**Foundations of cognitive physics: the cornerstone of understanding nature and ourselves**

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【Abstract】Matter, energy, structure and time are the most basic elements of human cognition and machine cognition, and are the common cornerstones of human intelligence and artificial intelligence. Information is not matter, nor is it energy. It is a derivative formed on structure and time. Above the four elements are the soft structure of thought and the hard structure of matter, which correspond to mathematics based on imagination and reasoning and physics based on observation and evidence, respectively. Cognitive physics is based on mathematics and physics. The mission of cognitive physics is to explain human cognition and its formation process with the theories and methods of physics, and to condense and replay human intelligence with artificial intelligence, and to use machines to imitate and expand human cognition. In the future, we must break through the limitations of Turing machines and develop difficult-to-calculate memory intelligence and embodied interactive intelligence; use cognitive physics theories and methods such as cloud models, data fields, topological potentials, and cloud transformations to formalize human uncertainty cognition, form cognitive spirals, and realize self-growth of cognition; develop interactive, learning, and self-growing cognitive machines, and open up a new direction of artificial intelligence in which each intelligence has its own intelligence, intelligence of all intelligences, and intelligence and intelligence are shared.

【Key words】cognitive physics artificial intelligence human intelligence matter energy structure time

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**introduction**

Hawking tells a story at the beginning of "A Brief History of Time". Russell was once taught a lesson by an old lady at a popular science lecture on astronomy: "The world is not that complicated. It is just a flat plate on the back of a turtle." Russell asked back: "What is the turtle standing on?" The old lady replied: "Young man, you are quite smart. There is a bigger turtle under the turtle. It is a turtle on top of a turtle!"

This "turtle tower" may seem absurd, but it contains profound philosophical speculation, revealing the logic of human cognition of nature and cognition of itself. The entire activity of human cognition is to explain and solve various practical problems encountered by humans in the process of survival and reproduction. Cognition is a self-contained system, including cognition of the objective universe, and also includes the more profound and vast subjective spiritual world of human beings. Compared with other species on the earth, humans have created a splendid culture and civilization, invented a variety of cognitive tools and machines, extended the physical intelligence of human flesh outside the body, and tools and machines have become physical existence in the real world, becoming the ecology of human civilization, and artificial intelligence is accelerating the change of human beings themselves. Humans have leaped step by step from "foragers" to "planters", "producers" and "builders", and are now leaping to "creators". Compared with other higher species, it is cognition that makes humans successful.

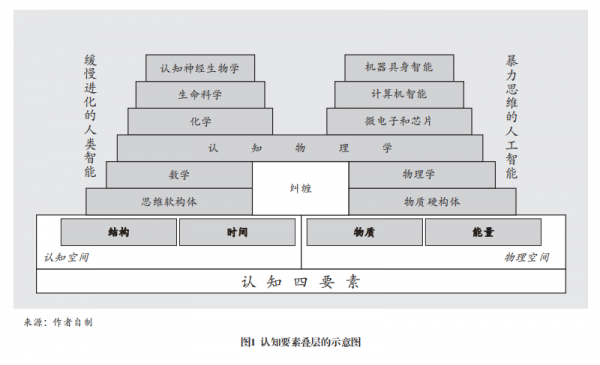
However, cognitive machines are not life, but mechanical, physical, and electronic devices. How can we use the theories and methods of physics to explain the perception, thinking, decision-making, and actions of machines? How can we explain how machine cognition is like and unlike humans? The simplicity and warmth of cognitive physics lies in the fact that it not only contains the "Tao" of human cognition, but also points out a "path" to achieve artificial intelligence. Since 2000, based on the idea of ​​"uncertain artificial intelligence", the author has tried to use natural science to explore the mystery of human subjective cognition, use the theories and methods of physics to explain human cognition and its formation process, and use machines to imitate and expand human cognition. This article will start with the logical relationship between human intelligence and the elements of artificial intelligence, explore the cornerstone of human cognition of nature and itself, and open up a new direction of artificial intelligence multi-cognition with each intelligence having its own wisdom, the wisdom of others, and the wisdom of all intelligences.

**Finding the cornerstone**

The saying of “turtles stacked on top of turtles” is to logically order the evolution of human cognition of nature and itself. Based on this idea, the author carefully sorted out the logical relationship between various elements in human intelligence and artificial intelligence, and obtained the result shown in Figure 1.

Whether it is human cognition or machine cognition, the bottom "turtle" stands on a foundation stone composed of four elements: matter, energy, structure and time. Among them, matter and energy are real existences at the physical level, structure and time are abstract thinking at the cognitive level, and are state parameters for human cognition of the existence and change of matter and energy. In the human spiritual world, structure is used to express the topology and deformation of matter in space, and time is used to express the movement and change of matter, reflecting the transfer and conversion of energy.

Above the four elements are the soft structures of thought and the hard structures of matter, in which spirit and matter are entangled. The hard structures of structure and time parasitizing on matter and energy constitute the embodiment of the machine; while the numbers, symbols, and information in the machine thinking process are a large number of soft structures, just like the thoughts expressed by people in the cognitive space. They parasitize on the hard structures or other existing soft structures, and can guide themselves, that is, bootstrap; can reuse themselves, that is, recursion; can be used recursively, that is, iteration; and can self-copy or modify to constitute imagination. The soft structures in the human cognitive space are the elements of thinking, supporting figurative thinking, logical thinking, and intuitive thinking, reflecting people's rich imagination and creativity, and reflecting the spiritual world.

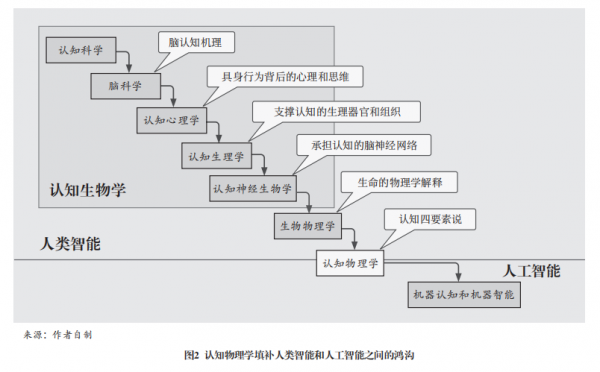


Above the soft structure of thought and the hard structure of matter are mathematics based on imagination and reasoning, and physics based on observation and evidence. Above mathematics and physics is cognitive physics. The mission of cognitive physics is to use the theories and methods of physics to explain human cognition and its formation process, and to use machines to imitate and expand human cognition. Evolution by natural selection vividly describes how the complexity of life develops step by step. But can it be explained by physics? As the most advanced species in nature, under the law of survival of the fittest, in the process of iteration, human cells, tissues and organs have undergone a slow natural evolution process for tens of millions of years, so there is human cognition based on "carbon base" and human intelligence is formed. The development of cognition promotes the development of human intelligence. Above cognitive physics are chemistry, life sciences, and cognitive neurobiology. Among them, chemistry is the support of life sciences, and mathematics and physics are the support of chemistry. Looking at the other side, it corresponds to the development of machine cognition. Above cognitive physics are microelectronics and chips, computer intelligence, and machine embodied intelligence. Generally speaking, the lower layer sets boundaries and provides theoretical support for the upper layer, and the upper layer provides implementation paths for the lower layer and proposes new missions. Machines simulate human cognition, being like humans yet not like humans.

Compared with machine cognition, the natural evolution of human cognition is very, very slow. Let us carefully review the important nodes of human cognition: more than 1 million years ago, humans walked out of Africa, 250,000 years ago, humans lived by hunting and gathering, 10,000 years ago, humans began to settle down and farm, and 5,000 years ago, they had language and writing and entered a civilized society; Aristotle, the founder of ancient Greek philosophy, was born in 384 BC, Newton, the founder of modern physics, was born in 1643, and Newton published "Mathematical Principles of Natural Philosophy" in 1687, which vaguely laid the foundation for humans to later understand and distinguish natural sciences, philosophy and mathematics, and human cognition began to embark on the road of science; more than 200 years ago, the invention of power machines such as spinning machines and steam engines promoted the process of the industrial revolution, and humans entered the "steam age"; in 1879, the pioneer of the scientific revolution, theoretical physicist Einstein was born, and proposed the theory of general relativity in 1915; in 1912, Turing, the father of computer science and artificial intelligence, was born, and Turing's life greatly promoted the formation and development of computer science. Looking back at history, it has been less than a hundred years since humans have generally used electronic computers, and now the dialogue between machines and humans is everywhere and at all times. It has been less than a hundred years since artificial intelligence has completed machine cognition based on "silicon" by violently condensing and replaying human thinking. It has been condensed into today's machines. What a remarkable and rapid progress!

**The entanglement between physics and mathematics**

Cognitive physics steps on two "turtles": mathematics and physics. The relationship between the two cannot be simply discussed under the logic of "who is the basis of whom". Mathematics does not belong to material science. It excludes the specific content of matter and formalizes it through abstraction, and uses logic and symbols to carry out thinking activities and expressions in terms of quantity, structure, change and spatial topology. For example, negative numbers, irrational numbers, imaginary numbers and even all numbers are not physical realities. The axiomatization and mathematization of physics were once the goals generally pursued by great scholars. Mathematics studies the abstract relationship between numbers and shapes, which is a soft structure of thinking, an invention, and the pursuit of beauty; physics searches for the hard structure of matter in the physical world, which is discovery, empirical evidence, and the pursuit of truth; they are entangled with each other and learn from each other. In the intelligent era, mathematics based on imagination and reasoning has become the most important foundation of human and machine thinking. Whether mathematics belongs to the natural science sector or the cognitive science sector is debatable. Professor Yang Zhenning believes that mathematics and physics are a bit like two "opposite" leaves. They are separated in most parts and develop along their own veins, but the basic parts are surprisingly entangled. The Church-Turing Thesis, named after Turing and his mentor Church, has profound philosophical implications. It was originally intended to draw a boundary between mathematics and physics, but this boundary is entangled and can be extended to "mind vs body". Mathematicians rely on their feelings in the material world and their abstractions to continuously propose mathematical conjectures, which are constantly proved or revised, and thus mathematics has developed. For example, the Goldbach conjecture, the Riemann conjecture, the NP-complete problem, etc., mathematics puts aside the dimensions of various physical meanings and gives different things the same symbols and laws at a highly abstract level, so that seemingly unrelated things or phenomena can be unified and explained to a certain extent. Unfortunately, the contribution of mathematics to time is not as great as its contribution to structure. Inspired by matter and energy in the universe, the mathematical world contains many things that do not exist in the universe. Its structure abstracted by human brain cognition becomes an "imaginary reality", such as coding, data, symbols, text, concepts, information, knowledge, etc. These soft structures are not real physical existences. There is also entanglement between the soft structure of thought and the hard structure of matter. Sometimes, solving a mathematical problem can promote the solution of a type of physical problem; sometimes, solving a physical problem can promote the solution of a type of mathematical problem.



Newton found mathematical precision for classical physics, but chemistry and biology lacked a solid foundation at that time. They needed to study uncertainty, probability theory and statistics, and the mechanism of emergence or enlightenment. Life sciences have become increasingly prosperous in recent years, such as structural biology, cognitive neurobiology, gene editing, etc. With the widespread use of computers, as well as the rapid development of microelectronics technology and chips, computer intelligence and cognitive physics, people keep asking questions: Is life a machine, or is the machine life? How are human cognition and machine cognition the same and different? These are exactly the questions that cognitive physics wants to study. The mission of cognitive physics is to explain and fill the gap between human intelligence and artificial intelligence (see Figure 2). Now it seems that in addition to matter and energy, structure and time also play an incredible role in the cognition of nature and human beings themselves.

**The entanglement between objective nature and subjective cognition**

Since ancient times, as one of the species on Earth, the biggest problem facing humans is material satisfaction in the process of survival and reproduction. Along this main line, humans have continuously strengthened their ability to acquire and act in the material world, and constantly conquered and transformed the material world to ensure their own survival and reproduction. The birth of modern science also originated from the cognition of the material world, and then developed into "material and energy science, technology and engineering", acting on matter to meet human material needs and change the state of existence or properties of matter. Modern science covers basic disciplines such as physics and chemistry, and later developed into organic chemistry, medicine and life sciences to explain the natural laws in physical space and the universe, explain the life course of human beings, and even try to create artificial life. Its research object is a real material hard structure.

Compared with this main line, human spiritual activities and intelligent activities are only cognition in the subjective world of human beings, and are the common product of a person's feelings, perceptions and memories. We can regard it as an independent spiritual existence, that is, a soft structure of thinking. In fact, it is very difficult to explain the objective existence of the physical world through subjective cognition. We can only explain what the material world has left in the human brain. Inventions and discoveries directly related to spiritual and cognitive activities, such as the emergence of human language and writing, the birth of education, the birth of theology, religion, philosophy, literature, art, music, and fine arts, are earth-shaking; the development of genetics in life sciences, the discovery of the double helix structure of DNA, and the success of gene editing, especially the universality of mathematics and storage programs, have promoted the invention of programmable electronic computers, which is even more earth-shattering. Unfortunately, the universe is not moved by humans, it is free and silent.

The process of human cognition of the universe is based on observation and empirical evidence. Usually, we only believe in "reality" and see "existence". However, there are many soft structures of thinking based on imagination and abstraction in the human brain, which will also produce "virtual" and "soft" things. All human thinking activities are inseparable from abstraction. Cognition originates from abstraction in the perception process and compresses it into soft structures of different scales. The brain and nervous system with abstraction, association and memory capabilities formed by natural evolution is the biological basis for humans to abstract structure and time. The sensory organs and cerebral cortex tissues formed by long-term evolution of humans, especially the interaction of a large number of nerve cells, are the thinking organs that form time perception. If there were no memories of different lengths, including visual residues, such as instantaneous memory, working memory and long-term memory, we would only live in the present and would not have the concept of time for material movement and change. Memory provides continuity for our past and present cognition. As a famous saying in psychology says, life is memory. If there is memory, there will be forgetting, otherwise the brain will be overwhelmed. Turing also has a famous saying: forgetting is a significant manifestation of human intelligence. Humans have to use limited memory to understand the infinite universe, so they abstract structure and time, which is conducive to association, imagination and creativity. This is "passively" formed by humans in the long-term natural evolution, natural selection, and survival of the fittest in order to achieve survival and reproduction. There is no isolated structure in the universe that is separated from matter and energy, nor is there isolated time that is separated from matter and energy. An important example is that in 1967, the physics community unanimously agreed to use the atomic structure explained by field theory to define "seconds". The interval of one second is the duration of 9192631770 cycles of electromagnetic radiation corresponding to the transition between the two hyperfine energy levels of the ground state of cesium 133 atoms. From the dimensions defined by the physical constants, it can be seen that it is time T that defines the length L and mass M, and it is also time that describes entropy increase and negative entropy. With the concept of time, matter and energy can be mapped into topological structures and relationships at different times in cognitive space. Therefore, among the four elements of the interaction between two virtual and two real, structure is reflected in material objects, and time is reflected in energy or motion changes.

**Information is neither matter nor energy. What is information?**

Information is a derivative formed in structure and time, and is the reference to the soft structure of thinking, nothing more. The smallest element that constitutes human writing is a symbol or stroke. The most basic abstraction in mathematics is 0 and 1, the most basic abstraction in algebra is constants and variables, and the most basic abstraction in geometry is points, lines and planes. On the basis of abstraction, cognition produces associations and interactions, from linear to nonlinear, from certainty to uncertainty, from reversible and reducible to irreversible and irreducible, from simple to complex. In the human cognitive space, if there is no abstraction and association, there will be no numbers, symbols and codes, mathematics, language and text, not to mention information, knowledge and models, equations, algorithms and programs. Symbols, text, models, algorithms, and programs are all soft structures, which are non-material and non-objective, but are just human intelligent activities. For example, people can recognize the hard structures such as the graphics "A" printed on paper and walls, and merge, classify and abstract them into the soft structure "A" in the cognitive space. Soft structures are not stored in an isolated memory unit, but are reflected in the topology of the human brain neuron network. Various abstract concepts, such as "mountain", "water", "tree", "house", "person", "pet", etc., are all soft structures of thinking. Depending on different occasions and tasks, they can variably refer to the same or multiple specific entities in the physical world (such as girl, woman, elder sister); the same hard structure can also be variably given various soft structures in the cognitive space in different situations and environments, and can even be very different soft structures. The information that people often talk about is just the tip of the iceberg of soft structures. With the help of soft structure thinking, imagination and creation, the human brain explains the human spiritual world, human cognition, and the value of life, opening up "structural and temporal science, technology and engineering."

The soft structures of thought, including information, are not real entities that constitute the physical world and do not have objectivity or materiality. At the same time, structure and time are also deeply and subtly parasitic in material and energetic science, engineering, and technology, explaining the material world in which humans live, and quietly permeating into various man-made objects, becoming more and more real entities in physical space, such as man-made buildings, artificial satellites, the Internet, intelligent machines, and even artificial life. To facilitate understanding, let's look at the following example about music.

The music score created by the human brain is a soft structure that expresses information, emotions, art and humanity, and is metaphysical. The same music score can be performed on different hard structures (instruments). No matter which hard structure is used to play it, such as violin, erhu, piano, drum set, etc., it is the same music score. The music score is metaphysical, spiritual, and non-material; while the music people hear is an objectively existing, slow and fast changing, strong or weak sound wave signal with a rich spectrum in the physical world, which contains matter, energy, structure and time. It is physical, embodies beauty, and also embodies the unity of knowledge and action. The magnificent scene presented by the symphony is often the external manifestation of "emergence".

**Conclusion**

Cognitive physics proposes that matter, energy, structure and time are the most basic elements of human and machine cognition. The earth relies on the alternation of the sun and the moon and the cycle of the four seasons to maintain order, and human social groups rely on structure and social order to maintain operation. Like life, they all rely on negative entropy for survival. Similarly, cognitive machines use energy to generate clocks, and clocks generate timing, support recursion, and maintain machine negative entropy. If the clock does not stop and interacts with the outside world, then thinking and cognition will not stop. A person's life is about 80 years, which is about 2.5 billion seconds in length. The thinking cycle of a person is usually sub-second to millisecond level, while the thinking cycle of a cognitive machine can be picosecond (10 seconds to 12 seconds). If machines are calculated in femtoseconds and humans are calculated in seconds, the ratio of 1 femtosecond to 1 second is close to the ratio of 1 second to 32 million years. Let the machine condense and replay the total amount of thinking of a 100-year life, and it can be completed in less than a few seconds. This is the violent thinking of the machine. At the same time, the machine has the advantages of concentration and no fatigue. In the future, we must break through the limitations of Turing machines and develop incalculable memory intelligence and embodied interactive intelligence; use cognitive physics theories and methods such as cloud models, data fields, topological potentials, and cloud transformations to formalize human uncertainty cognition, obtain structure through abstraction, trigger analogies through association, and form feedback through interaction, and then integrate symbolism, connectionism, and behaviorism to form a cognitive spiral and achieve cognitive self-growth; develop interactive, learning, and self-growing cognitive machines to explore how machine cognition is like and unlike humans, and open up a new direction for artificial intelligence in which each has its own wisdom, all share the wisdom of others, and all share the wisdom of the same.

Looking back at the statement "turtles on top of turtles" at the beginning of this article, matter, energy, structure and time have become the common foundations of human cognition of nature and ourselves, and the common foundations of human intelligence and artificial intelligence. Artificial intelligence condenses and replays human intelligence, and at the same time answers the fundamental question of "information is not matter, not energy, what is information?"

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