

## Chapter 1

### Introduction

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.

#### 1.1 The Dream of Mankind

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? The answer is the intelligence revolution with the goal of replacing work performed by human brain work with machine brain which is the dream of mankind.

The Industrial Revolution was a period from the 18th to the 19th century where major changes in agriculture, manufacturing, mining, and transport had a profound effect on the socioeconomic and cultural conditions in the United Kingdom. The changes subsequently spread throughout Europe, North America, and eventually the world. The industrial revolution was one of the most important events in history which extends human's hand to achieve physical power enlargement.

In the history of human development, it is a never-ending pursuit to free people from both manual and mental labor with machines. The industrial revolutions enable machines to perform heavy manual labor instead of people, and thus lead to a considerable economic and social progress. To make machines help relieve mental labor, a long cherished aspiration is to create and make use of intelligent machines like human beings.

Aristotle (384-322, BC) proposed the first formal deductive reasoning system, syllogistic logic, in the Organon. Francis Bacon (1561-1626) established the

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inductive method in the *Novum Organum* (or “New Organon”). Gottfried Leibniz (1646-1716) constructed the first mechanical calculator capable of multiplication and division. He also enunciated the concepts of “*characteristica universalis*” and “*calculus ratiocinator*” to treat the operations of formal logic in a symbolic or algebraic way, which can be viewed as the sprout of the “thinking machine”.

Since the 19th century, advancement of sciences and technologies such as Mathematical Logic, Automata Theory, Cybernetics, Information Theory, Computer Science and Psychology laid the ideological, theoretical and material foundation for the development of AI research. In the book “*An Investigation of the Laws of Thought*”, George Boole (1815-1864) developed the Boolean algebra, a form of symbolic logic to represent some basic rules for reasoning in the thinking activities. Kurt Gödel (1906-1978) proved the incompleteness theorems. Alan Turing (1912-1954) introduced the Turing Machine, a model of the ideal intelligent computer, and initiated the automata theory. In 1943, Warren McCulloch (1899-1969) and Walter Pitts (1923-1969) developed the MP neuron, a pioneer work of Artificial Neural Networks research. In 1946, John Mauchly (1907-1980). and John Eckert (1919-1995) invented the ENIAC (Electronic Numerical Integrator And Computer), the first electronic computer. In 1948, Norbert Wiener (1894-1964) published a popular book of “*Cybernetics*”, and Claude Shannon (1916-2001) proposed the Information Theory.

In 1956, the term “Artificial Intelligence” was coined, and the Dartmouth Summer Research Project on Artificial Intelligence(AI), proposed by John McCarthy, Marvin Minsky, etc., was carried on at Dartmouth College with several American scientists of psychology, mathematics, computer science and information theory. This well-known Dartmouth conference marked the beginning of the real sense of AI as a research field. In 1958, A. Newell and H. A. Simon made the following forecasts of AI boldly:

- (1) Within ten years, a computer would become the world chess champion.
- (2) Within ten years, a computer would discover or prove meaningful mathematical theorems.
- (3) Within ten years, a computer would be able to compose a beautiful music.
- (4) Within ten years, a computer would be able to implement most of psychology theories.

These optimistic forecasts made by artificial intelligence pioneers motivated people to do research continuously and led many encouraging progresses. But along the way, the traditional artificial intelligence researchers still faced considerable confusions.

During the past more than 50 years, great progress has been made of AI research. Theories of heuristic searching strategies, non-monotonic reasoning, machine learning, etc. have been proposed. Applications of AI, especially expert systems, intelligent decision making, intelligent robots, natural language understandings, etc. also promoted the research of AI. Presently, knowledge engineering based on knowledge and information processing is a remarkable characteristic of AI.

## 1.2 The Rise of Intelligence Science

The goal of AI research is to make computer have human like behaviors, such as listening, talking, reading, writing, thinking, learning and adopting to ever-changing environments etc. In 1977, E. Feigenbaum, a young scholar of Stanford University and graduate student of Simon put forward the concept of knowledge engineering in the 5th International Joint Conference on Artificial Intelligence (IJCAI'1977), which marked the transition from the traditional reasoning to the knowledge-centered research in artificial intelligence research.

Knowledge is the national wealth and information industry is vital for a country's development. The fifth generation computer - intelligent computer symposium was held in Tokyo Japan in October of 1981. Professor Moto-Oka Tohru from Tokyo University proposed "the fifth generation computer system: FGCS". After that Japan made an ambitious plan to develop the fifth generation computers in 10 years. In the summer of 1982, Japan established "the new generation of computer technology institute" (ICOT) headed by Fuchi Kazuhiro. Japan Ministry of International Trade and Industry fully supported the plan and the total investment budget reaches to \$430 million. Eight large enterprise including Fujitsu, NEC, Hitachi, Toshiba, Panasonic and sharp were invited to this project.

It took almost ten years on the project for ICOT colleagues, who even had no time for normal lives and spent all times between the lab and their apartments. However the outcome of the FGCS was somehow tragic. Its failure in 1992 might come from the bottleneck of key technologies such as human-machine dialogue and program automatic proving. After that, Professor Fuchi Kazuhiro had to return to his university. Also somebody thought that the FGCS is not a totally failure, in that it achieved some expected goals in the first two phases. In

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June 1992, ICOT demonstrated the prototype of FGCS with 64 processors for parallel processing, which had similar functions of human left brain, and could perform advanced precision analysis on proteins.

The failure of FGCS pushed people to find a new way for researches on intelligence. Intelligence requires not only function simulation, but also mechanism simulation. Intelligence requires not only top-down reasoning also bottom-up learning as well, which may be finally combined to achieve human level Intelligence. The perceive components of brains including various feelings such as vision and auditory, movements and language cortex regions play not only the role of input/output channel, but also contribute to thinking activities directly.

In 1991, a special issue on the foundation of AI was published in *Journal of Artificial Intelligence* (Vol.47) to point out some trends of AI research. D. Kirsh proposed five foundational problems in AI (Kirsh, 1991):

(1) Pre-eminence of knowledge and conceptualization: Intelligence that transcends insect-level intelligence requires declarative knowledge and some form of reasoning-like computation-call this cognition. Core AI is the study of the conceptualizations of the world presupposed and used by intelligent systems during cognition.

(2) Disembodiment: Cognition and the knowledge it presupposes can be studied largely in abstraction from the details of perception and motor control.

(3) Kinematics of cognition are language-like: It is possible to describe the trajectory of knowledge states or informational states created during cognition using a vocabulary very much like English or some regimented logic-mathematical version of English.

(4) Learning can be added later: The kinematics of cognition and the domain knowledge needed for cognition can be studied separately from the study of concept learning, psychological development, and evolutionary change.

(5) Uniform architecture: There is a single architecture underlying virtually all cognition.

All these questions are cognitive problems critical to AI research, which should be discussed from the perspective of fundamental theories of Cognitive Science. These questions have become the watershed for different academic schools of AI research, as different academic schools usually have different answers to them.

In 2003, the author published the paper entitled “Perspectives on cognitive informatics” (Shi et al., 2003). This article points out that intelligent science is the study of fundamental theory and technology of intelligence and the interdisciplinary subject of brain science, cognitive science and artificial intelligence. Brain science studies the intelligence mechanism of the brain, establishes the model of the brain and reveals the essence of human’s brain from molecular level, cell level and behavior level. Cognitive science studies perception, learning, memory, thinking and awareness of human. Artificial intelligence studies simulations, extensions and expansions of human intelligence using artificial methods and techniques to realize machine intelligence. The three disciplines work together to study and explore the new conceptions, new methods and new theories of intelligence science, and will create a brilliant future in the 21<sup>st</sup> century.

In 2004, J. Hawkins published a book entitled “On Intelligence” (Hawkins, 2004). He started carefully the study at the interrelation of intelligent and intelligent behavior, and analyzed the famous Turing test. Intelligence cannot make intelligent agent think they are intelligent in any case. Turing offered a profound insight. But as time goes by, J. Hawkins gradually realize this is mediocre and useless: it is more of an escape, rather than a useful definition of intelligence (Colwell, 2005).

J. Hawkins described John Searle’s “Chinese house” test. In this test, an intelligent agent is put in a room. The agent followed physical instructions without pausing in any place of the room. By this way, the agent would answer a series of questions correctly (these questions are written in Chinese which can not be understood by the agent) and eventually walked out of the room.

John Searle pointed out that the recipients with Chinese output presumed the agent in the room must understand Chinese, might even show thought-provoking insights. But the agent itself did nothing intelligently at all, neither a machine. It only simply followed instructions which are written by some people.

John Searle said that he did not know what intelligence is, but this test showed that computers do not have intelligence. John Searle’s experiment clearly showed that the Turing test can be easily fooled. We must do more on intelligence, not just some subjective judgments.

Some people think the agent, instructions and room all reflect the intelligence-try our best to avoid the fact that we know little about intelligence, although we have done plenty of long-term works in many branches of science.

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The human brain is the most complicated system in the known universe. It is formed by the huge quantity of neurons and synapses. The neurons and synapses both are highly complicated, highly multifarious and highly complete electronic-chemical apparatus. The beauty of thinking may just contain in the complexity of the brain. The research in neural science has revealed that a simple nervous may have the amazing complexity, which reflects that its function, evolution history, structure and encoding scheme will work on any future disciplines of the brain complexity.

Brain science is a big science system consisting of various brain-researching disciplines. It studies the structure and functions of the brain, the relations between the brain and human behavior and thinking. Brain science also explores brain evolution, its biological components, neural networks and its corresponding mechanisms. Human's recognition on brains takes a long time from the superficial to the deep. This history can be divided into three phases according to the research levels.

The first phase may be called precursor period. In this period, humans gradually realize that the brain is the organ for thinking, and have a superficial understanding of its structures. During the 5<sup>th</sup> to 7<sup>th</sup> century BC, people in China had realized the association between brain and thinking.

Brain has been deeply studied in Ancient Greece. Pythagoras and Plato both hold that the brain produces senses and wisdom. Democritus thought that the brain produces atoms, which in turn produces soul activities. Hippocrates affirmed that the brain was the thinking organ with an anatomy approach. Erasistratus from the Alexander school studied structures of brains using the same approach. Herophilus distinguished cerebellums and cortexes. Galen, an ancient Greek doctor, further discovered internal structures of brains, such as corpus callosum, pineal gland, and put forward the theory that the left brain is responsible for feeling and the right brain for movement.

The second phase is the mechanical period. The major progresses were the establishments of reflexology and positioning theories. Middle Age witnessed little progress in researches on anatomical brain. With the development of modern sciences, researches on brain developed rapidly. In the 18th century, Hubble, a Swiss physiologist, found that brains transmit stimulates using nerve. René Descartes put forward the brain's reflexology theory and the dualism theory in which spirit and brains interacted with each other. Russian scholar N. M. Сеченов perfected the brain's reflexology theory. In the 19th century, Austrian physician F. J. Gall established the positioning theory initially, which later

formed as craniology science. French doctor Paul Broca discovered the Broca's area by dissecting the brains of aphasia patients, which marked as the science foundation of positioning theory. The study of brain in this period has some traits of Mechanism.

The third phase is the modern period. In this period, the brain was studied from multi-levels, multi-layers and multi-views, including not only global study but also partial study, not only systematical study but also study on the Neurons, cell and molecular level, not only the study on physical, chemical, psychological but also comprehensive research. At present, there are many methods for brain-investigating. Some of them are listed as follows:

(1) Black-box methods. Due to the complexity of brains, researchers can not study brain's thinking mechanisms from outside, so the only remainder method is to presume its work mechanism from the processed results after information is sent to brains.

(2) Electrical science methods. These methods explore the mechanism of brains' activities by investigating brain waves. In 1848, German scholar DuBois Reymond firstly recorded the current activities of nerve tissue. In 1929, H. Berger from German firstly recorded electroencephalograms in his son's scalp. He recorded rhythmical slow-wave at about 10 times/sec. Now, the brain electrical methods have been used for many purposes and researches.

(3) Brain damage methods. The relations between the degree of injured brains with their influences on intelligence and behavior are used to reveal brains' function. These methods have been widely used in the theories about brains positioning and unitary.

(4) Neuron methods. Neurons are used to understand brains.

(5) Chemical methods. In brains, there are not only electrical activities, but also chemical movements. It relies on chemicals for information transferring, memory, thinking, and controlling mood. The chemical method investigates activities in brains by studying brains chemical substance and its functions.

Computational neuroscience is the stimulation and study of nervous systems using mathematical analysis and computer simulation methods from different levels ranging from the real creature physical models of neurons, their dynamic interactions and structure learning of neural networks, to quantitative calculation theory of brain tissue and nervous tissue, from studying the non-program, adaptive and brain-style nature and potentials of information processing to

explore new mechanisms of information processing mechanism, to finally create artificial brains.

It takes a long period for the study of computational neuroscience. In 1875, Italian anatomists C. Golgi firstly identified individual nerve cells using a dyeing method. In 1889 R. Cajal founded the neuron theory, in which nervous systems are built with independent nerve cells. Based on this theory, in 1906 C. S. Sherrington put forward the notion of synapses between neurons (Sherrington , 1906). In the 1920s, E. D. Adrian proposed the nerve action potentials. In 1943 W.S. McCulloch and W. Pitts put forward the M-P neural network model (McCulloch & Pitts 1943). In 1949, D. O. Hebb put forward the rules for neural network learning(Hebb, 1949). In the 1950s, F. Rosenblatt proposed perception machine model (Rosenblatt, 1962). The neural computation has made great progress since 1980s. J. J. Hopfield introduced the “Lyapunov” function (also called calculated energy function) and proposed the criterion of network stability for associative memory and optimization calculation (Hopfield, 1982). Amari did various works on the mathematical theory of neurons network including statistical neural dynamics, dynamics theory of neuron field, associative memory, and particularly fundamental works in information geometry(Amari, 1985). The research on computational neuroscience tries to reflect the following characteristics of the brain: ① Cerebral cortex is a grand and complex system with extensive connections. ②The computation in the brain bases on large-scale parallel simulation processing. ③The brain is strongly “error-tolerate” and is skilled in association, generalization, and analogy. The function of the brain was restricted not only by innate factor, but by the other acquired dispositions as well, such as experience, learning and training. This shows that the brain is self-organized and adaptive to environments. Many human intelligence activities are not controlled by logical reasoning, but by training.

Cognitive psychology explains human’s complex behaviors in terms of information processing. It absorbs the outcomes of Gestalt psychology and behaviorism. It also holds that complex phenomena can be study when they are decomposed into simpler primary parts. When a person is stimulated, he relies on his experience to decide how to response. Experiences include the state of his body and the context of his memory. Therefore, stimulation and current psychological states both decide the reactions.

Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. In recent years, the development of cognitive

science to be the international scientific community, especially developed countries, the government attached great importance and large-scale support. With perceptual expression, learning and memory in the process of information processing, thinking, language model, and based on environmental awareness as a breakthrough point, the calculation of cognitive theory and scientific experimental methods and strategies to achieve the direction of original innovation; explore innovative learning mechanism, the establishment of functional brain imaging database, put forward a new machine learning theory and methods.

Since firstly proposed in 1956, Artificial Intelligence had made great progress and success, especially in the aspect of using knowledge to solve problems, and promoted knowledge science. Since knowledge plays more and more important roles in the civilization of mankind, humans has entered the society of informationism, and walked towards the knowledge society. People aim at the general rules and characteristics of the knowledge. In 1977, E. Feigenbaum proposed the concept of knowledge engineering, which made the knowledge information processing into an engineering phase.

We can see that 1980's is knowledge engineering, 1990's is intelligent information processing. The rise of intelligence science quietly when enter the 21st century. In 2002 a dedicated Website entitled Intelligence Science and Artificial Intelligence has appeared on Internet, which is constructed by author and his colleagues. A special book entitled Intelligence Science written by author was published by Tsinghua University Press in 2006 (Shi, 2006). The first International Conference on Advanced Intelligence was held in 2008 in Beijing. World Scientific Publishing has decided to publish the Series on Intelligence Science in 2008.

### **1.3 Research Contents**

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 (Intelligence Science Website). Following Ten big issues of intelligence science will be viewed as main research contents.

### ***1.3.1 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 neighboring neurons<sup>15</sup>. 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.

### ***1.3.2 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 (Shouval , 2007).

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.

### ***1.3.3 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.

### ***1.3.4 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 (Dehn, 2008).

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 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 (Tarsia, 2003). 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.

### ***1.3.5 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 (Chomsky, 1957). 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 (Mayeux etc., 1991).

### ***1.3.6 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 framework. 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 leaning 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, evolutionary 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.

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 (Machine learning Website).

### ***1.3.7 Thought***

Thought is a reflection of essential attributes and internal laws of objective reality in conscious, indirect and generalization by human brain with consciousness (Shi, 2008). 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 (Shi, 1990).

### ***1.3.8 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 (Norman, 2002). 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.

### ***1.3.9 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, 1994). 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<sup>29</sup>. 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.

### ***1.3.10 Mind modeling***

Mind is a very important issue in intelligence science, and also it is a tuff 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 (Medical dictionary Website). 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 (Anderson, 1993). 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 (Newell, 1990). 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.

#### **1.4 Research Methods**

Many different methodologies are used to study intelligence science. As the field is highly interdisciplinary, research often cuts across multiple areas of study, drawing on research methods from psychology, neuroscience, cognitive science, artificial intelligence and systems theory.

### ***1.4.1 Behavioral experiments***

In order to have a description of what constitutes intelligent behavior, one must study behavior itself. This type of research is closely tied to that in cognitive psychology and psychophysics. By measuring behavioral responses to different stimuli, one can understand something about how those stimuli are processed.

(1)*Reaction time.* The time between the presentation of a stimulus and an appropriate response can indicate differences between two cognitive processes, and can indicate some things about their nature. For example, if in a search task the reaction times vary proportionally with the number of elements, then it is evident that this cognitive process of searching involves serial instead of parallel processing.

(2)*Psychophysical responses.* Psychophysical experiments are an old psychological technique, which has been adopted by cognitive psychology. They typically involve making judgments of some physical property, e.g. the loudness of a sound. Correlation of subjective scales between individuals can show cognitive or sensory biases as compared to actual physical measurements.

### ***1.4.2 Brain imaging***

Brain imaging involves analyzing activity within the brain while performing various cognitive tasks. This allows us to link behavior and brain function to help understand how information is processed. Different types of imaging techniques vary in their temporal (time-based) and spatial (location-based) resolution. Brain imaging is often used in cognitive neuroscience.

(1)Single photon emission computed tomography(SPECT) and *Positron emission tomography*(PET). SPECT and PET use radioactive isotopes, which are injected into the subject's bloodstream and taken up by the brain. By observing which areas of the brain take up the radioactive isotope, we can see which areas of the brain are more active than other areas. PET has similar spatial resolution to fMRI, but it has extremely poor temporal resolution.

(2)*Electroencephalography(EEG).* EEG measures the electrical fields generated by large populations of neurons in the cortex by placing a series of electrodes on the scalp of the subject. This technique has an extremely high temporal resolution, but a relatively poor spatial resolution.

(3)*Functional magnetic resonance imaging*(fMRI). fMRI measures the relative amount of oxygenated blood flowing to different parts of the brain. More oxygenated blood in a particular region is assumed to correlate with an increase in neural activity in that part of the brain. This allows us to localize particular functions within different brain regions. fMRI has moderate spatial and temporal resolution.

(4)*Optical imaging*. This technique uses infrared transmitters and receivers to measure the amount of light reflectance by blood near different areas of the brain. Since oxygenated and deoxygenated blood reflects light by different amounts, we can study which areas are more active (i.e., those that have more oxygenated blood). Optical imaging has moderate temporal resolution, but poor spatial resolution. It also has the advantage that it is extremely safe and can be used to study infants' brains.

(5)*Magnetoencephalography*(MEG). MEG measures magnetic fields resulting from cortical activity. It is similar to EEG, except that it has improved spatial resolution since the magnetic fields it measures are not as blurred or attenuated by the scalp, meninges and so forth as the electrical activity measured in EEG is. MEG uses SQUID sensors to detect tiny magnetic fields.

### ***1.4.3 Computational modeling***

Computational models require a mathematically and logically formal representation of a problem. Computer models are used in the simulation and experimental verification of different specific and general properties of intelligence. Computational modeling can help us to understand the functional organization of a particular cognitive phenomenon.

There are two basic approaches to cognitive modeling. The first is focused on abstract mental functions of an intelligent mind and operates using symbols, and the second, which follows the neural and associative properties of the human brain, and is called subsymbolic.

(1) *Symbolic modeling* evolved from the computer science paradigms using the technologies of Knowledge-based systems, as well as a philosophical perspective. They are developed by the first cognitive researchers and later used in knowledge engineering for expert systems. Since the early 1990s it was generalized in systemics for the investigation of functional human-like intelligence models, such as personoids, and, in parallel, developed as the SOAR environment. Recently, especially in the context of cognitive decision making, symbolic

cognitive modeling is extended to socio-cognitive approach including social and organization cognition interrelated with a sub-symbolic not conscious layer.

(2) Subsymbolic modeling includes *Connectionist/neural network models*. Connectionism relies on the idea that the mind/brain is composed of simple nodes and that the power of the system comes primarily from the existence and manner of connections between the simple nodes.

#### ***1.4.4 Neurobiological methods***

Research methods borrowed directly from neuroscience and neuropsychology can also help us to understand aspects of intelligence. These methods allow us to understand how intelligent behavior is implemented in a physical system. There are several approaches, such as Single-cell recording, Direct brain stimulation, Animal models, Postmortem studies and so on.

#### ***1.4.5 Simulation***

Simulation is an artificial testing means, which establishes on the basis describes the system structure or course of conduct, and has a certain amount of logical relations or relations between simulation model, accordingly test or quantitative analysis, in order to obtain the correct all kinds of information in terms of analyzing the nature of the system elements and their mutual relations and in accordance with the purpose of system analysis. The difference with experimental or practical systems is that simulation is not based on actual environment, but as the actual system image of the system model and the corresponding "artificial" environment carried out under. Simulation can truly describe system operation, evolution and the development process.

### **1.5 Research Roadmap of Intelligence Science**

Human's scientific undertaking is facing the challenges from the following four big problems: the nature of matter, the origin of universe, the essence of life and the generation of intelligence. Intelligent science aims at the last one, maybe the most difficult and important one - how is the intelligence generated from materials?

Intelligence is the essence of life science and technology, the core of information science and technology, and the frontier and commanding height of modern science and technology. Its research involves deeper mysteries of science and touches the fundamental topics in philosophy. Therefore, once the researches in intelligence make a breakthrough, deep influence will be made on the national economy, the progress of society development, and the security of nation. At present, intelligent science is in the transition period of methodology, the high tide of theoretical innovations and the start period of large-scale applications. So it is full of original opportunities.

Research on intelligence science just started. It is difficult to give the precise roadmap. Following the development trends will be outlined.

### **1. Short-term goal (2010-2020)**

Research on the representation of perceptual information, including the visual, auditory information processing, explore perceptual feature binding mechanisms and objects. Develop computer has human like behaviors such as listening, talking, reading, writing.

Learning is the accumulation process of experience and knowledge, as well as performance improvement of system's behaviors by understanding and mastering temporal associations towards outsides, a basic kind of cognitive activities. The neural biology foundation of learning is the synaptic plasticity for associative structures between nerve cells, which has become a very active research field. The emergence from perceptual cognition to rational knowledge is also an interesting problem.

During the human evolution, language's utilization makes the brain's two hemispheres develop with different functions. The language is the most complex, systemized and widely used symbol system. Language symbols represent not only specific things, status and actions but also abstract concepts. The Chinese possesses the unique characters coupling sounds, shapes and contents tightly and is significantly different from Indian and European languages because of its unique morphology and syntax system, text system, and voice tone system. It is a best opportunity for us to open the door of wisdom by studying Chinese from the nerve, cognition and computation levels.

### **2. Medium-term goal (2020-2035)**

Explore the central location of human memory, hippocampus, and other human-related learning and memory center of the working principle, clarify the initial

memory information storage and retrieval mechanisms, particular working memory.

Working memory system can store and process information simultaneously, which is different from short-term memory which emphasizes only the storage function. Working memory is divided into three components: central executive system, visual-spatial preliminary processing system and the articulatory loop. A large number of behavior researches and neuropsychological evidences show the existence of the three components. Knowledge on the structures and functions of working memory are constantly enriched and perfected. People found that working memory is tightly related to language comprehension, attention and inference, and may contain mystery of intelligence.

### **3. Long-term goal (2035-2050)**

Explore the neural basis of human consciousness and its biological mechanism, as well as joint consciousness and so on. Consciousness is perhaps one of the biggest mysteries and the current research results may be one of the highest achievements. The study on consciousness can start with awareness and unawareness, and finally discover the difference between nerves related materials in brain's activities. The final goal will develop brain-like computer, or machine brain with human-level intelligence and reach the football team composed of intelligent robots defeat the professional football team in the 2050 World Cup.