-way analogy among the mind, the brain, and computers. Mind, brain, and computation can each be used to suggest new ideas about the others. There is no single computational model of mind, since different kinds of computers and programming approaches suggest different ways in which the mind might work.

Artificial Intelligence develops programs to allow machines to perform functions normally requiring human intelligence, that is, attempts simulation, extension and expansion of human intelligence using artificial methodology and technology. Russell points out four approaches to artificial intelligence have been followed\textsuperscript{14}.
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• Acting humanly: the Turing test approach
• Thinking humanly: the cognitive modeling approach
• Thinking rationally: the “laws of thought” approach
• Acting rationally: the rational agent approach

Traditional work in artificial intelligence was based on the physical symbol system hypothesis. In terms of the above hypothesis led to many successes both in creating tools that can achieve elements of intelligent behavior, as well as in illuminating the many components that make up human intelligence. Previous research on artificial intelligence mainly simulates the human intelligence functionally and views the brain as black box. Research scientists of intelligence science are changing the situation and exploring innovative strategy and methodology for investigating the principles and key technology of intelligence from cross multiple subjects. The book titled Intelligence Science presents a primary framework in detail.

3. Ten Big Issues of Intelligence Science

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. Ten big issues of intelligence science will be discussed in this section.

3.1. Basic process of neural activity

The brain is a collection of about 10 billion interconnected neurons. Neurons are electrically excitable cells in the nervous system that process and transmit information. A neuron’s dendritic tree is connected to a thousand neighbouring neurons. When one of those neurons fire, a positive or negative charge is received by one of the dendrites. The strengths of all the received charges are added together through the processes of spatial and temporal summation. The aggregate input is then passed to the soma (cell body). The soma and the enclosed nucleus don’t play a significant role in the processing of incoming and outgoing data. Their primary function is to perform the continuous maintenance required to keep the neuron functional. The output strength is unaffected by the many divisions in the axon; it reaches each terminal button with the same intensity it had at the axon hillock.

Each terminal button is connected to other neurons across a small gap called a synapse. The physical and neurochemical characteristics of each synapse determines the strength and polarity of the new input signal. This is where the brain is the most flexible, and the most vulnerable. In molecular level neuron signal generation, transmission and neurotransmitters are basic problems attracted research scientists to engage investigation in brain science.
3.2. **Synaptic plasticity**

One of the greatest challenges in neuroscience is to determine how synaptic plasticity and learning and memory are linked. Two broad classes of models of synaptic plasticity can be described by Phenomenological models and Biophysical models.\(^\text{16}\)

Phenomenological models are characterized by treating the process governing synaptic plasticity as a black box. The black box takes in as input a set of variables, and produces as output a change in synaptic efficacy. No explicit modeling of the biochemistry and physiology leading to synaptic plasticity is implemented. Two different classes of phenomenological models, rate based and spike based, have been proposed.

Biophysical models, in contrast to phenomenological models, concentrate on modeling the biochemical and physiological processes that lead to the induction and expression of synaptic plasticity. However, since it is not possible to implement precisely every portion of the physiological and biochemical networks leading to synaptic plasticity, even the biophysical models rely on many simplifications and abstractions. Different cortical regions, such as Hippocampus and Visual cortex have somewhat different forms of synaptic plasticity.

3.3. **Perceptual representation and feature binding**

The perceptual systems are primarily visual, auditory and kinesthetic, that is, pictures, sounds and feelings. There is also olfactory and gustatory, i.e. smell and taste. The perceptual representation is a modeling approach that highlights the constructive, or generative function of perception, or how perceptual processes construct a complete volumetric spatial world, complete with a copy of our own body at the center of that world. The representational strategy used by the brain is an analogical one; that is, objects and surfaces are represented in the brain not by an abstract symbolic code, or in the activation of individual cells or groups of cells representing particular features detected in the visual field. Instead, objects are represented in the brain by constructing full spatial effigies of them that appear to us for all the world like the objects themselves or at least so it seems to us only because we have never seen those objects in their raw form, but only through our perceptual representations of them.

As you know that the binding problem is an important problem across many disciplines, including psychology, neuroscience, computational modeling, and even philosophy. Feature binding is the process how a large collection of coupled neurons combines external data with internal memories into coherent patterns of meaning. According to neural synchronization theory, feature binding is achieved via neural synchronization. When external stimuli come into the brain, neurons corresponding to the features of the same object will form a dynamic neural assembly by temporal synchronous neural oscillation, and the dynamic neural assembly, as an internal representation in the brain, codes the object in the external world.

In 1990, Eckhorn and coworkers proposed a Linking Field Network according
to the synchronized neural oscillation in the visual cortex of cat.\textsuperscript{17} Linking Field Network can synchronize stimuli evoked oscillations at different regions in the visual cortex if the regions have similar local coding properties. Referred to noisy neural model, Bayesian method and competition mechanism a computational model for feature binding has been proposed.\textsuperscript{18} Fig. 1 illustrates the structure of a sample neuron in the Bayesian Linking Field Model.

In cognitive research a neuron to represent a perceptual object, its feeding pre-synaptic neurons usually denote its composing features or compartments and its linking pre-synaptic neurons indicate other objects, which have more or less relations with this neuron. Thus, if we leave linking inputs out of consideration, based on the relationship of parts and whole, we get:

\[ P(X) = \sum_i w_i P(f_i) \]  

where \( X \) is the neuron we concern, \( f_i \) is its feeding pre-synaptic neuron, \( w_i \) is weight for synaptic connection, which indicates the importance of \( f_i \) as a part in the whole entity \( X \).

In the following we examine the influence from linking inputs. Suppose that all the linking inputs are conditionally independent. Based on Bayesian theorem, we get:

\[ P(X|l_1, l_2, \ldots) = P(X) \cdot \prod_j w'_j P(l_j) \]

where \( X \) is the neuron we concern, \( l_j \) is its linking pre-synaptic neuron, \( w'_j = P(l_j|X)/P(l_j) \) is weight for synaptic connection, which represents the importance of \( l_j \) to \( X \). \( P(X) \) is the prior probability calculated from feeding information; \( P(X|l_1, l_2, l_3, \ldots) \) is the post probability after getting information from linking inputs; \( P(l_j) \) is the firing probability of \( l_j \).
Let $X_1$ and $X_2$ be two different neurons; $F_1$ and $F_2$ be the set of their feeding pre-synaptic neurons respectively. Then there exists competitive relation between $X_1$ and $X_2$ if and only if at least one of the two conditions below holds.

- $F_1 \cap F_2 \neq \emptyset$
- Exist $f_1 \in F_1$ and $f_2 \in F_2$, and $f_1$ and $f_2$ are competitive.

To implement competitive relations, we normalize the firing probabilities of the neurons that are competitive each other. Let $X_1, X_2, \ldots, X_n$ be $n$ neurons that are competitive each other; $P_{\text{before}}(X_i)$ is the firing probability of $X_i$ before competition. Then the firing probability of $X_i$ after competition is:

$$P_{\text{after}}(X_i) = \frac{P_{\text{before}}(X_i)}{\sum_{j=1}^{n} P_{\text{before}}(X_j)}$$

Bayesian Linking Field Model is a network composed of interconnected neurons, which has the following properties:

a) It utilizes noisy neural model, where the inputs and outputs of neurons are firing probabilities, but not pulse.
b) Each neuron has two parts of inputs, namely feeding inputs and linking inputs. Neurons integrate their inputs nonlinearly according to Formula (1) and (2).
c) Weights of connections between neurons reflect the statistical relation between them, and can be learnt via learning.
d) The outputs of neurons are determined by both their own inputs and the outputs of their neighbors. The competition among related neurons is accomplished according to Formula (3).

3.4. Coding and retrieval of memory

A brain has distributed memory system, that is, each part of brain has several types of memories that work in somewhat different ways, to suit particular purposes. According to the stored time of contents memory can be divided into long term memory, short term memory and working memory. Research topics in memory exist coding, extract and retrieval of information. Current working memory attracts more researchers to involve.

Working memory will provides temporal space and enough information for complex tasks, such as understanding speech, learning, reasoning and attention. There are memory and reasoning functions in the working memory. It consists of three components: that is, central nervous performance system, video space primary processing and phonetic circuit.\textsuperscript{19}

Memory phenomena have also been categorized as explicit or implicit. Explicit memories involve the hippocampus-medial temporal lobe system. The most common current view of the memorial functions of the hippocampal system is the declarative
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memory. There are a lot of research issues that are waiting for us to resolve. What is the readout system from the hippocampal system to behavioral expression of learning in declarative memory? Where are the long-term declarative memories stored after the hippocampal system? What are the mechanisms of time-limited memory storage in hippocampus and storage of permanent memories in extra-hippocampal structures?

Implicit memory involves the cerebellum, amygdala, and other systems. The cerebellum is necessary for classical conditioning of discrete behavioral responses under all condition. It is learning to make specific behavioral responses. The amygdalar system is learning fear and associated autonomic responses to deal with the situation.

3.5. Linguistic cognition

Language is fundamentally a means for social communication. Language is also often held to be the mirror of the mind. Chomsky developed transformational grammar that cognitivism replaced behaviorism in linguistics.

Through language we organize our sensory experience and express our thoughts, feelings, and expectations. Language is particular interesting from cognitive informatics point of view because its specific and localized organization can explore the functional architecture of the dominant hemisphere of the brain.

Recent studies of human brain show that the written word is transferred from the retina to the lateral geniculate nucleus, and from there to the primary visual cortex. The information then travels to a higher-order center, where it is conveyed first to the angular gyrus of the parietal-temporal-occipital association cortex, and then to Wernicke’s area, where the visual information is transformed into a phonetic representation of the word. For spoken word the auditory information is processed by primary auditory cortex. Then the information input to higher-order auditory cortex, before it is conveyed to a specific region of the parietal-temporal-occipital association cortex, the angular gyrus, which is concerned with the association of incoming auditory, visual, and tactile information. From here the information is projected to Wernicke’s area and Broca’s area. In Broca’s area the perception of language is translated into the grammatical structure of a phrase and the memory for word articulation is stored. Fig. 2 illustrates language processing based on Wernicke-Geschwind model in brain.

3.6. Learning

Learning is the basic cognitive activity and accumulation procedure of experience and knowledge. Through learning the system performance will be improved. Perceptual learning, cognitive learning, implicit learning are active research topics in the learning area.

Perceptual learning should be considered as an active process that embeds particular abstraction, reformulation and approximation within the Abstraction frame-
work. The active process refers to the fact that the search for a correct data representation is performed through several steps. A key point is that perceptual learning focuses on low-level abstraction mechanism instead of trying to rely on more complex algorithm. In fact, from the machine learning point of view, perceptual learning can be seen as a particular abstraction that may help to simplify complex problem thanks to a computable representation. Indeed, the baseline of Abstraction, i.e. choosing the relevant data to ease the learning task, is that many problems in machine learning cannot be solve because of the complexity of the representation and is not related to the learning algorithm, which is referred to as the phase transition problem. Within the abstraction framework, we use the term perceptual learning to refer to specific learning task that rely on iterative representation changes and that deals with real-world data which human can perceive.

In contrast with perceptual learning cognitive learning is a leap in the process of cognition and generate knowledge through clustering, classification, conceptualization and so on. In general, there are inductive learning, analogical learning, case-based learning, explanation learning, evolutional learning connectionist learning.

The core issue of cognitive learning is self-organizing principles. Kohonen has proposed a self-organizing maps which is a famous neural network model. Babloyantz applied chaotic dynamics to study brain activity. Haken has proposed a synergetic approach to brain activity, behavior and cognition.
Introspective learning is an inside learning of brain, which means without input information from outside environment. We have proposed a model for introspective learning with 7 parts in Figure 3, such as expectant objective, evaluation, explanation, reconstruct strategy, meta cognition, case bases and knowledge base.

Fig. 3. Introspective learning.

The term implicit learning was coined by Reber to refer to the way people could learn structure in a domain without being able to say what they had learnt. Reber first proposed artificial grammars to study implicit learning for unconscious knowledge acquisition. It will help us to understand the learning mechanism without consciousness. Since middle of 80’s implicit learning become an active research area in psychology.

In the Machine Learning Department within Carnegie Mellon University’s School of Computer Science researchers receive $1.1 million from Keck Foundation to pursue new breakthroughs in learning how the brain works. Cognitive neuroscience professor Marcel Just and computer science professor Tom Mitchell have received a three-year grant from the W. M. Keck foundation to pursue new breakthroughs in the science of brain imaging.

3.7. Thought

Thought is a reflection of essential attributes and internal laws of objective reality in conscious, indirect and generalization by human brain with consciousness. In recent years, there has been a noteworthy shift of interest in cognitive science. Cognitive process rises man’s sense perceptions and impressions to logical knowledge. According to abstraction degree of cognitive process, human thought can be divided into three levels: perception thought, image thought and abstraction thought. A hierarchical model of thought which illustrates the characteristics and correlations of thought levels has been proposed in Ref. Fig. 4 shows the hierarchical thought model of brain.
Perception thought is the lowest level of thought. Behavior is the objective of research in perception thought. Reflection is a function of stimulus. Perception thought emphasizes stimulus reflection schema or perception action schema. The thought of animal and infant usually belong to perception thought because they can not introspect, and also can not declare empirical consciousness. In perception thought, intelligent behavior takes place without representation and reasoning.

Behavior-based artificial intelligence has produced the models of intelligence which study intelligence from the bottom up, concentrating on physical systems, situated in the world, autonomously carrying out tasks of various sorts. They claim that the simple things to do with perception and mobility in a dynamic environment took evolution much longer to perfect. Intelligence in human have been taking place for only a very small fraction of our evolutionary lineage. Machine intelligence can take evolution by the dynamics of interaction with the world.

Image thought adopts intuitive imagery as thinking element. Intuitive imagery is one kind of information which acquires through processing perceptual representation, but does not yet generate concepts of language. Typical image thought is pattern recognition which can deal with pattern information, such as character, image, speech, classification and recognition of objects, and so on.

Based on perceptual knowledge, the process which reflects the common properties and exposes internal relations of distinct objects through concepts, judgment and inference is called abstraction thought. Concepts are no longer the phenomena, the separate aspects and the external relations, while reflect the essences and internal relations of objects. Judgment represents the certain relations between conceptions. Inference acquires new knowledge from existing knowledge. There are existing deductive reasoning, inductive reasoning, and abductive reasoning currently.
By means of judgment and inference one is able to draw logical conclusions. Logical knowledge is capable of grasping the development of the surrounding world in its totality, the internal relations of all its aspects.

Attention focuses consciousness to produce greater vividness and limits the number of thoughts that can be entertained at one time. Attention forces human thinking process from parallel to sequential in terms of leaping from image thought to abstraction thought.

3.8. Emotion

The mental perception of some fact excites the mental affection called the emotion, and that this latter state of mind gives rise to the bodily expression. Emotion is a complex psychophysical process that arises spontaneously, rather than through conscious effort, and evokes either a positive or negative psychological response and physical expressions. Research on emotion at varying levels of abstraction, using different computational methods, addressing different emotional phenomena, and basing their models on different theories of affect.

Since the early 1990s emotional intelligence is systematically studied. Scientific articles suggested that there existed an unrecognized but important human mental ability to reason about emotions and to use emotions to enhance thought. Emotional intelligence refers to an ability to recognize the meanings of emotion and their relationships, and to reason and problem solve on the basis of them. Emotional intelligence is involved in the capacity to perceive emotions, assimilate emotion-related feelings, understand the information of those emotions, and manage them.

3.9. Nature of consciousness

The most important scientific discovery of the present era will come to answer how exactly do neurobiological processes in the brain cause consciousness? The question “What is the biological basis of consciousness?” is selected as one of 125 questions, a fitting number for Science’s 125th anniversary. Recent scientifically oriented accounts of consciousness emerging from the properties and organization of neurons in the brain. Consciousness is the notions of mind and soul. The physical basis of consciousness appears to be the most singular challenge to the scientific, reductionist world view. Francis Crick’s book ‘The astonishing Hypothesis’ is an effort to chart the way forward in the investigation of consciousness. Crick has proposed the basic ideas of researching consciousness:

a) It seems probable, however, that at any one moment some active neuronal processes in your head correlate with consciousness, while others do not. What are the differences between them?

b) All the different aspect of consciousness, for example pain and visual awareness, employ a basic common mechanism or perhaps a few such mechanisms. If we could understand the mechanisms for one aspect, then we hope we
will have gone most of the way to understanding them all.

Chalmers suggests the problem of consciousness can be broken down into several separate questions. The major question is the neuronal correlate of consciousness (NCC) which focuses on specific processes that correlate with the current content of consciousness. The NCC is the minimal set of neurons, most likely distributed throughout certain cortical and subcortical areas, whose firing directly correlates with the perception of the subject at the time. Discovering the NCC and its properties will mark a major milestone in any scientific theory of consciousness. Several other questions need to be answered about the NCC. What type of activity corresponds to the NCC? What causes the NCC to occur? And, finally, what effect does the NCC have on postsynaptic structures, including motor output.

3.10. Mind modeling

Mind is a very important issue in intelligence science, and also it is a tough problem. Mind could be defined as: “That which thinks, reasons, perceives, wills, and feels. The mind now appears in no way separate from the brain. In neuroscience, there is no duality between the mind and body. They are one.” in Medical Dictionary.

A mind model is intended to be an explanation of how some aspect of cognition is accomplished by a set of primitive computational processes. A model performs a specific cognitive task or class of tasks and produces behavior that constitutes a set of predictions that can be compared to data from human performance. Task domains that have received considerable attention include problem solving, language comprehension, memory tasks, and human-device interaction.

Researchers try to construct mind model to illustrate how brains do. Anderson and colleagues have demonstrated that a production rule analysis of cognitive skill, along with the learning mechanisms posited in the ACT model, provide detailed and explanatory accounts of a range of regularities in cognitive skill acquisition in complex domains such as learning to program Lisp. ACT also provides accounts of many phenomena surrounding the recognition and recall of verbal material, and regularities in problem solving strategies.

In the early 1980’s, SOAR was developed to be a system that could support multiple problem solving methods for many different problems. In the mid 1980’s, Newell and many of his students began working on SOAR as a candidate of unified theories of cognition. SOAR is a learning architecture that has been applied to domains ranging from rapid, immediate tasks such as typing and video game interaction to long stretches of problem solving behavior. SOAR has also served as the foundation for a detailed theory of sentence processing, which models both the rapid on-line effects of semantics and context, as well as subtle effects of syntactic structure on processing difficulty across several typologically distinct languages.

The Society of Mind offers a revolutionary theory of human thought. Marvin Minsky proposes that the mind consists of several kinds of non-thinking entities, called agents. Agents alone repeat their tasks with great acumen, but they execute
their work with no understanding of it. Thought occurs when societies of agents interact and relate, much as a jet engine’s components work to generate thrust. Human personality is not controlled by a centralized “conductor” in the brain, but rather emerges from seemingly unintelligent and unconnected mental processes, or “agents.” With Minsky’s theory as a metaphor, participants will reach a new sensitivity to the many different parts of the mind that are engaged when we enjoy and respond to music.

4. Research Approaches

Research on intelligence science should take experiments, computational modeling, simulation together at varying levels. Cognitive experiments involve assessing some aspect of cognitive performance. Examples include assessing verbal abilities such as the ability to recognize spoken words or read written words. They also include assessing visual tasks such as the ability to recognize figures that are hidden in an image. In cognitive neuroscience functional MRI (fMRI) has had a major impact. fMRI now has a small but growing role in neuroimaging.

Current neuroscience research has emphasized novel concepts for clinicians, such as the role of plasticity in recovery and the maintenance of brain functions in a broad range of diseases. There is a wider potential for clinical fMRI in applications ranging from presymptomatic diagnosis, through drug development and individualization of therapies, to understanding functional brain disorders.

Computational modeling is a very important approach helping to construct theoretical framework to reflect the essence of objects. Neural computing studies on the essence and capacity of information processing with nonprogramming, adaptive and brain paradigm through modeling neuron and neural networks. Different areas in the brain perform different functionally significant tasks. Information geometry emerged from studies of the intrinsic structure of the manifold of probability distributions and is applicable to a wide variety of information systems. Information geometry provides a new tool for neural computing.

In 1985 Amari has presented information geometry for neural information processing. Based on information geometry we have proposed neural field theory. The research object of neural field theory is referred to try to understand the transformation mechanism, dynamical behavior, capability and limitation of neural networks models, by the study of globally topological and geometrical structure on parameter spaces of neural networks models. The body of work is primarily devoted to investigate the global structure properties in the non-linear manifold by the set of all neural networks, the information processing mechanism about organizing and embedding submanifold by simple models into the manifold by general richer information systems. The research is also viewed to explore deeper theoretical foundation and new approach to develop the key concept and framework of neural information processing, and to pursue new breakthrough in the research of computation model for understanding of human-like recognition mechanism.
shows you the neural field model.

Fig. 5. Neural field model.

The basic ideas of information geometry for neural information processing can be described as follows: consider a neural networks set including modifiable parameters, such as weights and threshold, summarized in a vector form \( \theta = (\theta_1, \theta_2, \ldots, \theta_n) \), then the set of all the possible neural networks realized by changing forms a \( n \)-dimension manifold \( N \) or submanifold embedding into more complex information processing manifold \( S \), i.e. in many case, the set of a family of neural networks model can be represented by a finite dimension submanifold \( N \), where parameter \( \theta \) play the role of a coordinate system in \( S \). Under the framework of information geometry, for an adaptive system, one of the important problems we confront is to explore the new mathematical tools such as geometrical and topological structure on the parameter space that can be applied to describe the organization mechanism about how submanifold is embedded into a larger manifold, and provide an unifying approach to formulate the general principle about architecture-based learning by using the mechanism of embedding neural networks submanifold into the manifold by more richer information processing system. Neural field theory attempts to address the problem about geometrical and topological code mechanism by all information system. The goal of doing this is to study the optimal hybrid between field organization model and field action model with the architecture of simple complexes on parameter space, It will give a new framework of neural information processing.

Expert system is another good example which to simulates expertise to solve special domain problem through reasoning based on knowledge base. Expert systems must be knowledge-rich even if they are inference engine poor. For a long time
artificial intelligence has focused its attentions on the development of clever inference methods, but the power resides in the knowledge which reflects the experiences of domain specific experts.

5. Perspective on Intelligence Science

The intelligence revolution with the goal to replace human brain work by machine intelligence is the next revolution in human society. The intelligence revolution has passed 2 stages. First stage is information technology which started in 1946 the first computer ENIAC completed. Second stage is knowledge technology which started in 1965 the first expert system DENDRAL, a prototype for expert systems and the first use of artificial intelligence in biomedical research. In 1977 Feigenbaum proposed knowledge engineering terminology to indicate the knowledge stage stepped into matured period. Now the third stage of intelligence revolution is started. The first special book dedicated to Intelligence Science and Special Website entitled intelligence science and artificial intelligence will promote the progress of the third stage of intelligence revolution.

The incremental efforts in neuroscience and cognitive science provide us exciting solid foundation to explore brain model and intelligent behavior. We should research on neocortical column, population coding, mind model, consciousness etc. for the human-level intelligence and brain-like computer. We believe that intelligence science will make great progress and new breakthroughs in the coming 50 years. Let us work together to contribute our intellect and capability to promote the development of intelligence science and become a bright spot of human civilization in 21 century.

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References

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