Theory of Logical Information Model & Logical Information Network

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Abstract

In the 2010s, with the gradual maturity of connectionism tools such as deep learning algorithms and neural networks, another wave of artificial intelligence (AI) has been set off. However, it has been more than 6 years since AlphaGo made great achievements in 2016, and AI research has once again encountered a bottleneck on the way to further development. Due to its relying too much on the theoretical basis based on probability theory, connectionism has been unsatisfactory in the aspects of causal reasoning and interpretability, which has been criticized by many people as not being real intelligence.

After analyzing the logic basis of the mainstream schools such as connectionism and symbolism, this article combines the core elements of them and proposes a logical information model with strong logicality and practicability. The model and the large-scale information network based on it are expected to fundamentally improve the problems of causal reasoning and interpretability, and become a new theoretical breakthrough in constructing a new knowledge graph structure, and even moving towards artificial general intelligence (AGI).

However, the theoretical research of this model is still at an early stage. The current model design is only limited to pure text information, and the compatibility of other information sources, such as graphics and sound, remains to be explored. Meanwhile, it's also necessary to test the complex characteristics for the model in the huge data environment of logical information network. Meanwhile, it also awaits to test the complex characteristics for the model in the huge data environment of logical information network. In addition, for trustworthy AI that is required to realize strong logicality, or AGI suitable for different application scenarios, it is also necessary to further develop and verify its core "dynamic information algorithm" in the logical information network environment of massive data.

Although it is still far from the goal of AGI, and there are many problems to be solved, it is still worth trying to summarize and explore new routes when the existing AI routes encounter bottlenecks.

Keywords: Artificial General Intelligence (AGI); Logic; Logical Information Model; Logical Information Network

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1. Introduction

Since ancient times, human scholars have always been passionate about exploring the mystery of intelligence. What is the essence of intelligence? This is one question that many philosophers and brain scientists have been working hard to research.

In 1956, the concept of **"Artificial Intelligence" (AI)** was jointly proposed by a group of scholars from mathematics, information science, computer science, neuroscience and psychology, who attempted to simulate human intelligence with machines. In the following 50 to 60 years, many artificial intelligence schools emerged in the academic community, among which the most three influential schools are symbolism based on physical symbol system assumption, connectionism based on neural network and machine learning algorithm, and behaviorism based on cybernetics and "perception - action" control system.

The three schools had different perspectives on the fundamental theories and technology route, and each had its own strengths. In this case, it formed long-term debates. With deepening of research, people gradually realized that the three schools should be integrated and learn from each other, to make up for own shortcomings. Then, the three schools began to synthesize. Some experts have begun to try to establish a unified framework or model that can integrate the three schools, with methods including AORBCO model, the mechanism approach, and HARPIC architecture and so on. However, currently most of these models are still in the theoretical construction level, lack of clear modeling methods, and it is difficult to help to implement the system functions of the three schools in the short term.

Meanwhile, there are still many differences in people's understanding of the concept of "intelligence" and no unified cognition has been formed. People from different disciplines give their respective understandings from different perspectives. At present, experts in artificial intelligence roughly have three kinds of views on it, which are: The "thinking theory" holds that intelligence comes from brain thinking activities, the "knowledge threshold theory" holds that intelligent behavior depends on the amount of knowledge available, and the "evolution theory" holds that intelligence comes from adaptive behavior after perceiving the external environment and evolves gradually.

These three types of views lead the three schools to develop in different directions. However, they are not absolutely opposite and exclusive. From the perspective of cognitive science, they collectively cover the capabilities to acquire knowledge, to think and use knowledge to solve problems, and to perceive and adapt.

It is not difficult to see that knowledge is critical to intelligence, and it is the basis of all intelligent behavior. So where does knowledge come from? In the field of knowledge management, knowledge is considered to be the laws and experiences obtained from the refining of information, while information comes from the analyzing of various data, and data is the signal which reflects the state of objective things through sensory organs or observation instruments.

Human senses the surrounding world by seeing with their eyes, hearing with their ears, and touching with their hands. When the sensory organs such as visual, auditory, tactile senses obtain signals from external light, sound, force and other stimulus, the corresponding perceptual information is reflected and recorded in consciousness. When there is a certain amount of interlinked information, consciousness summarizes it into some laws, of which knowledge consists. After a great deal of knowledge is mastered and integrated, it gradually forms human wisdom. This is the process currently known how human achieve intelligence. (Figure 1)

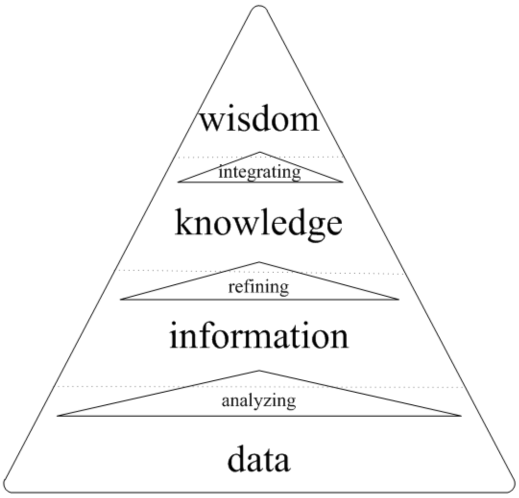

Figure 1: Diagram of the relationship of "data - information - knowledge - wisdom".

We hope to create a machine with similar intelligence to human beings, so we need to solve several problems, such as "how to make the machine perceive external signals", "how to transform signal data into information that can be recognized by itself", and "how to extract more advanced rules from information". Another way to express these problems is how the machine achieves acquisition, recognition, storage, processing, transformation and some other functions of data, information and knowledge. In these issues, the most important, and the foundation of them all is, how do the machine represents data, information and knowledge? That is, what is the representation model of data, information and knowledge for a machine?

In current database technology, data models are roughly divided into two categories: logical models that express concepts and relationships, and physical models that describe the form of data storage. Similarly, we can also think of human's knowledge memorization as a physical model for storing data. If we list the logical and physical models used by human intelligence and artificial intelligence to represent knowledge, information and data respectively, we can see it as following Table 1.

Table 1: Relationship of "intelligence - model".

	physical model	**logical model**
human intelligence	brain neurons	logical reasoning
artificial intelligence	relational databases	unknown, not unified

At present, the data physical models used by artificial intelligence are mostly based on mainstream relational databases. The physical model of human intelligence has not been thoroughly studied, and as far as research is concerned, the function of memory is mainly carried out by brain neurons.

Although there are many logical models of artificial intelligence, there is no unified norm in academic direction, and everything is still under exploration. In the existing logical models, some of them can only solve single or limited problems, such as the Deep Neural Networks (DNN) and its data models adopted by the AI Go program AlphaGo. Or the Knowledge Graph model, which has been gradually attached to the domain of artificial intelligence research in recent years. And some of them are still describing the functions of intelligence abstractively (also known as conceptual models in this phase), such as those unified models of the three schools that still need to be further developed.

In contrast, the logical model of human intelligence has been researched over thousands of years, and has formed a series of rigorous disciplines. Its form takes logical reasoning as the core, linguistics and philosophy as the foundation, logic, mathematics and other rational disciplines as the backbone. It has a strict theoretical basis, with a large number of academic research results, which is quite mature. Meanwhile, the problem how to represent data, information and knowledge is a priority for AI development trends in establishing unified models. The logical model of human intelligence has rich and mature research experience, which can bring inspiration to the logical model of artificial intelligence, and provide guidance in causal reasoning, interpretability and other aspects.

This article tries to elaborate a new general information model from the perspective of the logical model of human intelligence. The model is constructed in accordance with the basic features of logical reasoning, so the information based on this model can be used as basic units to build a system of logical self-compatibility among these units. This system has a network-like data structure, so it can be called **"Logical Information Network" (LIN)**. Each information unit in the network can be referred to as **"Logical Information Unit" (LIU)** or **"Information Unit" (IU)** for short. And the structure of each information element is a part of this general information model, which can be called **"Logical Information Model" (LIM)**.

2. Logical Model

The foundation of rational thinking comes from logical reasoning.

Humans have been studying reasoning for more than two thousand years. As early as in the period of ancient Greek, Aristotle (ancient Greek: αριστοτέλης) has assembled the best of his predecessors and created a complete system of formal logic. In the 17th, 18th century, Leibniz, G.W., Boole, G. and some other mathematicians established the discipline of "mathematical logic" on the basis of formal logic. It is characterized by the extensive use of symbols and mathematical methods to deal with logical problems. Well into the 20th century, mathematical logic has successively obtained several epoch-making achievements, such as Gödel's Incompleteness Theorem, Tarski's Truth Theory of formal language, and Turing Machine with the theory of its application. And it has laid the foundation for the development of information science, computer science, and artificial intelligence.

With the increasing academic influence of mathematical logic, many logicians believe that the modern logic represented by mathematical logic is much superior to the traditional logic represented by Aristotle's formal logic in both depth and breadth. As the famous Polish mathematical logician Tarski, A. said, "The new logic surpasses the old in many respects, -- not only because of the solidity of its foundations and the perfection of the methods which are employed in its development, but mainly on account of the wealth of concepts which have been investigated and the wealth of laws which have been discovered. Fundamentally, the old traditional logic forms only a fragment of the new, moreover a fragment which is entirely insignificant from the standpoint of requirements of other sciences, and of mathematics in particular."*[1]

However, unlike traditional logic, the language of mathematical logic is based on ideographic symbols, rather than grammars of natural language. Therefore, it is essentially the logic of symbols, or artificial language based on symbolic logic, rather than formal logic which taking natural language into account. There are also many people who believe that mathematical logic is not suitable for formalization of natural language.

Even, many traditional logicians do not accept mathematical logic. They believe that mathematical logic is essentially a branch of mathematics, and only a basic discipline in discrete mathematics. It is not a part of logic science, and cannot represent the development direction of logic research, either. Just like the British mathematical logician Russell B.A.W., who tried to define the arithmetic concepts with logical concepts, then deduce the arithmetic with the formal system, and deduce all mathematics, after establishing a formal axiom system of propositional calculus and first-order predicate calculus. Although it was not completely successful, it also made mathematical logic further mathematical, thereby completely deviating from the thought in traditional formal logic, which advocates taking reasoning format as the main tool to explore from the known to the unknown.

Whether formal logic and mathematical logic are regarded as two different disciplines, or the latter is seen as a continuation and expansion of the former, there are always logical thinking and the basic elements of logic, such as reasoning, judgment and concept, running through them. The thinking process of humans via reasoning, judgment and concept to understand and distinguish the objective world is exactly the logical abstract thinking. Among them, reasoning, judgment and concept are the inner meaning of logical thinking, and the corresponding external expressions are argumentation, proposition and word groups. The logical information model as set forth herein, and the system to be constructed by this model, is also based on these logical elements.

This is another interpretation of traditional logic connotations. And it is also attempting to combine it with the research results of modern information science, and develop a different kind of scientific system, just as the mathematicians combined traditional formal logic with mathematical symbols.

[1] "The new logic" means the modern logic, and "the old logic" means the traditional logic.
This paragraph comes from *Introduction to Logic and to the Methodology of Deductive Sciences*, Tarski, A., 1994, Page 17, 18.

2.1 Argument-Proposition Model

2.1.1 Argumentation & Proposition

Logic is the discipline for studying reasoning and argumentation, which are the most basic elements in logic. Reasoning is considered to be a kind of abstract thinking process in a broad sense, which is a general term for thinking ways of concluding things or their intrinsic properties. Reasoning involves the whole thinking process through people's internal mental operations of drawing results from known or assumed reasons, or finding reasons for the known results. Argumentation is an external expression corresponding to the inherent reasoning thinking activities, which is composed of a set of statements. Only one statement is called "conclusion," and the rest are called "evidences" that support the conclusion. It can be said that reasoning is intangible, exists only in abstract thinking, and argumentation is tangible. There are various forms of argumentation, and syllogism, such like "all M is P, all S is M, so all S is P", is one of the typical forms.

Indeed, in the eyes of many researchers of formal logic, there are still many different points of view on the concepts of reasoning and argumentation, the relationship between them, and their role in logic research. In this article, however, since we are not entirely to look at them from the perspective of formal logic category, we don't strictly pursue their indistinguishable similarities and differences. What we are concerned with is the process of that a set of statements are combined to form a complete inference in the stage of expressing an argument. Here the process is called "**argument process**", or "**argument**" for short.

The statement in an argument is "**proposition**". Proposition, defined in philosophy, logic, mathematics, linguistics, etc., is what one concludes by using a declarative sentence. Proposition refers both to the statement of thing itself, and usually to the semantics expressed by the statement.

Reasoning is the core of logic, and proposition is the cornerstone of all reasoning. In traditional formal logic, statements composed of words are used to state propositions, while that's tended to be expressed in functional ways such as logic calculus in mathematical logic.

2.1.2 Naive Argument-Proposition Model

In the artificial language of the computer domain, "**object**" is treated as an abstract form of objective things, and object-oriented analysis is the basis of information modeling. In this article, we will map the logic elements such as propositions to objects, and construct models with object-oriented thinking.

From the object-oriented perspective, proposition can be a class of objects, which form is a set of statements in words. And argumentation is another class of objects made up of a set of proposition objects and a set of rules.

Let's start with a simple example.

Example 1:

"① All mammals are warm-blooded animals. ② No lizards are warm-blooded animals. ③ Therefore all lizards are nonmammals." *[2]

It is obvious to see that this passage is a simple argument. From the perspective of traditional logic, it consists of three propositions, with proposition ①, ② as evidences, and proposition ③ as conclusions. With the method of diagramming which is commonly used in logic, it's graphically to represent the structure of an argument, and display the flow of evidences and conclusions in a chart or picture. Figure 2 is a logical diagram of Example 1:

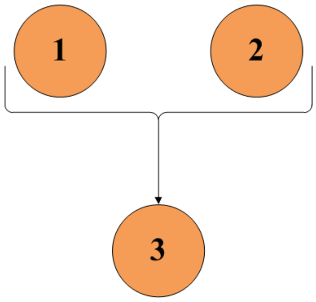

Figure 2: Logical diagram of Example 1.

If switching to an object-oriented perspective, the sentences in Example 1 are three instances of proposition objects, and the entire paragraph is a complete instance of argument object. Moreover, the instances of these three proposition objects also play the role of evidence and conclusion in the instance of the argument object. In other words, they are the attributes named "evidence" and "conclusion" in the instance of the argument object. The diagram of such an object model (Figure 3) has many similarities to the logical diagram.

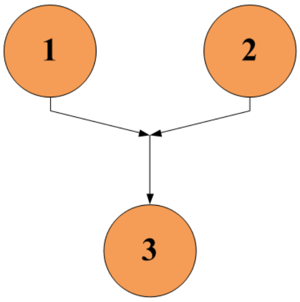

Figure 3: Argument model diagram of Example 1.

Obviously, this is a very simple information model, which contains the core, and most naive logical relationship, the relationship between propositions and arguments. A complete argument contains a set of propositions, and an argument is a process that combines a set of propositions. This process involves at least two propositions, one of which is defined as a "**conclusion**" and the other or several of which are defined as "**evidences**" or "**premises**." These propositions of premises support for the proposition of conclusion. Such a simple object model can be called "**Naive Argument-Proposition Model**", or a simple "**Argument Unit**".

[2] This paragraph comes from *Introduction to Logic*, Fourteenth Edition. Copi, I.M. Cohen, C. McMahon, K., 2013, Page 257.

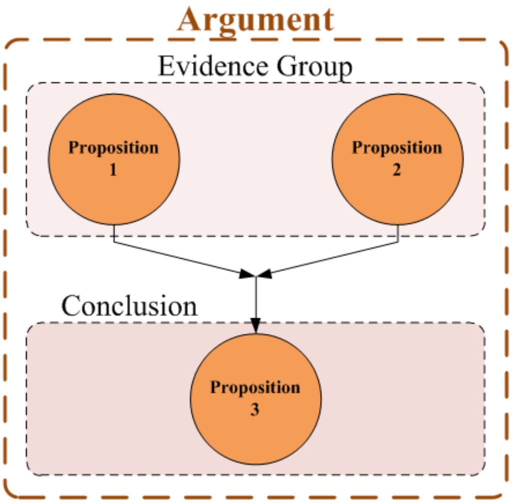

Figure 4: Diagram of naive argument-proposition model.

2.1.3 Complex Argument-Proposition Model

A diagram of a naive argument-proposition model is clearly shown in Figure 4.

The object content of an argument-proposition model reflects a simple argument, which could be something like "the cell phone automatically shuts down because its battery is exhausted", or "the earth rotates on its axis, so the day and night cycle occurs on the earth." However, if you want to express a complex argument, the argument-proposition model needs to be superimposed. Here are some examples to illustrate one by one.

Example 2:

"① Because the greatest mitochondrial variations occurred in African people, ② scientists concluded that they had the longest evolutionary history, ③ indicating a probable African origin for modern humans." *[3]

In Example 2, ①, ② and ③ are three propositions. Proposition ① serves as the evidence of proposition ②, and proposition ② serves as the conclusion of proposition ①. Meanwhile, proposition ② serves as the evidence of proposition ③, and proposition ③ serves as the conclusion of proposition ②. Among them, proposition ② serves both as the conclusion of proposition ① and as the evidence of proposition ③.

[3] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 44.

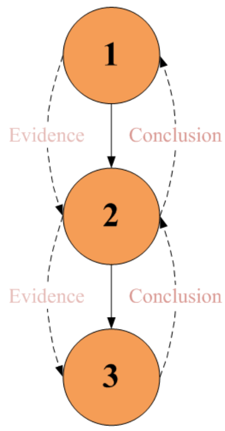

Figure 5: Argument model diagram of Example 2.

Example 3:

"① An outstanding advantage of nuclear over fossil fuel energy is how easy it is to deal with the waste it produces. ② Burning fossil fuels produces 27,000 million tons of carbon dioxide yearly, enough to make, if solidified, a mountain nearly one mile high with a base twelve miles in circumference. ③ The same quantity of energy produced from nuclear fission reactions would generate two million times less waste, and it would occupy a sixteen-meter cube. ④ All of the high-level waste produced in a year from a nuclear power station would occupy a space about a cubic meter in size and would fit safely in a concrete pit." *[4]

In Example 3, ①, ②, ③ and ④ are four propositions. Proposition ②, ③, and ④ serve as evidences of propositions ①, and proposition ① serves as the conclusion of propositions ②, ③, and ④.

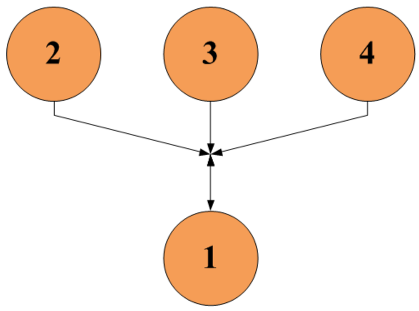

Figure 6: Argument model diagram of Example 3.

Example 4:

"① The Big Bang theory is crumbling .... ② According to orthodox wisdom, the cosmos began with the Big Bang-an immense, perfectly symmetrical explosion 20 billion years ago. ③ (The problem is that) astronomers have confirmed by observation the existence of huge conglomerations of galaxies that are simply too big to have been formed in a mere 20 billion years .... ④ (Studies based on new data collected by satellite, and backed up by earlier ground surveys, show that) galaxies are clustered into vast ribbons that stretch billions of light years, ⑤ and are separated by voids hundreds of millions of light years across. ⑥ Galaxies are observed to travel at only a small fraction of the speed of light. ⑦ Mathematics shows that such large clumps

[4] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 47, 48.

of matter must have taken at least one hundred billion years to come together -- five times as long as the time since the hypothetical Big Bang." *[5]

In Example 4, the interrelationship between propositions is a little more complicated than in the previous examples. Proposition ④, ⑤ and ⑥ serve as evidences to provide support for proposition ⑦, "the great length of time that would have had to elapse since the Big Bang". Then, this proposition is used to support proposition ③ as sub-conclusion, that "structures as large as those now seen are too large to have been formed in that period of time". And from that sub-conclusion ③, combined with proposition ②, a short statement of the original symmetry and spread that the Big Bang theory supposes, which serve as evidences jointly, we infer the final conclusion of the passage, that is ① "the Big Bang theory is crumbling " -- the proposition with which the passage begins.

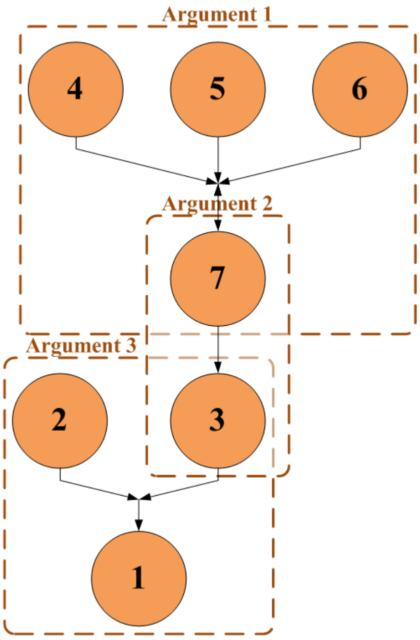

Figure 7: Argument model diagram of Example 4.

In Example 4, there are several propositions as evidences, providing support for a propositional conclusion. There is also one proposition, both as the conclusion of a proposition and as the evidence of a different propositional conclusion. Such a situation is very common in complex argumentative paragraphs.

A complex argumentative paragraph can be a paragraph of two or three hundred words, or a text carrier consisting of hundreds or thousands of words. Usually, an academic paper has tens of thousands of words; and an academic book has no less than three or four hundred pages, with hundreds of thousands or even millions of words. *[6] The number of arguments that exist in the argumentative paragraph of this level should normally also be measured in at least tens of thousands. Not to mention in every academic field, there will be a lot of books, papers, articles, etc. There will be a lot of cross-references between them, the most intuitional example is that all kinds of professional magazine articles and journal papers will indicate the citation sources of part content, with the views or factual statements in other people's articles as their evidence, to support

[5] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 52.
[6] For example, the book *Introduction to Logic* (13th Edition, The Chinese Version) has 753 pages and about 751,000 words.

some own viewpoints in the articles. In addition, most academic books include references at the end of the book. The essence of these forms is a kind of crossed information network composed of argument and proposition units, which come from the argumentative paragraphs, interrelated with each other.

2.2 Definition & Narration

Propositions express what they conclude by statements. And linguistically, there are many forms of statements, each of which plays a slightly different role in argumentation. In order to improve the rationality of the model, we add two types of objects associated with propositional statement, which are named as "definition" statement and "narration" statement.

2.2.1 Definition

To clarify what definition here refers to, as well as the relationship between definition and proposition, we must start with concept. "Concept" is another important research object in traditional logic. Generally, concept is regarded as the minimum unit in logical thinking, and it is a thinking form that refers to and reflects the characteristic attributes of things. The external expression of concept is mainly words, namely the words and phrases in the form of language, such as "light", "mathematics", "artificial intelligence", "chess", etc. Concept is generalization and mapping of external specific objects in the internal thinking, and words refer to these objects as their "signs" or "labels".

In logic, concept is considered to have two features: "denotation" and "connotation". The specific objects referred to by concepts are called the denotations of concepts, while the connotations of concepts are the characteristic attributes of the objects they refer to. If denotation reflects the "quantity" of things and answers the question of "which", then connotation reflects the "quality" of things and answers the question of "what".

There are many logical methods to make a concept clear, especially to reveal its connotation. "**Definition**" is the most basic one. Definition is considered to describe or illustrate a particular term with a set of symbols or symbol strings. This is a very intuitional expression. The particular term is the expression in words of the concept to be defined, it is called "**definiendum**" in definition, and the set of symbols or symbol strings used to describe it is called "**definiens**". For example, "'motor car' is 'the vehicle driven by the movement of machine that can be driven on the road'", this sentence can be used as a definition of the concept of "motor car", while "the vehicle driven by the movement of machine that can be driven on the road" is the expression of its connotation.

The fundamental method of definition is "**stipulative definition**", that is, the definition of "directly assigning meaning to some symbol". This is a way in which anyone can operate, anyone can introduce new symbols or words and have the freedom to specify or assign to it with any meaning which (s)he is concerned about. For example, in astrophysics, the concept "black hole" was introduced to refer to "the star whose gravitational collapse makes rapid substances not escape its gravitational grip". The way of definition is extremely similar to the act of assigning values to variables in computer languages. In fact, strictly speaking, the act of assigning values to variables is essentially a kind of defining act.

Definition plays a very important role in scientific theory. At present, the most widely applied definition method in the academia is "definition by genus and difference", that is, the definition method which uses the genus term that determines the designated range of the definiendum, with the "specific difference" description of the characteristic attributes of the referent object of the definiendum relative to other species in the same genus. The expression can be simply described as "**definiendum = specific difference + genus term**", such as "equilateral triangle", "quantum computer", "neural networks based on deep learning", etc.

Meanwhile, many rules and restrictions have been put forward for definition in various systems of logic, which can be summarized as follows: "a definition must be neither too broad nor too narrow", "the definiens must not include the definiendum directly or indirectly", "a definition must be clear, and must not be expressed in ambiguous, obscure or figurative language", "a definition should not be negative when it can be affirmative", etc.

However, not all concepts can be defined by genus and difference, and definition is not exclusive to scientific research. Definition also plays an important role in daily thinking. When people need to identify or describe unknown daily things, they tend to make the denotation of the involved concept clear by defining the connotation of the concept. At this point, limited by the different knowledge levels, it is difficult to ensure that everyone can use the scientific methods to make definitions. But using some specific words in one's own cognition to define is something that everyone can do. Such specific words may have no general learning background, may be derived entirely from the preferences of the definition originator, and may not even be any character in current languages. For example, before primitive humans could use any modern language, they could use their body language, hieroglyphics, frescoes and other ways to describe the animals, plants and various natural phenomena they saw. This is a kind of original behavior of definition. At such time, any scientific definition methods or rules are meaningless. Therefore, the most basic way of definition is still stipulative definition, and all other definition methods and rules are based on stipulative definition.

In essence, definition is the act of associating definiendum with definiens that is considered to be intrinsically related. This act is usually to connect definiens to definiendum by some specific words, such as "is (be)" in the sentence "bird is a kind of warm-blooded vertebrate with feathers" (Example 5). This is called "**connective of definition**" in most systems of logic. There are also some other similar words, including "can be seen as", "be called as", "regard ... as ...", "define ... as ...", and so on. It is easy to see through these words that the statements constituted by their connection have the nature of asserting something. Because they themselves are also typical connectives for propositional statement.

It is difficult to say that Example 5 is just a definition and not a proposition, or just a proposition and not a definition. In fact, the statements of some definitions have the nature of definition and proposition, or it can be said that definition itself is an act performed in a form that conforms to propositional statement. In terms of performance, we can use definitions as the equivalent of propositions in arguments in logical information model, that is, definition statement has the same effect as propositional statement in argument. Thus, definition also plays a very important role in logical reasoning, which is no less useful than proposition. This is beyond doubt, as can be seen from various examples.

Example 6:

"How should we define the word 'planet'? ① Planets are simply bodies in orbit around the sun and that there are nine planets in the solar system -- of which the smallest is Pluto, made of unusual stuff, with an unusual orbit, and most distant from the sun. ② But other bodies, larger than Pluto and oddly shaped, have been recently discovered orbiting the sun. Are they also planets? Why not? ③ Older definitions had become conceptually inadequate. ④ An intense controversy within the International Astronomical Union (IAU), still not fully resolved, has recently resulted in a new definition of 'planet' .... ⑤ Needed were definitions that would accommodate new discoveries as well as old, while maintaining a consistent and fully intelligible account of the entire system. ⑥ Such definitions were adopted by the IAU in 2006. A planet is a celestial body that, within the Solar System, (1) is in orbit around the Sun; and (2) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape; and (3) has cleared the neighborhood around its orbit. In a system other than our solar system, the new definition requires that the body (1) be in orbit around a star or stellar remnant; and (2) have a mass below the limiting mass for thermonuclear fusion of deuterium; and (3) be above the minimum mass/size requirement for planetary status in the solar system." *[7]

In Example 6, ① is the old definition of "planet". It together with proposition ② serve as evidences, and they together with proposition ③, which serves as the conclusion, constitute a complete argument. In this argument, a definition plays the role of evidence. That is, the old definition of "planet", and the discovery of celestial bodies that don't fit the definition, jointly provide support for the perspective that the traditional definition is flawed.

Definition can serve not only as evidence in argument, but also as conclusion. Also in Example 6, "the traditional definition of 'planet' is flawed" as stated in proposition ③, combined with the improvement requirement of the planet definition in proposition ⑤, i.e. "accommodate new discoveries as well as old", jointly support the new planet definition, which is elaborated as ⑥. These statements also constitute a complete argument in which definition plays the role of conclusion.

It's actually quite common for definition to play an important role in argument, especially in the study of science and philosophy. Because science and philosophy are always in the forefront of the times, there are always more opportunities to touch the unknown concepts in these domains. At this time, it is necessary to seek definitions for new concepts, which is precise and rigorous enough to help to form a theoretical system in the study. Therefore, in scientific academic arguments, definition is a very important component. Similarly, definition is also indispensable for the argument-proposition model.

[7] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 88, 89.

2.2.2 Narration

Definition statement is a statement with the nature of asserting, so it can be applied in argument. Since the denotation of statement is very large, the forms of statement with the nature of asserting are not only definition statement.

Definition statement has its typical feature, that is, its connectives of definition are limited and rare, which makes it easy to identify the form of definition statement. However, not all statements that contain connectives of definition are definition statements. For example: "Galileo was on the first time to see the mountains and valleys on the moon with his homemade telescope" (Example 7). Obviously, the "was" here is not used as the connective of definition to define the word "Galileo", but rather to highlight such a thing that "Galileo used his homemade telescope to see the mountains and valleys on the moon for the first time".

Such a statement has an obvious nature of asserting, but it also narrates a "fact", or rather "objective phenomenon." This fact carries a certain amount of information, such as "Galileo", "telescope", "homemade", "see ... on the moon", "first time", etc., as well as the information conveyed by their combination. Such a fact statement is different from a definition statement. Definition mainly reflects the subjective understanding, which is a reflection of individual's cognition of objective things (namely concepts). However, fact is the presentation of objective things, and description of what happens or exists outside the subjective world.

It is worth noting that a statement of fact is not directly equivalent to the fact itself, and sometimes it may be a statement completely contrary to the fact. Just like the deeds of Galileo mentioned in Example 7 were not necessarily true. According to records, Galileo Galilei was not the first person to observe the moon through a telescope and depict its surface. A few months before Galileo turned his homemade telescope, magnified 20 times, towards the moon, the British astronomer Thomas Harriot had pointed a 6-magnification telescope at the moon, and drawn the first map of moon surface observed through the telescope on July 26, 1609. However, it was just relatively brief and didn't show much detail.

For some other examples, in court, the suspect can plead that (s)he did not break the law. In business competition, the competitors can accuse each other of stealing their ideas, or poaching their clients, and so on. The speech sentences of these pleas or accusations all belong to this kind of fact statement, but they all stand on their own point of view only, and narrate the "facts" accepted by themselves. If the contents that they described contradict each other, it is almost certain that at least one of the two opposing sides does not tell the truth.

Since this "fact" statement is not that "fact," in the model, we will replace the ambiguous word "fact" with the more neutral word "narration".

"Narration statement" is another important form of statement with the nature of asserting besides definition. Thus, narration, just like definition, also can serve not only as evidence in argument, but also as conclusion. For instance, ③"older definitions had become conceptually inadequate" in Example 6 is a narration statement. It is both the conclusion of the previous half argument, and the evidence of the latter half. Similarly, the evidences and conclusions in Example 2, 3, and 4 are all narration statements.

It can also be seen from the above examples that the expression form of narration is diverse, and is not like definition which is limited to the formalization of connective of definition. Therefore, narration statement can play a more important role in argument than definition.

Definition and narration, which are different but complementary to each other, collectively constitute the components of propositional statement. They are, so to speak, two types of statement with obvious features, both of which are subsets of propositional statement. In this way, the objects of definition and narration can be naturally added to the argument-proposition model as subclass objects of propositional statement.

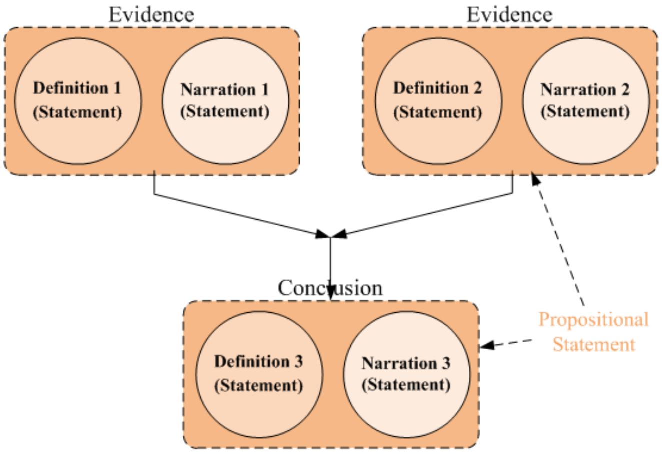

Figure 8: Diagram of argument-proposition model after adding definition and narration.

2.3 Truth-Value of Proposition & Validity of Argument

2.3.1 Truth-Value of Proposition

The thinking form corresponding to proposition is "**judgment**". Proposition states things through statement, and judgment reflects that the thinking subject has judged something and gets result. The result can be affirmative or negative, or even uncertain or unknowable. This involves the most important element associated with proposition and judgment **--** "**truth-value**". True-value is just the result given after judgment. We can use an object called "truth-value" in the model to reflect the effect of judgment.

In logic, it is usually believed that each proposition is true or false, so the corresponding truth-value connotation is "true" or "false". What it means is that the proposition associated with it is a true proposition or a false proposition. For example: "the sun rises in the east and sets in the west every day", this proposition is a true proposition for us. And "human can fly directly in the air without the aid of other tools" is obviously a false proposition at a glance. The system of logic in which truth-value is expressed by "truth or false" is classified as "**two-valued logic**" in logic.

However, the truth-value of some propositions cannot be completely determined due to the limitation of observation conditions. For example: "the solar system was born 4.6 billion years ago", or "the sun will die in about 5 billion years". Since this is too far away from the distant past or future, it exceeds human's current capability of direct verification. After all, the duration of human history since recorded is generally considered to be only a few tens of thousands of years, so it is difficult to get absolutely real observations about it.

How to view the truth-value of such propositions? There are some differences between traditional logic and modern logic on this point. Most views in traditional logic believe that the truth-value of such propositions is temporarily unknown, but it must be true or false, just has not reached the point of perception in current situation. However, in modern logic, a new branch of mathematical logic, which is different from two-valued logic -- "**many-valued logic**", holds that the truth-value of proposition can have other values besides being true or false.

Many-valued logic is the combination of a series of systems of logic. In particular, three-valued logic and infinite-valued logic are the most representative ones. These systems of logic are relative to two-valued logic, whose meanings lie in the explanations for the truth-values other than "true or false" from their respective systems, and the declarations of different philosophy views of logic. Both the "true and false" in two-valued logic, and the truth-values other than "true and false" in many-valued logic, can be used as the connotation of the "truth-value" object in our model.

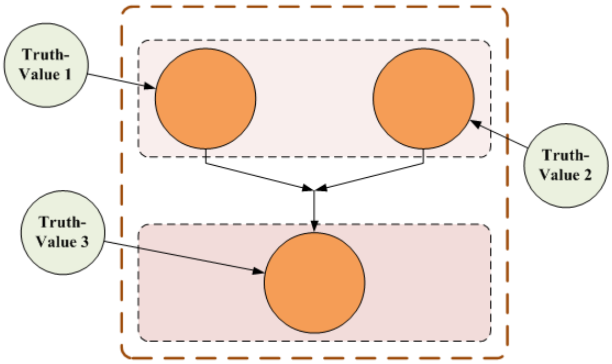

Figure 9: Diagram of argument-proposition model after adding truth-value of proposition.

2.3.2 (Special) Validity of Argument

Truth value is an attribute of a single proposition, while for a set of propositions, especially one that can form an argument, "**validity**" is a feature used to define the relationship between them. Therefore, it is also necessary to use an object called "validity" to reflect this attribute of argument in the model.

The validity of an argument, i.e. determining whether an argument is "valid" or "invalid," depends on the relationship between its evidences and conclusion, and not directly on the truth-values of the propositions it contains. In the existing systems of logic, there can be valid arguments whose conclusions and one or more evidences are false, and there also can be invalid arguments whose conclusions and all evidences are true. In other words, there is basically no absolute final conclusion about the relationship between the validity of argument and all combinations of true and false evidences and conclusions.

In fact, not only the relationship between validity and true or false evidences and conclusions is difficult to measure strictly, but also the value of validity itself is not just defined distinctly as "either valid, or invalid, only". Traditional logic divides argumentation into two categories, **deductive argument** and **inductive argument**, according to the degree of evidences' support for conclusion in an argument. An argument is a deductive argument when its evidences are asserted to support its conclusion decisively. That is, a deductive argument is the one that can be clearly judged that it is valid or invalid. In contrast, inductive arguments are those arguments that cannot make it clear whether their evidences support the conclusions. Thus, the validity of inductive argument cannot be expressed as "valid" or "invalid". In general, inductive arguments may be said to be "better" or "worse", "weaker" or "stronger", and so on.

Both the "valid or invalid" of deductive arguments and the validity values without complete confirmation of inductive arguments can be regarded as the connotation of the "validity" object in the model.

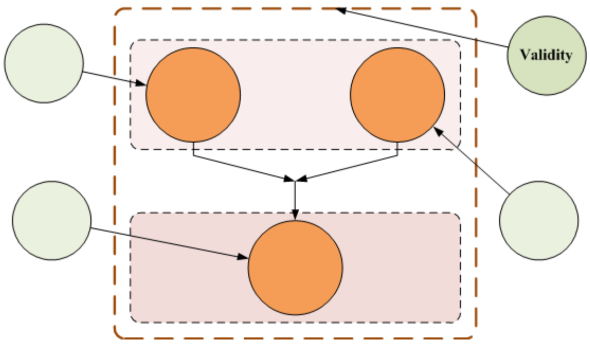

Figure 10: Diagram of argument-proposition model after adding validity of argument.

2.4 Condition

2.4.1 Condition of Proposition

i.

Each proposition can have its corresponding truth-value, no matter whether it is true, false or meaningless. However, it is not real that the truth-value of every proposition is definitely unique, or invariable in any case.

For example: "Pluto is a planet in the solar system." This proposition would have a completely different truth-value if it had been proposed in different years, such as around 1930 or around 2005. Before 1930, this proposition is meaningless, since the celestial body had not been discovered yet and the noun "Pluto" was not used by the public in connection with "planet". From 1930 till 2005, this proposition became true as Pluto was discovered and named by humans. Since 2005, however, this proposition has become false with Pluto's demotion to dwarf planet. There is, of course, the possibility that the truth-value of this proposition will be turned to true again, once Pluto is reclassified as a planet in the future. It can be seen that the truth-value of this proposition should be classified as "uncertain about true or false" without any time context applied. That means it could be true or could be false. How to get an exact value, depends on the time that the proposition is proposed. The time when a proposition is proposed, in this case, is a **condition** of the proposition.

Each proposition, more or less, may have some conditions that become a factor affecting its truth-value. For example: "A total solar eclipse is underway, you can see this spectacular view as long as you look up." In this proposition, the location is a condition that affects its truth-value. As we all know, when an eclipse occurs, it's only possible to see it if you're in daylight. People in the black night on the other side of the earth, cannot directly observe the solar eclipse. For another example: "When the water in a vessel is heated up to 100 ℃ and reach the boiling point, it will turn into steam." In this example, the altitude or atmospheric pressure is one of the truth-value conditions of the proposition. After all, countless experiences have shown that atmospheric pressure varies at different altitudes, and different atmospheric pressure affects the boiling point of water.

Of course, the time, place and other conditions of a proposition do not only refer to the time and place when the proposition is proposed. In themselves, propositions also carry similar relevant information, which can be combined with external conditions to affect the connotation of propositions. For example: "A rainbow appeared on the sky after the rain, and it could be seen anywhere in this city." The explicit location information appears in the proposition statement, which is also a condition that can affect the truth-value of the proposition.

Both the conditional content appears explicitly in proposition and the conditional information implied outside the proposition statement, we can map them to the corresponding conditional objects in the model, and establish the relationship with proposition objects.

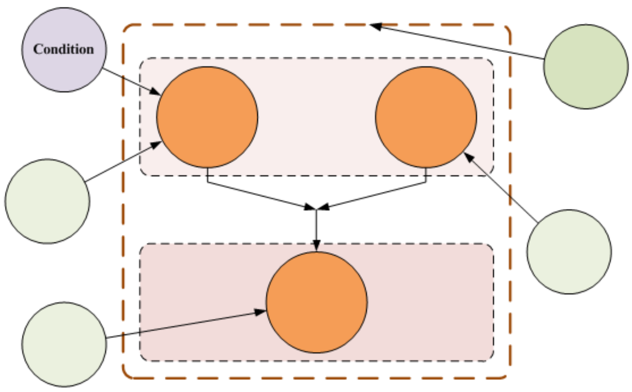

Figure 11: Diagram of argument-proposition model after adding condition of proposition.

ii.

It will bring different connotations in categorical propositions with different quantifiers. For example, "all whales are mammals" and "some whales are mammals" convey fundamentally different meanings.

According to different quantifiers, traditional logic divides propositions into three categories: singular, particular and universal, which can be distinguished by quantifiers such as "the one", "some" and "all". In mathematical logic, the objects of singular propositions can be regarded as all objects in the class containing only the unique object, that is, singular proposition can also be classified into universal proposition. In terms of expression, singular objects often use proper nouns, singular pronouns and so on as subject term, and the quantifiers of them are concealed. So mathematical logic retains only the universal and existential (namely particular) quantifiers, which are respectively indicated by the symbols "$\forall$" and "$\exists$". Their meanings can be respectively understood as those corresponding quantifiers, such as "all ...", "any ...", "for everything ...", and "there is ...", "exist ...", "at least one ...” etc., used to qualify subject terms.

Both the quantifiers in natural languages and the corresponding symbols in artificial languages, all limit the scope of the subject terms that appear in propositions. Therefore, they can be seen as scope conditions in propositions, and directly affect the truth-value of propositions.

iii.

Besides the categorical propositions in the above examples, there is a class of compound propositions in all types of propositions, which has the condition that affects its own assertion. That is **hypothetical** (or **conditional**) **proposition**, also called **implication** in symbolic logic.

As we all know, hypothetical propositions usually exist in the form of "if ..., then ...". It contains at least two component propositions. The proposition after "if" (also known as antecedent) represents a hypothesis that exists as a hypothetical condition for the proposition after "then" (also known as consequent). The hypothetical proposition itself does not conclude whether its component propositions are true or false. It only asserts that the truth-value of the consequent will be true, if the antecedent is satisfied, that is, the antecedent is true. Just like "If ① a piece of blue litmus paper is placed in acid solution, then ② the paper will turn red". In this proposition, component ① provides hypothetical condition for component ②. Component ② is implemented when component ① is satisfied.

iv.

Time, place, and other factors, each of which can be a single condition of a proposition. Meanwhile, multiple single conditions are imposed on a proposition in different forms, and then they can be seen to become a group of compound conditions, which jointly affect the truth-value of the proposition. Here are three propositions for example:

Example 8:

① "The total amount of domestic oil consumption in this year has increased 10% from last year."

② "If oil consumption continues to increase, the domestic oil reserves will be exhausted in 50 years."

③ "If the growth momentum of the oil consumption remains, even if the oil imports are doubled, it will not change the trend of depletion of domestic oil reserves."

Among them, the single conditions in proposition ①, such as "in this year", "from last year" and "domestic", form the compound condition of "the total amount of ... oil consumption ... has increased 10% ...". In proposition ②, the antecedent "oil consumption continues to increase" and the time condition "in 50 years", jointly serve as the compound condition of "oil reserves will be exhausted". And in proposition ③, "the growth momentum of the oil consumption remains" and "the oil imports are doubled" serve as the antecedent of hypothetical proposition, providing conditions for the truth-value of the sentence that "not change the trend of depletion of domestic oil reserves".

It can be seen from the above examples that whether a single condition, a compound condition formed by a combination of multiple single conditions, or an antecedent of hypothetical proposition can all be used as conditions that affect the truth-value of proposition.

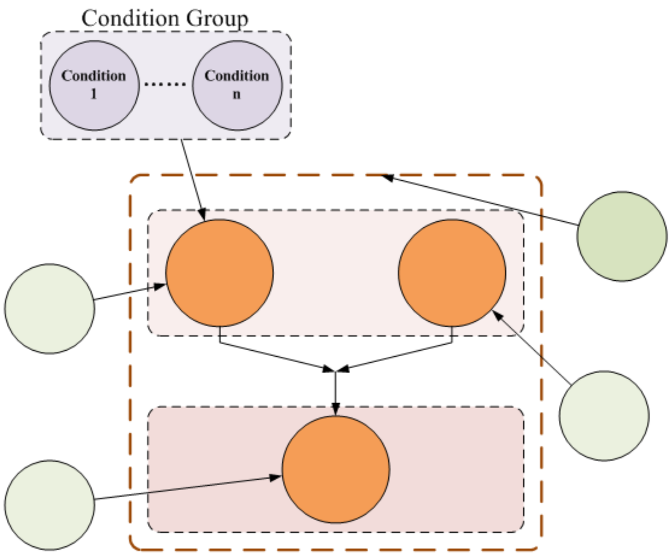

Figure 12: Diagram of argument-proposition model after adding compound condition of proposition.

2.4.2 Condition of Argument

i.

Proposition can have conditions that affect its truth-value, just as argument can have conditions that affect its validity.

When a proposition is used as an evidence or conclusion in an argument, a single condition of this proposition, or a compound condition composed by several single conditions, may also be used as a condition of the argument in which it is presented, no matter whether it is explicit or implicit.

For example: "① No one was present when life first appeared on earth. Therefore ② any statement about life's origins should be considered as theory, not fact." *[8]

"On earth" is the location condition of the evidence proposition ①, it also implicitly affects the conclusion proposition ② of the argument, and the validity of the whole argument.

Another example: "① Over the past hundred years, the rate of species extinction under human intervention has been 1000 times faster than the natural rate. ② At this rate, we are likely to lose 50% to 75% of earth species in this century."

"Over the past hundred years" is the time condition of the evidence proposition ①, and "in this century" is the time condition of the conclusion proposition ②. In addition, they also affect the validity of the argument. Furthermore, although "under human intervention" is a modifier of "species extinction" in proposition ①, it also plays a restrictive role on the whole argument, and is a restrictive condition of the argument.

ii.

The scope conditions that universal and particular quantifiers bring to propositions, can also be important conditions in the arguments to which they belong.

Example 9:

① "All mammals have lungs. All whales are mammals. Therefore all whales have lungs."

② "All soldiers who want to be generals are not cowards. Some soldiers are cowards. Therefore some soldiers don't want to be generals."

③ "All visible light is electromagnetic wave. No sound wave is electromagnetic wave. Therefore no sound wave is visible light."

These are typical examples of **categorical syllogism**. All syllogisms consist of three propositions, which serve as evidences and conclusion in the argument. All three propositions of categorical syllogism contain universal or particular quantifiers and belong to the category of universal or particular propositions. "All" in argument ①, "all" and "some" in argument ②, and "all" and "no" in argument ③ are the scope conditions of the propositions in their arguments, and also the scope conditions of these syllogistic arguments. Thus, it is not difficult to see that all universal and particular quantifiers in categorical syllogisms can be used as the scope conditions of the syllogistic arguments.

iii.

Categorical propositions constitute categorical syllogism, and hypothetical propositions constitute **hypothetical syllogism**. In both pure and mixed hypothetical syllogisms, the hypothetical proposition antecedents can be the hypothetical conditions of the whole argument.

Example 10:

[8] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 6, which appears on a sticker affixed to biology textbooks in the state of Alabama, U.S.

"① If the first soldier tells the truth, then this is the gate of life. ② If this is the gate of life, then the other gate is the gate of death. Therefore, if the first soldier tells the truth, then the other gate is the gate of death."

"③ If the second soldier tells the truth, then this is the gate of life. The second soldier tells the truth. Therefore, this is the gate of life."

In the two sets of hypothetical syllogisms in Example 10, ① "if the first soldier tells the truth", ② "if this is the gate of life", and ③ "if the second soldier tells the truth" respectively serve as the hypothetical conditions in these arguments.

iv.

A complete argument is made up of a set of evidences and a conclusion. Evidences are generally considered to be equivalent to the word "premises". They are called premises because they support the soundness of conclusion. Conclusion is the core of argument, and evidence is the basis for supporting this conclusion, and the prerequisite for reaching the conclusion's validity, that is, the premise condition (namely precondition) of the conclusion's validity.

"**Because (evidence) <proposition ②>, <proposition ③> ..., so (conclusion) <proposition ①>.**" In general, all arguments can be taken or transformed into such a form like this. This is a typical way of expressing an argument. If we put it in a different way, it could be "**Based on the argument <proposition ②>, <proposition ③> ..., it will conclude <proposition ①>.**" This is a lossless conversion, and it also shows how evidence supports conclusion.

v.

Sometimes, due to the diversity of language expression and the environment in which it is expressed, there are some implicit conditions in an argument. Implicit conditions may exist in the statements of context. For example, in Example 10, the former argument might imply the condition ④ : "There are two gates, one for life and one for death." It determines the truth-value of hypothetical proposition ②, and it must come from the preceding text of the source where the argument comes from.

Implicit conditions can be single conditions or compound conditions. It can be one or several different types of conditions, such as scope conditions, hypothetical conditions, premise conditions, etc. For example, the implicit condition ④ in Example 10 is a single premise condition.

From a linguistic point of view, if all the "all"s in Example 9 are omitted, it does not affect the connotation of the argument or the fluency of the statement. "All mammals have lungs" and "mammals have lungs" seem to be equivalent. If having got this point, it is not difficult to understand another matching meaning that the scope condition "all" is implied in both of the arguments after all the "all"s are omitted.

Example 11:

"If the opponent of the death penalty is incorrect in his belief that the death penalty doesn't deter (homicide), he is responsible for the murder of innocent individuals who would not have been murdered if the death penalty had been invoked." *[9]

In addition to the premise that "if the opponent of the death penalty is incorrect in his belief that the death penalty doesn't deter (homicide)", there could also be an unstated premise supporting the conclusion of the argument in Example 11, that is, "Protecting the lives of innocent individuals from murder justifies the execution of murderers if other murderers are then deterred by the fear of execution." Based on these premise conditions, it is concluded that those who believe that the death penalty does not deter murderers are responsible for the lives of innocents who are subsequently murdered.

Example 12:

"Love looks not with the eyes, but with the mind; And therefore is wing'd Cupid painted blind." *[10]

In this example, it can be understood that the argument implies the hypothetical condition "if there is a wing'd Cupid", the premise conditions "Cupid is a symbol (or synonymous) of love" and "blindness is to see with the mind rather than with the eyes".

Taken together in this section, conditions of an argument could be a combination of one or more of all the conditions in all the propositions that make it up. They work together on the connotation of predicate term in the conclusion of the argument, and become the context that affects the validity of the whole argument.

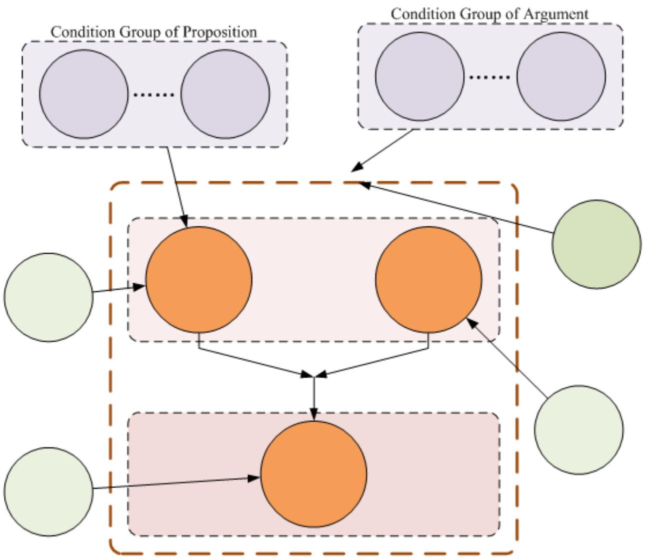

Figure 13: Diagram of argument-proposition model after adding condition of argument.

[9] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 16, which originates from one of the two strong but controversial arguments, in parallel, regarding the justifiability of the death penalty, presented by the chair of the Department of Sociology at City College, CUNY.

[10] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 22, which originates from *A Midsummer Night's Dream*, Shakespeare, W., act 1, scene 1.

2.5 Reconsider Concept

2.5.1 Concept & Definition

We have already mentioned "**concept**" in the previous sections in this chapter. At that time, there was no in-depth elaboration (of the objects directly related to it in the model), just in order to lead to the associated "definition" through "concept".

Definition is not only a statement form to clarify the concept connotation, but also a method to clarify the concept connotation. Its standard statement form is composed of words whose roles are definiens, definiendum and connective of definition respectively. In essence, definition is an act of pairing a set of definiens and definiendum, and setting up a certain degree of equivalence between their connotations.

The connotation of concept is the impression of a particular object (or a class of objects) produced in internal thinking activities. As a language form used to describe this particular object (or a class of objects), concrete words correspond to abstract concepts. Therefore, in definition statement, the two sets of words, definiens and definiendum, which are separated by connective of definition, must have their corresponding concepts. In other words, definiendum is a concept to be clarified, and the equivalent definiens also belongs to the category of concept.

Definiens and definiendum can be a single concept, respectively, or a combination of several concepts.

Example 13:

① "Lion is a (kind of) Felidae animal."

② "Lu Xun was a litterateur."

③ "A motor vehicle is a vehicle driven on the road and powered by the movement of machines."

④ "The first requirement for a planet in a celestial system is to orbit a star or stellar debris."

In definitions ① and ②, "lion", "Felidae animal", "Lu Xun" and "litterateur" are all independent concepts. In definition ③, "motor vehicle" is an independent concept, and "vehicle driven on the road and powered by the movement of machines" is a combination of concepts. And in definition ④, "the first requirement for a planet" and "to orbit a star or stellar debris" are both combinations of concepts.

In fact, in many scenarios, the definiendum and definiens of definition statement often appear inconsistent in the denotation. For example, in definitions ① and ② of Example 13, the denotation of "lion" is smaller than that of "Felidae animal". And "Lu Xun" is singular, the denotation of "litterateur" is naturally larger than its.

It is not difficult to see that the denotation of definiendum is usually smaller than that of definiens. This is actually easy to understand. The connotation of a concept is regularly multi-level and multifaceted, and it is difficult to summarize it completely in a few words. For example, the connotation of the concept "human" is very rich, and there are many definition statements describing its connotation. Some people say that human is "an animal that can walk upright and cannot fly", others say that it is "an animal that can think and speak", or "an animal that can make and use tools". These statements fit the connotation of "human", but they are not comprehensive enough to cover all the connotations. It should be said that each sentence only expounds the local features in the connotation of "human", that is, the partial attributes of "human". Take "human is an animal that can walk upright and cannot fly" for example, which is actually defining the ability of walking and flying in the attributes of "human". In other words, "human is an animal with walking ability and no flying ability".

Similar to proposition and argument, concept can also have conditions. Moreover, we can see that in those combinations of concepts, basically some concepts exist as attributes or conditions of other concepts. For example, "human is an animal of XXX", and those "XXX" are attributes of "human", which are also used to be conditions of limiting "animal". Another example, in definition ③ of Example 13, "driven on the road" and "powered by the movement of machines" are conditions of the concept "vehicle". And in the phrase "the first requirement for a planet" in definition ④, "the first requirement" is an attribute of the concept "planet".

Moreover, to a certain extent, condition of a concept can be transformed with a concept. For example, "As a chemical concept, water is a compound of chemical formula H_2O." In this sentence, "as a chemical concept" is the restrictive condition of the definition statement in the second half of the sentence. Without changing its connotation, we can deform it into: "Water in the chemical concept is a compound of chemical formula H_2O." In this form, the definiendum is changed from "water" to "water in the chemical concept".

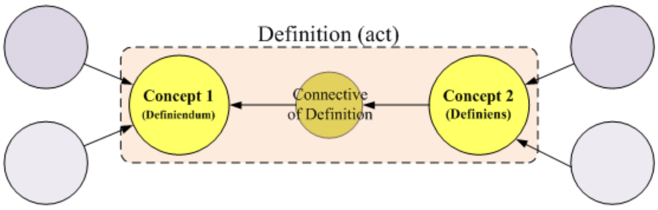

Figure 14: Diagram of concept-definition model.

2.5.2 Concept & Proposition

Compared with "concept", the "proposition" to which the definition statement belongs and the "argument" composed of propositions are the logic concepts which are more common and easier to be understood and accepted. However, argument is composed of propositions, and proposition is composed of concepts.

A propositional statement is composed of a certain amount of words grouped together according to a set of structural forms, which are usually regarded as the grammatical rules of natural language. These words correspond to their own conceptual connotations, and the grammatical rules can be explained in the form of propositional statements. Therefore, in the final analysis, a proposition is formed by a certain amount of concepts.

It is worth noting that in mathematical logic, the concepts in propositions are more commonly called "terms". Because the logic part of mathematical logic is the logic that studies the components of proposition, and the subject and predicate terms in propositional statement are the main objects of its research. The narrow term refers to the words that act as the subject and predicate in categorical proposition. Of course, there is a broader view that terms should also include quantifiers and connectives. However, in our model, we think this view is still too narrow. We tend to regard any word in sentences, including any symbol, as belonging to the category of concept. Actually, there is no contradiction between the two. Term is not equal to concept, and the meaning of term to mathematical logic is also different from that of concept to logical information model. Only the subject and predicate are paid attention to in mathematical logic, because they can be extracted, and then the statement can be symbolized and functionalized, so that the rest of the sentence can be abandoned and the truth-value calculus of proposition can be focused. In this way, it is not easy to be affected by the changeable language habits in natural language on the truth-value of proposition, but simultaneously the potential information in natural language are ignored.

For example, the proposition "Metal conducts electricity." can be formalized as "f(x): x conduct(s) electricity, $x \in$ metal" in the category of mathematical logic. When x is "copper" or "iron" belonging to metal, the corresponding description of function value is "Copper conducts electricity." or "Iron conducts electricity." Of course, we can also use sentences such as "Copper is conductive.", "Iron can conduct electricity." and "Silver has the function of conducting electricity.", which are also suitable to be classified into this formalized function. However, these descriptions are not equivalent from the perspective of the concepts contained therein. "Conduct(s) electricity" is a common concept among the sentences, which is also the core predicate of the formalized function, and the words "is", "can", "have (has)", "function" and so on are their own unique concepts. Perhaps these unique concepts are not enough to affect the convergent meaning of the whole sentences at the predicate logic level, but more information can be conveyed in these various descriptions. Unique words themselves have different conceptual connotations, and different phrases formed by the combination of these words may also contain various hidden information such as language habits, mood, and even context. This is also an important difference between natural language logic and symbolic language logic.

Adding concept object to the argument-proposition model forms the "**Argument-Proposition-Concept Model**". (As shown in Figure 15)

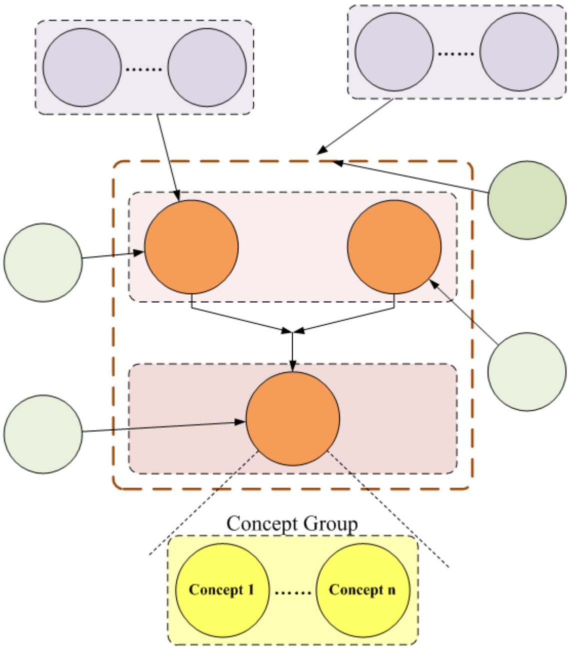

Figure 15: Diagram of argument-proposition-concept model after adding concept.

3. Information Model

The last chapter mainly focuses on some core concepts of logic and constructs the prototype of logical information model. As a logical model of human intelligence that is expected to be used to manage information and represent knowledge, logicality is essential, but it is not all. How to contain and manage information organically while keeping logicality is the key point.

Although according to the standards of most current systems of logic, not all written and linguistic information is "logical", and there are also fallacies and non-assertive statements. However, this does not prevent us from making reasonable expansion on the basis of the argument-proposition-concept model, supplemented by the research methods of information science, so that the model can be more compatible with all information, and the information network built based on this model can better play its role of "**container-ability**".

3.1 Doubt & Explanation

i.

Human beings began to explore in the domain of information science, which is usually regarded as the information theory founded by Shannon, C.E. in the 1940s. What followed was the explosive scientific achievements made in this domain over the next 70 to 80 years, as well as a series of inventions with the greatest influence in human history, such as computer, Internet, mobile phone and so on. If we look back, we can see that these achievements came after the rapid development of natural sciences such as mathematics, physics, electromagnetism and other basic disciplines such as communication technology since the 17th century. So this seems to be a natural thing.

However, the reason why all this happened logically, and the brilliant academic achievements covering natural science, philosophy, literature, art and some other domains in just a few hundred years, is inseparable from the two ideological and cultural movements of the Renaissance and the Enlightenment in Europe since the 14th century. Regardless of the factors of political, religious and cultural in these two ideological movements, the source power that triggered and promoted the dissemination of scientific spirit in the later generations actually came from the spiritual core of positivism and criticism. Positivism, inherited from empiricism, advocates understanding the world from the perspective of observation and experience. Criticism, which criticizes old institutions, old religions, old thoughts and old sciences, criticizes everything that is unreasonable. Positivism and criticism are the foundation of modern positivist science. In fact, their essence is the skeptical thought, or skepticism, that has existed since the ancient Greek period contemporized with Aristotle.

Etymologically, the word "skepsis" that "**skepticism**" is derived from, originally refers to the meaning of "investigation", "inquiry", "examination", and “search" and so on in Ancient Greek. So "skepsis" here is not a word with negative emotions, but refers to doubt and confusion in the general sense. Of course, it is a kind of inquiry activity that seeks the truth unremittingly, a method to achieve knowledge through systematic doubt and constant testing. The process of scientific seeking for truth is from doubting to criticizing, then to recreating and reconstructing, and then this process is repeated continuously. The first of all should be the doubting. The doubting here is not a rhetorical question with emotional color, but a neutral question about what is not understood or unreasonable.

ii.

Doubt is an important tool to explore new knowledge on the road of science. Similarly, doubt also has extraordinary significance for information as the basis of knowledge. Moreover, although it is not a concept in the category of logic, it is also closely related to logic.

In our daily communication, there are not only arguments, propositions and concepts. "**Doubt**" is also one of the most important forms of expression.

First of all, it is a kind of linguistic behavior. When doubt is expressed in natural language or writing, its form is interrogative sentence. Secondly, it is also an internal thinking activity. Anything that is unknown or inconsistent with common sense may arouse our doubts and thinking around them. What is unknown may be a concept or proposition, and what is inconsistent with common sense may also be an argument. Any kind of logical element can be the target object of doubt, such as "Proposition A, is it true?", "Argument B, is it valid? ", "Concept C, what is it?"

If there is a doubt, there may be a corresponding "**explanation**". The results generated after thinking about doubts is the explanations for them in internal thoughts. Doubt comes from the questions about argument, proposition or concept, and usually its corresponding result is the content with the nature of asserting, that is, it is also argument, proposition or concept.

Example 14:

Salviati: "... How far may one go without geometry for a good philosophical exploration of the natural world?"

Sagredo: "... (And it must be admitted that) trying to deal with physical problems without geometry is attempting the impossible." *[11]

In Example 14, the question raised by Salviati is based on a hypothetical sentence expression. And Sagredo's response is a proposition, which is also based on hypothesis without hypothetical modifier. They are not simple arguments, propositions or concepts, but composite forms of transformations and reconstructions of these simple elements.

Moreover, this dialogue is not simply a targeted question and answer, but mixed in a series of complex language interactions. Such expressions are common in daily language communication. It is not difficult to see that, in fact, in ordinary verbal or written communication, in addition to the initiators' active expression, the explanation to doubt is also one of the most important forms that can trigger arguments or propositions.

After adding doubt and explanation, the model structure is shown in Figure 16. It can be seen that in such scenarios, it is possible to link different logical elements together in a form different from the general logical paradigm through doubts.

[11] This dialogue comes from the translations of *Dialogo sopra i due massimi sistemi del mondo, tolemaico e copernicano*, Galileo Galilei, 1632.

Galileo drew on the dialogue between Salviati and Sagredo to discuss the argument about falling velocity, and emphasized the importance of geometry in the study of physics.

It is worth noting that the former sentence comes from the translation of the Chinese version of this book, which is "……如果没有几何学，而要对自然界进行很好的哲学探索，人们究竟能走多远呢？".(*《关于托勒密和哥白尼两大世界体系的对话》*，伽利略 著，周煦良 等译，北京大学出版社，2006 年第 1 版，第 139、141 页。)

There are a few differences with the corresponding original English translation which is: "... Take note, Simplicio, just how far one may go without geometry and philosophize well about nature!" (*Dialogue Concerning the Two Chief World Systems: Ptolemaic & Copernican*, SECOND EDITION., Galileo Galilei, translated by Drake, S., foreword by Einstein, A., 1967, Page 200, 203.)

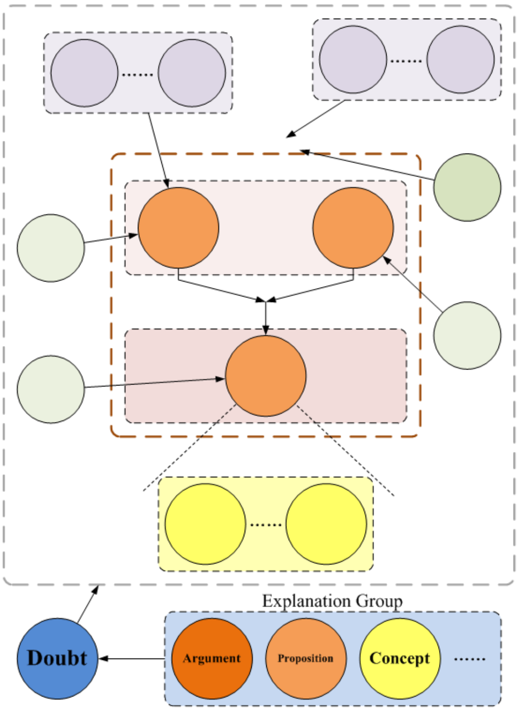

Figure 16: Diagram of argument-proposition-concept model after adding doubt and explanation.

iii.

Doubt is the basis of thinking, comparison and argumentation. As the thinking subject, the doubt generated by the basic information or data received from external objects prompts us to further process and analyze it in our thoughts in order to transform or extract valuable knowledge. Doubt is the basis of criticism, reflection and reform. Through the discovery, raising and research of problems in the past knowledge, we can break the stereotypes, get rid of the wrong mindset in traditional cognition, deny old theories, build new theories and re-establish new phased truths.

Without the ability to doubt, all we would know is the appearance of the world, that is, the information which we feel directly through our five senses of the whole body. Human beings will not understand the habits of birds, animals, plants and fruits, and there would be no animal husbandry and farming. They will not know the characteristics of metal, wood, stone and fire, nor invent and use tools. Productivity will not increase, civilization will not develop, and there will be no high-level intelligence.

When the Renaissance and the Enlightenment led human civilization to stride forward, doubt also played a great role in the development of science. In the 17th century, the doubt about apples falling from trees made Newton I. realize the theory of gravity. In the 18th century, Euler L. pioneered the study of graph theory in order to solve the seven bridges problem of Konigsberg. At the end of the 19th century, the confusions brought by the two famous "dark clouds" over the building of classical physics gave birth to the two new branches of physics, the relativity theory and quantum physics. Almost every achievement in the history of science is to solve a problem, or find an explanation to a doubt.

Similarly, in life, people who are not good at asking questions lack speculative thinking, so they can only be confined to the passively acquired information, and the knowledge structure is relatively rigid. However, those who are good at detecting doubts and raising questions are more likely to dig out the doubts in passive information and the contents hidden beneath the appearance. This is also more conducive to adjust their knowledge structures, improve their shortcomings, and make them sounder and more detailed.

Therefore, for an "intelligent" information model, there needs to be a link of self-thinking and self-analysis, in which doubt and explanation answers are an indispensable part.

3.2 Proposer & Observer

3.2.1 Proposer & Observer

Logic mainly studies the validity of argument, and the composition of proposition, which acts as internal element of argument, such as predicates, quantifiers, connectives and so on. However, little attention has been paid to the value of external entities related to argument. As we have mentioned above, judgment is a form of thinking which reflects that the thinking subject has judged the situation of something. At this point, the same is true for reasoning. This is not only related to the "situation of things", i.e. the statements of corresponding arguments and propositions, but also closely related to the "thinking subject". The "thinking subject" here refers to an individual or an organization, which can also be generalized as an entity. Usually arguments are put forward by such entities. Although these entities are not studied in the domain of logic, it is not difficult to see that these thinking subjects also play a great role in the process of reasoning, if one slightly removes his attention from the propositions and arguments as the research objects.

A proposition or argument that states the same sentence, may express different connotations while it is put forward by different thinking subjects. For example, if proposition ① in Example 8 mentioned above is proposed by a person comes from China, its connotation and truth-value may be completely different from those of the propositions proposed by persons come from Singapore, Southeast Asia, the Middle East, or even Europe and America.

A proposition or argument is presented by an entity. Here we call this entity the "**proposer**" of the argument or proposition, or the "exporter".

However, we should also see that, this is not the only one in terms of the relationships between arguments and entities. From the perspective of object orientation, it is a kind of "production" behavior for thinking subject to put forward an argument or proposition, and the argument or proposition is the "product" produced. Since there is "production" behavior, there may be corresponding "consumption" behavior. The subjects of "consumption" are those entities that see, hear and come into contact with arguments or propositions. Such entities are called "**observers**" or "receivers" of arguments or propositions.

The proposer puts forward or creates propositions and arguments, while the observers actively or passively learn propositions and arguments, along with their incidental information, and be allowed to respond to them. It can be seen from the difference between the behaviors of these two types of entities that the biggest difference between the proposer and observer lies in who is the owner of propositions and arguments. The proposer has the ownership of propositions and arguments, while the observer can comment on the propositions and arguments.

Take an example to illustrate.

Example 15:

"Einstein and Bohr were two giants in the field of quantum mechanics, and several academic debates between them had great influence in the history of science. As early as 1924, Bohr co-authored a paper entitled 'Über die Quantentheorie der Strahlung' (About the Quantum Theory of Radiation), which proposed a highly controversial point of view that energy and momentum need not be conserved in a single microscopic interaction process, but only in a statistical sense. In this regard, Einstein wrote in a letter to Born, another physicist: 'Bohr's ideas about radiation are very interesting. But ... I find it utterly unacceptable the idea that when an electron is irradiated by radiation, not only the moment of its jump, but also the direction in which it jumps, are chosen by its own free will.'" *[12]

As can be seen from Example 15, Bohr, N.H.D., as the proposer, formally expounded his point for explaining the wave-particle duality of radiation in the form of a paper. And Einstein, A., as an observer of this paper and its point, intuitively expressed his opposition, and then opened the prelude to the wonderful frontal confrontation between the two at the Conseils Solvay.

Through this example, we can learn that proposition and argument are not necessarily connected with the entities of proposer or observer, but with the role of proposer or observer. When a proposition or argument does not yet exist, it does not affect the existence of any entities. When a proposition or argument exists, its relation to an entity is connected through the role of proposer or observer.

Entities themselves do not change due to the role of proposer or observer, however, their roles are not invariable. Entity A, the proposer of proposition 1, can also be the observer of proposition 2, which is proposed by entity B, and this is actually quite common.

After adding proposer and observer, the model becomes the one shown in Figure 17.

[12] The content of the letter in this example comes from the translations of *《爱因斯坦文集》第一卷* (the Chinese version of *Einstein Collected Works (Volume I)*, FIRST EDITION., 1976, Page 193, "Objection to the idea that electrons have free will -- Letter to Mr. And Mrs. Born, 29 April 1924".

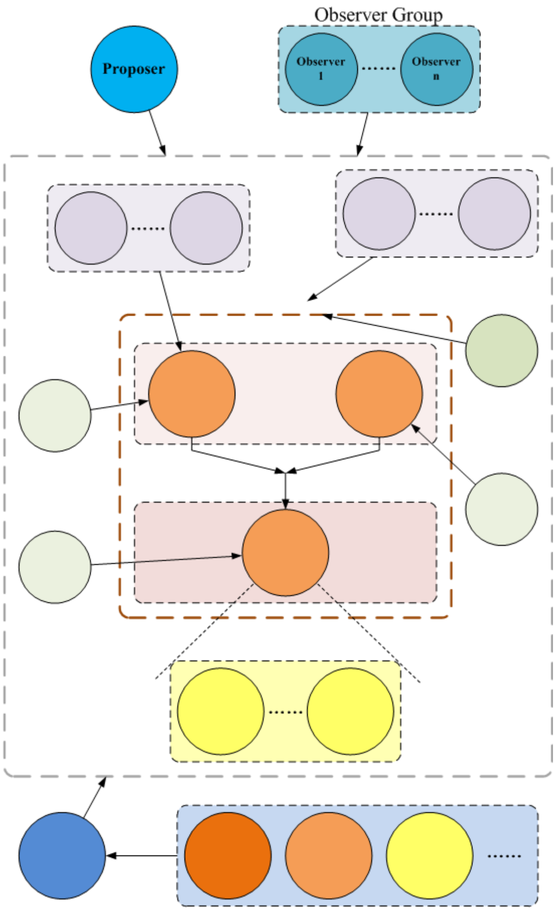

Figure 17: Diagram of argument-proposition-concept model after adding proposer and observer.

3.2.2 Declaration of Proposer & Response of Observer

i.

As a container of information, a logical information network can load any information and should not affect its content. Whether it is a proposition or argument, or any other object related to it, all these should depend on the "**declaration**" of proposer and the "**response**" of observer.

The object of a proposition or argument is established by a certain proposer. The proposer also needs to declare the truth-value of the proposition or the validity of the argument, perhaps including the matching conditions or attributes of the proposition or argument, and so on. An argument or proposition put forward by a proposer represents a viewpoint of the proposer's entity itself. It can have specific conditions and specific context, all of which are independent of the container and should not be limited by the container.

Proposer declares all the content he proposed, and observer responds accordingly to the observed content. Observer can confirm or deny an observed proposition, and can also make a valid or invalid judgment on an argument. This also represents a viewpoint of the observer entity itself, and be also independent of the container.

Every observer corresponds to a proposer, because proposer always exists prior to observer. If there is no proposition or argument put forward by proposer, there will be no corresponding observer. A proposition or argument may have no observer, but there must be a proposer. A proposition or argument can also have more than one observer, and each observer can give different feedback to the argument.

A same statement of sentence or word, put forward by different proposers, may express different connotations. Concurrently, the connotations learned from these statements by each observer may be different. Thus, on the statements of proposer, there may be positive or negative feedback from observers.

Different views or opinions represent controversy, which is very common not only in life but also in academic communication. For some research in unknown or frontier fields, different academic schools will debate and question each other, and there may even be completely contrary views, just like the century debate between Einstein and Bohr *[13]. All these are not only inevitable phenomena in the course of scientific development, but also one of the important driving forces to promote scientific progress. All the information generated in the process of academic debate is worth recording and retaining in the container of logical information network for future generations to observe and judge.

In many real-world scenarios, proposer presents propositions or arguments in varieties of forms. Whether the form of written papers, letters, newspapers and magazines, or the form of oral expression and face-to-face debate, or the form of communication media such as television, radio, and those packaged by digital carriers such as websites and Internet applications, they are all common ways of information transmission for propositions or arguments. And after learning the propositions or arguments, observers can also express their views on different carriers. Publishing comments or articles, replying to letters or emails, leaving messages on microblog or forums, arguing or agreeing with others face-to-face, etc. are all acceptable ways. The content of the opinion could be acceptance, that is, the same belief that the proposition is true or that the argument is valid; Or negation, that is, the belief that the proposition is false or that the argument is invalid; Or some evaluation on the proposition or argument; Or some modification suggestions on the statements or conditions of the proposition or argument, and their own views reflected by these suggestions.

ii.

Proposer can declare propositions, as well as definitions. The purpose of definition is to clarify the connotation of concept, that is to say, declaring a definition is equivalent to declaring the term of a concept and its corresponding connotation.

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[13] In the debate between Einstein and Bohr about quantum mechanics, both sides hold their own different opinions. The "Copenhagen School", composed of Pauli, W.E., Born, M., Heisenberg, W.K. and some other scientists, sided with Bohr and believed that human beings can only make probabilistic descriptions of physical processes in the micro world. However, Schrödinger, E.R.J.A. and de Broglie, L.V. supported Einstein's world view, believing that "the world strictly follows the law of causality, and there is no shadow of probability in sight at all". And they considered that quantum mechanics, which gave only the probability of motion at that time, was incomplete, but only a temporary form.

In our daily lives, we are likely to touch a large number of concepts all the time, including what we see and hear, and what we say from our own mouth. Who should declare the definitions of these concepts? Generally speaking, we learn common words from school, work, life, or interpersonal communication. However, these are not formal acts of declaring definitions. These words should be defined in officially recognized dictionaries. Behind all kinds of dictionaries, there are publishers and many editors as their proposers. Besides, non-popular fields, such as those at the forefront of research, are the most environments for the birth of new concepts. These new professional scientific words and their definitions have not been included in the dictionary in time, so it is natural for the corresponding researchers to act as the proposers of these definitions.

The editors of publishers and professional researchers, as the proposers of declaring definitions of concepts, represent the authority. However, it cannot be said that only the authoritative proposers can declare definitions. Each independent proposer should have the right to declare his own definitions. For example, we can give our children or pets a nickname, or mark a building as "company address" in our address book. However, the influence scope of these concepts is small, and the audiences are mainly the proposers themselves.

In addition, there are also some emerging words appear on the Internet, such as "Bu Ming Jue Li" (admiration arises despite my incomprehension of what you said), "Fo Xi" (Buddha-like, without desire), "Lan Shou Xiang Gu" (feel awful and want to cry), and so on. These words are neither declared by the authoritative proposers, nor hard to be traced back to their real proposers. They are gradually accepted by netizens in the network communication, and then become concepts with a certain audience.

The authoritative proposers can declare the official definitions, and non-authoritative individual proposers can also declare their own definitions, including the definitions that differ from the authoritative declarations. For example, there is a team called "Dallas Mavericks" in "NBA", the American Professional Basketball League. At the beginning of entering the Chinese market in the 1980s or 1990s, the team did not officially give the corresponding Chinese translation name. The folk fans spontaneously translated it as "Dallas 小牛队" (the team of calf), and it gradually became popular and was accepted by most fans. Until 2018, the team denied this translation officially, and announced that the Chinese translation of "Mavericks" in its team name would be "独行侠" (solitary chivalrous person) after collection and screening.

Even the definitions from authoritative declarations are not necessarily invariable. In the long years, old definitions may gradually be replaced by new ones. In fact, the first definition of "maverick" in the current Oxford dictionary is "a person who does not behave or think like everyone else, but who has independent, unusual opinions". In retrospect, initially, Maverick was only the surname of a rancher in the western United States, who was known for his unusual behaviors. Later, due to some coincidence and long-term language evolution, the word gradually evolved into its current meaning.

3.3 Information Unit

3.3.1 Information Unit

Upgrading from "argument-proposition" model to "argument-proposition-concept" model, it includes most elements of logical information model, such as concept and its attributes, proposition and its truth-value and conditions, argument and its evidences, conclusion, validity and conditions, definition and narration, etc. These elements not only completely reflect all the details of an argument, but also contain a certain amount of information. We can call each element containing information an independent "**information unit**".

Concepts constitute propositions, and propositions constitute arguments. A concept is an information unit. A proposition itself can be an independent information unit, or a combination of multiple information units of concept. Similarly, an argument can be a combination of multiple information units of proposition, and it can also exist as a single information unit.

It can be seen here that there are two different forms of proposition and argument in the model. Although their logical connotations are basically the same, they have different meanings as the objects in the model.

3.3.2 Atomicity

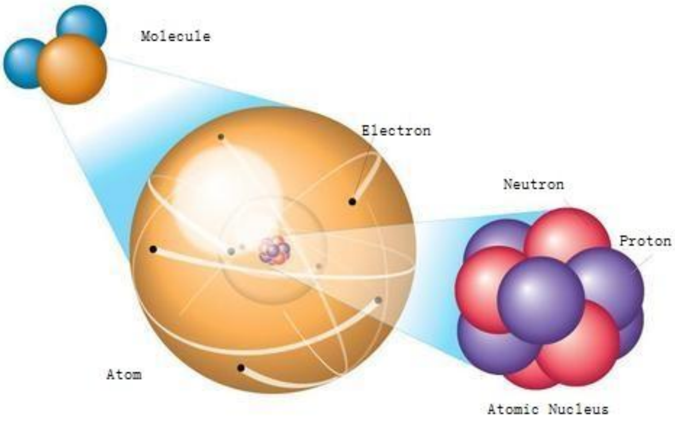
In various practical scenarios, the forms of argument vary greatly. Simple arguments can consist of only a few dozen words. Complex arguments can be papers, works and so on with as many as millions of words. Whether simple arguments or complex arguments, they are both made up of the smallest process units in argumentation. This process unit, in the view of most formal logic, is called "inference process". An argument contains at least one inference process, and a complete argument process is made up of many small inference processes.

As mentioned above, the information unit of argument of a naive argument-proposition model, that is, the combination of argument elements containing only one conclusion and at least one evidence, corresponds to a minimum unit in arguments. In this regard, we call that it has "**atomicity**" of logical argument process.

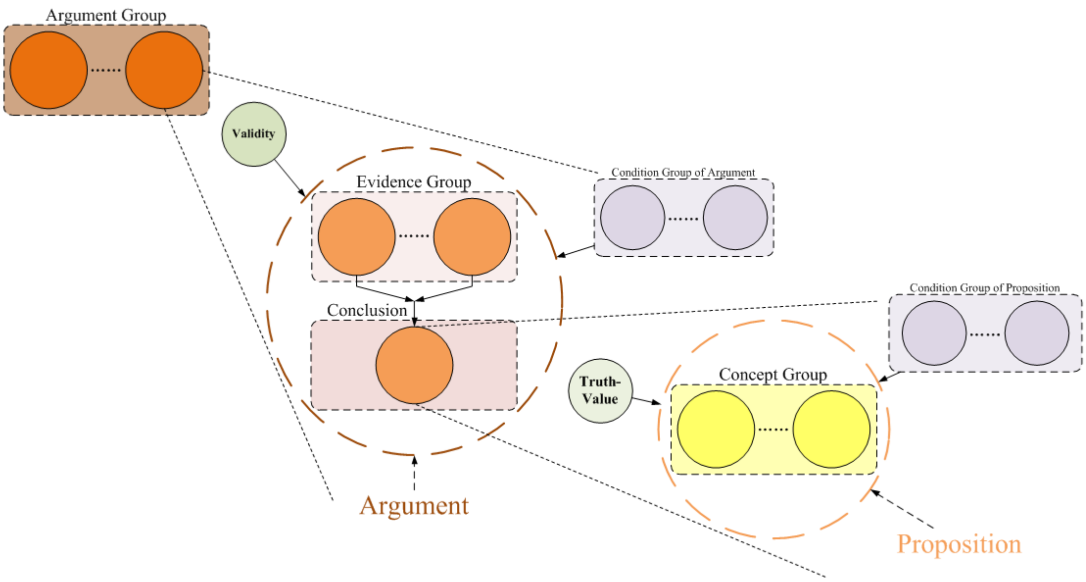
It should be noted that the "atomicity" here is not the same as the transaction "atomicity" mentioned in computer software technology. Transaction "atomicity" means that all operations in the process of a transaction are either successfully executed or not executed at all. And the "atomicity" here means that unit of argument has the independence of argumentation, that is, it is an inseparable inference process without changing the connotation of argument or any relevant information units.

Compared with transaction "atomicity", in fact, the "atomicity" here is closer to the currently known atomic characteristics. As we all know, atoms are inseparable basic particles in chemical reactions, but they can continue to be divided into protons, neutrons, electrons and even smaller particles like quarks in the domain of physics. Similarly, as the smallest unit of argument, a naive information unit of argument can no longer be separated. But as an information unit, it can also be divided into more types of information units such as proposition, concept, condition and so on.

On the other hand, several atoms can be assembled into the complex form of molecule, and molecule is the smallest unit to maintain the chemical stability of substances. Inside a molecule, an atom can still keep its original nucleus intact. Similarly, several information units of argument can also be assembled into the complex information unit group of argument. Those information units in the group still retain their independent connotations, and can also be disassembled from the current group if necessary.



(a)



(b)

Figure 18: Diagram of molecule, atom and nucleus, compared with the diagram of information unit group model.

3.3.3 Assembling & Disassembling

In introducing the atomicity of information unit, we mentioned "**assembling**" and "**disassembling**", which are a pair of mutually reversible acts between information unit and information unit group.

The acts of assembling and disassembling can be used between the information unit and information unit group of argument, so that several naive information units of argument can be classified into the same set of information units, and this set can be regarded as a complex information unit group of argument formed by the joint action of the connotations of these naive arguments. Conversely, for a complex information unit group of argument assembled from naive information units of argument, these naive information units of argument can also be disassembled from the group.

Moreover, assembling and disassembling can also be used for the combination of naive argument assembled from several information units of proposition, or the combination of proposition assembled from several information units of concept and other scenarios between various information units.

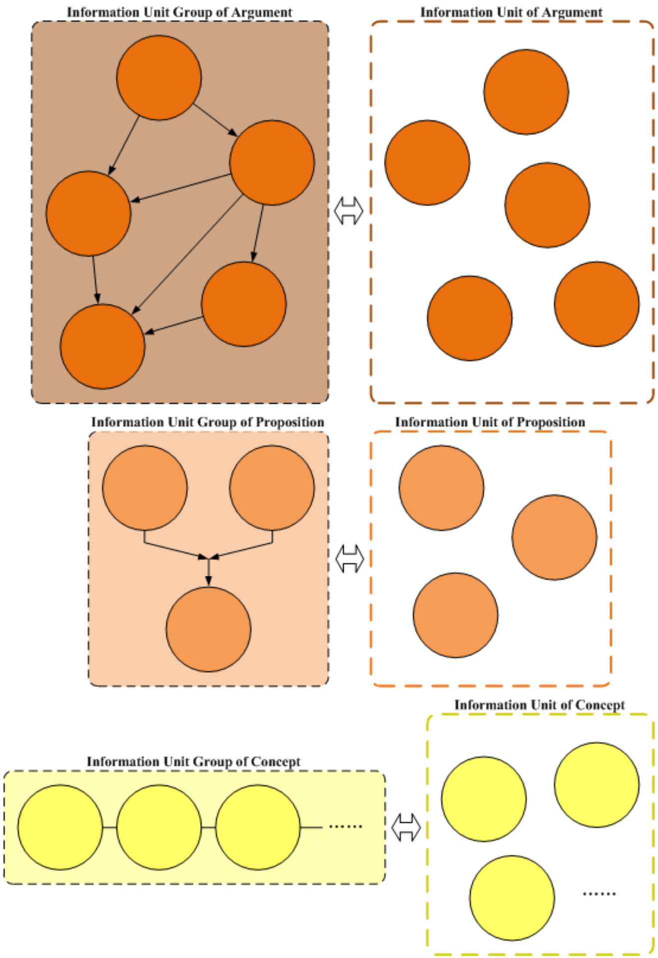


Figure 19: Diagram of assembling and disassembling of information unit group of argument, information unit group of proposition, and information unit group of concept.

3.4 Information Relation

Each information unit is independent, but there can be connections or **relations** between information units.

3.4.1 Mapping Relation

i.

"**Mapping relation**" refers to a correspondence or connection that can be established between any two (or two "classes" or two "groups", and sometimes more than "two") independent objects or things.

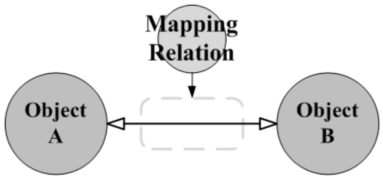


Figure 20: Diagram of mapping relation.

When a proposer attempts to establish such a relation, it is necessary to set up an appropriate connection for the two objects in this relation, which is usually linked by some similarity. For example, the sides of clocks and tires both look round, the sun and incandescent lamps both glow, cheetahs and rhinos both run on four legs, and so on.

ii.

In natural language, mapping relation is often reflected in rhetorical devices such as simile and metaphor. Someone describes, "Life is a journey", or "Business is a battlefield". Others call the Rh-negative type "panda blood" because it is very rare. These rhetorical devices can not only help to enhance the literary value, but more importantly, they also reflect a certain degree of similarity between different things. The reason why the similarity between things can be reflected lies in that simile and metaphor themselves imply the comparisons of these things and their attributes, namely "**analogy**". Analogy is the basis of simile or metaphor. Through the analogy of different things, the connection and similarity between them can be made clear.

In traditional logic, the most frequent form of logical reasoning that reflects the mapping relation is analogy-based reasoning, namely "**analogical reasoning**". Analogical reasoning usually starts from the situation that two or two classes of objects are similar or identical in many of their attributes, and that one (classes of) object is known to have other specific attributes, so it is inferred that the other (classes of) object may also have the same or similar specific attributes.

For example, the earth and Mars are both planets in the solar system. They have many of the same attributes, such as orbiting around the sun, rotating on their respective axes, having atmospheres and seasonal changes throughout the year, having temperatures suitable for the survivals of some known earth creatures, and so on. Finally, according to the special attribute that there are lives on earth, it can be inferred that there may also be signs of life on Mars.

In such analogical reasoning, there are multiple groups of mapping relations. Some researchers divided them into "attribute mapping", "predicate mapping" *[14] and other categories according to their different mapping characteristics. Attribute mapping refers to that the two concept objects in a mapping relation have similar attributes respectively. For example, the attribute "atmosphere" of the earth and Mars is "existence", and the attribute "plane projection shape" of clock and tire is "circle". On the other hand, predicate mapping refers to that the behaviors implemented by two different objects, i.e. the corresponding predicates, have a certain similarity. For example, both the earth and Mars "rotate" relative to their respective axes, and both the sun and incandescent lamps "glow". It is because of these similar or even identical attributes and predicates that it occurs a certain connection between the two (classes of) objects.

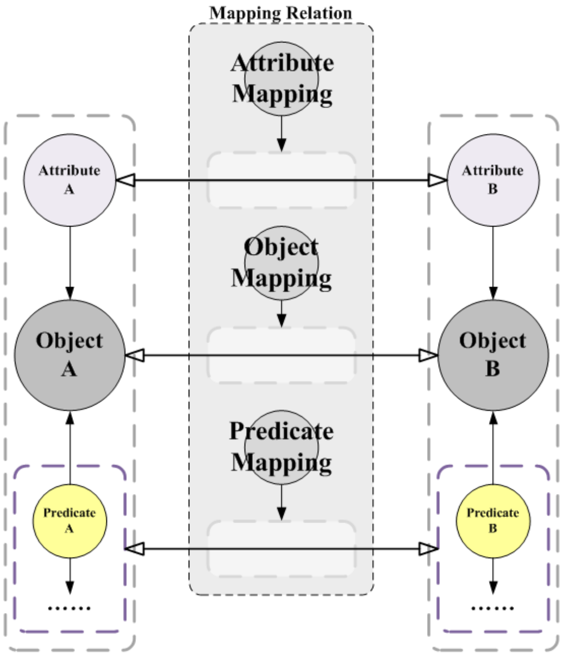


Figure 21: Diagram of mapping relation in analogical reasoning.

iii.

In discrete mathematics, especially in set theory, "mapping" and "relation" are also two important terms. However, the "mapping" and "relation" are not the same as the "mapping relation" in logical information model, although they are also a little bit related to each other. Whether "mapping", "relation", or "mapping relation", they all involve two or two classes of objects and express some kind of dependency between these two (classes of) objects.

In the domain of mathematics, "relation" mainly refers to the most basic binary relation, which is in the form of a set of ordered pairs. The elements in these ordered pairs are respectively derived from two other sets, and the binary relation reflects a connection between these two sets.

And in the two sets that conform to the correspondence reflected by "mapping", each element in one set has a unique element corresponding to it in the other set. The form of correspondence can be a group of ordered pairs or a general rule (generally denoted as f: $X \rightarrow Y$, or $y = f(x)$, where X and Y are two sets, and x and y are the elements of sets X and Y respectively).

[14] These phrases come from the paper *《逻辑学视域下的类比推理性质探究》(A Study of the Nature of Analogical Reasoning in the Perspective of Logic)*, Jin Li, Zhao Jiahua, 2015. This is called "relation mapping" or "predicate relation mapping" by the author in the paper. In order to avoid ambiguity, it is defined as "predicate mapping" in this article.

It is not difficult to see that the two (classes of) objects connected by mapping or binary relation are both sequential, just as the ordered pair <x,y> is not equal to <y,x>. Because of the definition, the set formed by the left elements of all ordered pairs in the set of binary relations is called the domain of binary relation, and the set formed by the right elements is called the range of binary relation, so the left and right elements are distinguished in meaning.

But mapping relation is different. It only maintains the connection between two (classes of) objects. Then, in specific application process, it is confirmed by the application mode whether to determine the order of the mapping relation. For example, in simile, we can liken the sun to an incandescent lamp in the air, or an incandescent lamp to an indoor sun. Of course, in analogical reasoning, in order to infer the unknown attributes of an object from the specific attributes of another known object, the mapping relation in this process generally has obvious order (or called inferential orientation).

Secondly, in a narrow sense, mapping and binary relation are only used to represent the connection between the elements of two sets. Although these elements may not be numbers and symbols in the domain of mathematics, their expression forms always need to follow the patterns of symbolic language in the category of set theory. Binary relation can be expressed as the Cartesian product of two sets X and Y, namely X×Y. It can also be expressed in the form of a set of ordered pairs, such as "{<x,y> | x∈X Λ y∈Y}". Or it can also be expressed in the form of an enumerable set, such as "{<x1,y1>, <x2,y2>, <x3,y3>}", and so on.

The objects in a mapping relation have no such restrictions at all. Their types can involve any information type in any domain, including mathematics. Their expression forms can be completely described in natural language, and they can also be compatible with the expression in symbolic language.

In the mathematical definitions, mapping is obviously associated with binary relation. Mapping is a corresponding relationship with restrictive conditions, while binary relation is a corresponding relationship between the elements of any two sets without any other restrictions. We can regard mapping as a special binary relation.

The two (classes of) objects in a mapping relation are more flexible, and even not restricted to the need of being elements of set. Mapping relation can be compatible with binary relation whether in terms of scope or expression. Therefore, binary relation can also be regarded as a special form of mapping relation.

3.4.2 Equivalence Relation

i.

In all mapping relations, there is a kind of special case, that is, when the two (classes of) objects in the mapping relation are completely equivalent. This case can be called "**equivalence relation**".

The so-called equivalence, namely complete equality. The two objects in equivalence relation have different connotations but the same functions, and can prove and deduce each other.

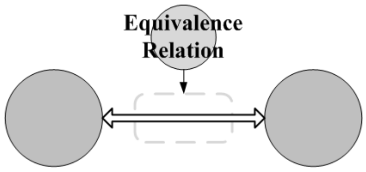


Figure 22: Diagram of equivalence relation.

For example, in *Euclid's Elements of Geometry*, which has ruled geometry for more than 2000 years, five postulates and five axioms are proposed as the basis of Euclidean axiomatic system of geometry, and the fifth postulate *[15] has been controversial, and was considered to be too lengthy and not sufficiently clear. For a long time, mathematicians have been trying to find its replacement, and there appeared a number of different propositions successively, which have been confirmed to be able to be mutually proved with the fifth postulate, such as "If three interior angles of a quadrilateral are right angles, then the fourth interior angle must also be a right angle", "Two intersecting lines cannot be parallel to a third line simultaneously", ① "Passing a point outside a line, there is one and only one line parallel to the line". Finally, since proposition ① is the most concise and clear, it has been widely adopted in textbooks of the countries all over the world as an expression instead of the fifth postulate. It is also called "**parallel postulate**". These propositions and the fifth postulate are considered to be equivalent to each other, that is, there are equivalence relations among them.

ii.

There is no formal study of equivalence relation and no specific connectives of equivalence in traditional logic. "Be ...", "like ...", "as ..." and "be equivalent to ..." etc., in natural language may be used as the connective between the two objects in equivalence relation.

However, in mathematical logic, a relatively complete formal system of equivalence relation has been developed, and there are also connectives specially used to express equivalence relation. The symbol "↔" is the connective of propositional equivalence *[16], the symbol "⇔" is the connective of propositional truth-value equivalence, and the symbol "=" is used as the connective of conceptual equivalence, etc. Of course, the symbol "=" is not limited to the category of mathematical logic, but also appears in most other mathematical domains, and is used to represent the conceptual equivalence of conceptual objects in the form of numbers or symbols.

iii.

It is worth noting that there is also a concept called "equivalence relation" in the binary relation of set theory. This equivalence relation means that when a binary relation on a set satisfies the three conditions of reflexivity, symmetry and transitivity, this binary relation is just called equivalence relation. This is a specific concept in set theory. The purpose of defining this concept

[15] The fifth postulate described in *Euclid's Elements of Geometry* is : "If a straight-line falling across two (other) straight-lines makes internal angles on the same side (of itself whose sum is) less than two right-angles, then the two (other) straight-lines, being produced to infinity, meet on that side (of the original straight-line) that the (sum of the internal angles) is less than two right-angles (and do not meet on the other side)."

[16] Propositional expressions linked by the symbol "↔" are also called "equivalent formula" in mathematical logic.

is to further introduce the concepts of "equivalence class", "partition" of set, "quotient" and so on. This has no correlation with the equivalence relation in logical information model, and in this respect it differs from the relationship between binary relation and mapping relation.

3.4.3 Causality Relation

i.

The most important relation between logical information is the derivation relation.

The book *《形式逻辑基础》(Foundations of Formal Logic)* holds that, "Structurally speaking, reasoning consists of premise, conclusion and derivation relation .... For a deductive reasoning, the way to logically deduce conclusion from premise is called derivation relation, or reasoning form." *[17] It can be seen that derivation relation is the relation that links the premises and the conclusion in reasoning. Corresponding to which in logical information model is an attribute in the information unit of argument, that is, the connection between those information units that play the role of evidence and conclusion. In the model, we call it "**causality relation**".

David Hume, the representative of skepticism philosophy and the 18th century British philosopher, once said: "All reasonings concerning matter of fact seem to be founded on the relation of Cause and Effect." *[18] Because of the "cause", so the "effect", and "Everything begins to exist for a reason", these are the most basic rules in the process of reasoning. With such a relation, we can link the set of propositions served as evidences and conclusions in any argument. As long as an argument has been formed, this relation naturally exists within it. Once this causality relation is broken, we can consider this argument invalid.

The relation of cause and effect does not make them at the same level, unlike those things that can be used to make analogy with each other in mapping relations. Usually there are obvious orders between them. That is, first cause, and effect after that.

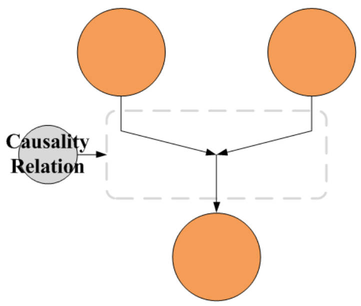


Figure 23: Diagram of causality relation.

[17] These sentences come from *《形式逻辑基础》(Foundations of Formal Logic)*, Zhu Zhikai, 1983, Page 112.
[18] This sentence comes from *An enquiry concerning human understanding*, Hume, D. Millican, P., Oxford University Press, 2007, SECTION IV: Sceptical Doubts concerning the Operations of the Understanding, PART I, Paragraph 4.

ii.

"Causality relation", or derivation relation, is an important part of logical reasoning.

In the 19th century, the British philosopher Mill, J.S. proposed five methods for analyzing and exploring causality in his book *A System of Logic*, which is called Mill's methods. *[19] However, it should be noted that the term "causal laws" mentioned in Mill's methods is not the same as "causality relation" in logical information model.

The so-called "causal law" refers to a general form of internal connection and interaction between objective things, which is the inevitable law between all individual appearances and their internal causes in the objective world as an organic whole. There are corresponding causes for any phenomenon in the world, ranging from the operation of celestial bodies to the change of atomic nucleus, the biological reproduction, the changeable atmosphere, and so on. There must be a cause for every effect. The traditional philosophical views before Hume generally accepted this kind of objective and inevitable causality. However, Hume believes that we don't have any evidence and reason to prove its truth. All propositions that seem to be definitely true, that is, they have intuitive "certainty", are considered to be true, just because they exist in our subjective thoughts.

This is not difficult to understand. The interaction between objective things in nature is independent of human subjective ideas, just like "Schrödinger's cat" *[20], which is locked in a separate closed container. We can only see the changes of objective things, but cannot directly see the connections behind them. The kind of connection we feel is just that we connect them together in our own subjective world.

Because, after each of us, as a thinking subject with independent cognitive ability, learn the information reflecting the phenomena of the objective world, in fact, it has been integrated into our subjective cognitive system. When we judge a certain thing or proposition "intuitively", it is not because of the so-called "instinct or intuition" that is unaffected by any influence, nor the direct feedback given by the objective world, but due to our already "processing" in consciousness. This "processing" will inevitably be affected by the received information (namely experience) in our previous cognition to a certain extent, and this effect determines that the knowledge and "certainty" about the causality relation between things in our conception cannot be obtained through so-called a priori reasoning, but from the accumulation of past experience.

As Hume wrote in his book *A Treatise of Human Nature*: "We have no other notion of cause and effect, but that of certain objects, which have been always conjoined together, and which in all past instances have been found inseparable. We cannot penetrate into the reason of the conjunction. We only observe the thing itself, and always find that from the constant conjunction the objects acquire an union in the imagination. " *[21]

From Hume's point of view, it can be seen that he does not doubt objective causality itself, but question how to obtain the knowledge of objective causality without loss.

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[19] Mill's methods are attributed to inductive reasoning, i.e. the method of agreement, the method of difference, the joint method of agreement and difference, the method of residues and the method of concomitant variation.

[20] "Schrödinger's cat" is an ideological experiment put forward by the famous Austrian physicist Schrödinger, which refers to locking a cat in a closed container containing a small amount of radium and cyanide. There is a chance that radium would decay. If the radium decays, it will trigger the mechanism to break the bottle containing cyanide, and the cat will die. If the radium does not decay, then the cat will survive. According to the theory of quantum mechanics, since radioactive radium is in the superposition of decay and no decay, the cat should be in a superposition of dead and alive cat. The dead and alive cat is the so-called "Schrödinger's cat".

[21] This paragraph comes from *A Treatise of Human Nature*, Hume, D., 1740, Book I: Of the understanding, Part iii: Of knowledge and probability, Section 6: Of the inference from the impression to the idea.

Since, from the perspective of epistemology, human beings cannot get rid of the subjective causality influenced by experience and directly understand the abstract noumena beyond experience, the knowledge connotation of such causality is bound to be limited by the difference of each subject's cognitive level in the process of recognition or dissemination. In other words, each of us has different understanding of the phenomenon and internal cause of a same object, and it is likely that there may be differences in the way we describe it.

In this case, there is a problem, that is, which of our subject's consciousness can fully reflect the objective laws? This is a question for which no definite answer can be given. Because even those who are recognized as the most intelligent scientific giants cannot ensure that all their views can truly and completely confirm the objective laws. For example, the "geocentric theory", supported by Aristotle, Ptolemaeus (ancient Greek: ΚλαύδιοςΠτολεμαῖος) and others, was refuted by Copernicus (Polish: Mikołaj Kopernik) with more accurate astronomical observation data in the 16th century, and then replaced by the "heliocentric theory". In the early 20th century, Shapley, H. and Hubble, E.P. successively calculated that the sun was not located in the center of the Milky Way galaxy, and the Milky Way galaxy was not the whole of the universe. Thus, the "heliocentric theory" was turned over and mankind was led into the era of modern cosmology.

Therefore, when we feed back the information that has been integrated into our subject's cognition, whether it is oral or written language, or with the help of body movements or expressions, it reflects our subjective will first and foremost, not objective laws. No matter how objective we think the content of our expression is, in essence, it is a subjectively obtained "causality relation", and there is still the possibility that it is different from the real law of the objective world.

Similarly, in the logical information network declared by proposers, "causality relation" also reflects the judgment of objective causality in the proposers' subjective consciousness, rather than the causal law of the absolute objective world.

iii.

The argument objects mapped to logical reasoning in logical information network is declared by proposers. Similarly, the causality relations and their categories in the arguments also come from proposers' declaration.

As we all know, logical reasoning is divided into deduction and induction according to the degree of support of evidences for conclusions. The difference between them does not lie in evidences and conclusions, but in "causality relations". In addition to the five Mill's methods, predecessors have also summarized some other analysis methods commonly used in deductive and inductive reasoning, mainly including syllogism *[22] in traditional deductive logic, enumeration, analogy, hypothesis, probability and statistics in inductive logic, as well as truth table, Venn diagram, 19 logical rules of inference, and so on, which are proposed in mathematical logic. These methods can also be used to assist proposers to judge the types of the arguments they declared.

Example 16:

[22] The syllogism mainly refers to categorical syllogism. In traditional logic, 19 forms of categorical syllogism were summarized, which were later reduced to 15 effective forms in mathematical logic.

"This earth which we inhabit, and the other planets, Saturn, Jupiter, Mars, Venus, and Mercury .... They all revolve around the sun, ... they borrow all their light from the sun, ... they are all subject to the same law of gravitation .... From all this similitude, it is not unreasonable to think that those planets may, like our earth, be the habitation of various orders of living creatures." *[23]

In example 16, analogy, which is the most common method in inductive logic, is used to infer their laws by comparing "the other planets" to "this earth". So we determine that the causality relation in this argument is based on analogy. In addition, studies in logic believe that in an analogical argument the support of evidences for conclusion is probable, and we cannot distinguish its validity by "valid" or "invalid", so we can only describe it by declaring the probability of validity or the description of validity degree.

For another example, in the preceding text, the arguments of Examples 1, 9 and 10 all use syllogism, which is a typical method in deductive logic, and their causality relations can be considered to be based on syllogism inference. Thus, the validity of these arguments can be directly described as "valid" or "invalid".

iiii.

Causality relation exists not only in argument, but also in a special kind of compound proposition, i.e. hypothetical proposition.

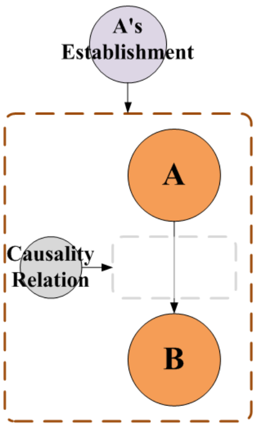
When a hypothetical proposition satisfies the condition that its antecedent is true, its consequent is also true. To put it another way, the antecedent of a hypothetical proposition exists as the precondition of its consequent under a hypothetical condition (i.e. the antecedent is tenable). Or it can also be said that the establishment of antecedent, together with the antecedent itself, is a premise condition of the establishment of consequent.

Without changing its connotation, a hypothetical proposition in the form of "if A, then B" can be transformed into an argument in the form of "Under the condition of assuming A's establishment, because A, so B" (Figure 24a), or "Because A, and assuming A's establishment, so B" (Figure 24b).

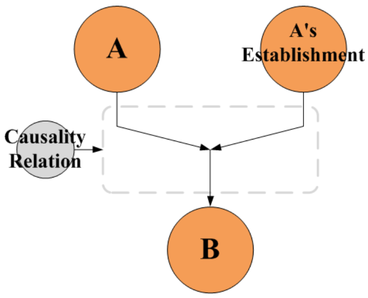
Just like the information meaning expressed by the proposition "If a piece of blue litmus paper is placed in acid solution, then the paper will turn red", it is equivalent to the inference that "Assume there is a piece of blue litmus paper and acid solution, because this paper is placed in acid solution, so it turns red".

Therefore, we can see that there is a causality relation between antecedent, the hypothetical conditions for the establishment of this antecedent, and consequent.

[23] This paragraph comes from *Introduction to Logic*, Fourteenth Edition., Page 487, 488.



(a)



(b)

Figure 24: Diagram of causality relation with hypothetical conditions.

3.4.4 Defining Relation

Based on a relation object such as "causality relation", we can combine multiple information units of proposition into information unit group of argument. There are many similar combined forms of relation and information unit group in logical information model. For example, as mentioned above, in a defining act, there must be a relation between the definiendum and definiens which are connected by the connective of definition. This kind of relation links the two information units of concept together which play the role of definiendum and definiens, and we call it "**defining relation**".

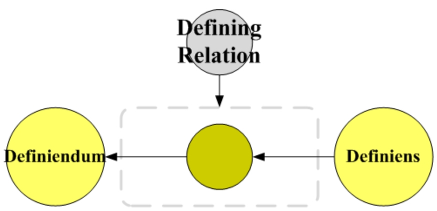


Figure 25: Diagram of defining relation.

The two information units of concept in a defining relation do not play an equal role. Definiens exists to clarify the connotation of definiendum. In the two, definiendum plays a dominant role, while definiens is an affiliate of definiendum. So there is an "**affiliation relation**" between the two. Basically, the content in definiens is appropriate to exist as an attribute of definiendum. For example, "vehicle" is an attribute of "motor vehicle", "celestial body" is an attribute of "planet", and "litterateur" is an attribute of "Lu Xun". Each attribute of definiendum is used to describe a certain property of definiendum, which can be appearance, essence, function, behavior, and so on. Therefore, to be exact, definiens is an affiliate of definiendum in the way of describing some properties of definiendum, which is the specific manifestation of the affiliation relation between the two.

In most cases, the affiliation relation between definiendum and definiens is determined and stable. Just like we say "Lion is a (kind of) Felidae animal", but we don't say "Felidae animal is a (kind of) lion". Because in general cognition, "lion" and "Felidae animal" have different connotations and unequal denotation. "Felidae animal" can be used as an attribute of "lion", but "lion" cannot be used as an attribute of "Felidae animal".

Of course, not all affiliation relations between definiendum and definiens are irreversible. For example, "Water is a compound of chemical formula H_2O". If the definiens and definiendum in this definition are exchanged, a new definition will be formed to express like that "The compound of chemical formula H_2O is water". It is not difficult to see that this new definition can also work. The reason is that although "water" and "compound of chemical formula H_2O" have different connotations, their denotations are equal. This is the "**synonymy relation**" within defining relation, besides the affiliation relation.

Each of the two information units of concept in synonym relation can be used as an affiliate of the other as a definiens, as well as an attribute of the other. This is equivalent to the superposition of two corresponding affiliation relations to form a synonym relation.

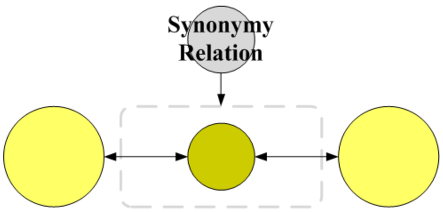
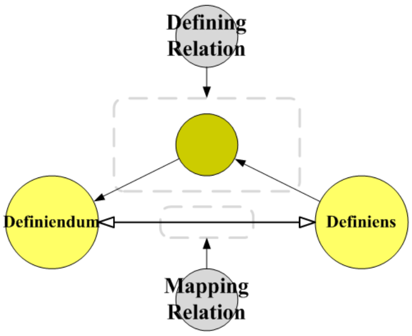
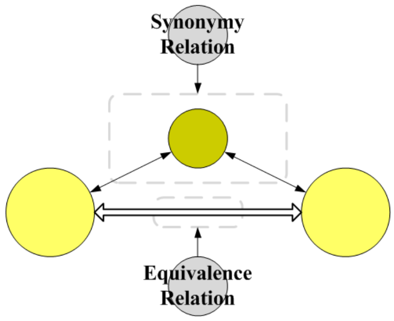


Figure 26: Diagram of synonymy relation.

The affiliation relation between the two concepts as definiendum and definiens links them together, which itself is the embodiment of some mapping relation between them (Figure 27a). And what exists between the two concepts in the synonym relation is an equivalent mapping relation, namely, equivalence relation (Figure 27b).



(a)



(b)

Figure 27: Diagram of the mapping relation within defining relation, and equivalence relation within synonymy relation.

3.4.5 Other Relations

There are many ways to associate an information unit with another one. In addition to the relations of mapping, equivalence, causality, definition and others mentioned above, there are also relation that links the objects of doubt, doubt target and explanation (let's call it "**D&E relation**"), and conditional relation between the object of proposition or argument and its condition objects, as well as some other relations in logical information model that will be mentioned in subsequent content.

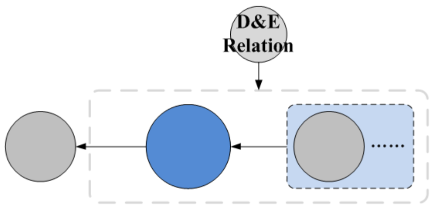


Figure 28: Diagram of D&E relation.

Furthermore, as a proposer, you can also establish **customization relations** based on information content or existing information relations in a logical information network. For example, the corresponding "**antonymy relation**" or "**near-synonymy relation**" can be constructed on the basis of synonymy relation. This requires the proposer of the attempt to construct the relation to declare the compliance with the criteria for such a relation.

Another example is that "**comparison relation**" can be further constructed based on the mapping relation of objects and combined with the relevant characteristics of the mapped elements (objects, or object attributes). The core of comparison relation is mainly "**greater-than relation**" and "**less-than relation**". Other comparisons of characteristic, such as high or low, far or near, light or heavy, fast or slow, bright or dark, beautiful or ugly, good or evil, superior or inferior, successful or fail, etc., are all based on these two relations and derived by combining with different attributes. There can be countless kinds of such derived relations.

In addition, besides causality and conditional relations existing in logical relations, from the perspective of linguistics, these relations are also contained in semantic relations in general sentences. Moreover, based on the characteristics of language expression, there can also be a variety of semantic relations in general sentences, such as juxtaposition, adversative, progression, selection, concession and so on, which are used to describe the different relationships between clauses. There could be own unique semantic relations between clauses in general sentences, and between sentences in paragraphs, even between paragraphs in articles. These semantic relations connect different components of articles, support the structure of a whole article, and also reflect a certain logical relationship among words.

3.5 Information Section

3.5.1 Fusing

Between multiple information units (or between information units and information unit groups), in addition to assembling and disassembling, there can also be acts called "**fusing**" and "**separating**".

The relationship between fusing and separating is similar to that between assembling and disassembling. Multiple simple and independent information units can be fused to obtain complex information units, and complex information units can also be separated into more and simple information units. *[24] However, fusing and separating are not reversible acts, unlike assembling and disassembling. Because their acts result in the production of new information units, not just around a "loose" relation between information units, as in assembling and disassembling.

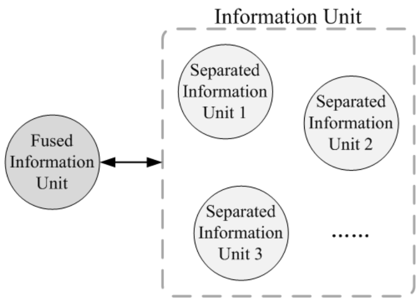


Figure 29: Diagram of fusing and separating of information units.

It is the simplest fusing way to integrate all the elements of an information unit group of naive argument into a complete and independent information unit of argument without changing its connotation. A more complex fusing scenario can be to integrate several information units of argument together with some other types of information units to form a more complex information unit. In terms of form, such information units can exist in the form of "academic papers", "research reports", "news reports" or "speeches", etc. In essence, it is still an information unit of argument, but its structure is more complex. We can also give it a new name, called "**argument section**".

[24] The "simple" and "complex" mentioned here are just a set of relative conceptual expressions.

3.5.2 Information Section

Argument section can be simply understood as a flat text formed by the free fusing of several groups of arguments. It can be regarded as one of the different forms of information unit of argument, or it can be called a subtype of information unit of argument. Such a definition is the embodiment of the typical generalization relationship in object-oriented thought.

However, based on the setting of the "declaration of proposer" mentioned above, the content in an argument section may be very complex in practical application scenarios. This may include the fusing of several groups of arguments, or the fusing of several independent propositions, or the fusing of propositions, arguments and other information units. It is even possible to fuse some contents that do not conform to the corresponding connotation of the meta-types of information unit we have set so far, such as some sentences that are considered non-propositional, or fallacies, etc. Such a section has already gone beyond the category of logical "argument" itself, but it has strong information tolerance, and the form of its connotation can also become rich and varied. For an argument section, strong information tolerance means that in most cases it may have richer connotation than a single information unit, that is to say, it can convey more information.

In the amount of information, what can be equivalent to argument section is the product of act "assembling" -- information unit group. Information unit group is a kind of stereoscopic representation formed jointly by multiple elements in logical information network. In contrast, an argument section is like a separate element projected onto a flat dimension. This separate element mixes the connotations of several information units. Such connotations may not purely reflect one or more arguments, but they must contain a large amount of information. From this perspective, it might be more appropriate to be called "**logical information section**" or "**information section**".

An information section may contain several different types of information units, or only a single information unit, whether it is an argument, a proposition, a concept, or even a proposer object. So, an information section can be regarded as an information unit (in some cases), but meanwhile, it is not completely equivalent to an information unit. Therefore, it is not difficult to predict that in the logical information network composed of information units, information section also have the node characteristics similar to information unit, that is, they can establish various relations with other information units or information sections, to jointly build a logical information network.

Information section is another important component of logical information model besides information unit. Its characteristics are crucial to other features of logical information network mentioned in subsequent chapters.

3.5.3 Separating

In contrast to fusing, separating is to separate part of the connotation of an information section (or information unit, which will be collectively referred to as "**information element**" below), and construct new information element based on this connotation.

For example, in Example 4 above, the whole paragraph is a complex argument, certainly it can also be an information section. The result obtained by separating ④, ⑤, ⑥ and ⑦ in it is a complete and naive argument. If ② is separated individually, it is an independent proposition. If the "Big Bang theory", "astronomers", "conglomerations of galaxies", "speed of light" and other contents are separated, they are some concepts. Furthermore, if ① with ② or ⑤ with ⑥ (certainly here also could be a combination of other forms) is separated, then it is just an ordinary information section, not other types of information units such as argument or proposition.

It is not difficult to see that both the source and target information elements by separating have type diversity, and are not limited to a single information unit type.

Furthermore, the separated information elements are new and independent, not part of the original information elements. However, as the source and target of the act separating, there must be a factual immanent correlation between them. We can regard this as an inherent, non-customized "relation" between information elements, which can be called "**source-target relation**". This relation is not limited between the source and target elements of the act separating, but can also exist between those of the act fusing, or even between those of other acts that produce new information elements.

This kind of relation between information elements, like "raw materials" and "products", can help to locate the "raw materials" of "products" and their composition more quickly, and provide different methods of information retrieval, which is conducive to many practical applications based on information retrieval.

4. Logical Information Model

The previous two chapters respectively expound the structure of the model from the perspective of logic and informatics. If these two parts are combined together, a complete logical information model is formed. However, if it is nothing more than that, there are still some defects and deficiencies in such a model. This chapter will make some settings and specifications from several aspects of the combination of logic and information, in order to promote the model more perfect.

4.1 Completeness

For a model used to build an information system, **completeness** is logically self-consistent without formal defects, which is very important.

Just as in the previous chapter, the concept of "logical information section" is introduced, because "logical information unit" is not enough to cover all information forms. Then the concept of "information element" is introduced in order to unify information unit and information section. So far, from the perspective of information, the loophole in this area has been filled.

However, logic and informatics are two fields that are not completely integrated with each other. When they are placed together, there are bound to be many contradictions between them to be reconciled in order to finally meet the completeness of the system.

4.1.1 Completeness Extension of Statement

First of all, the most obvious contradiction lies in the category of proposition.

It is generally believed in logic that a sentence is not a proposition if it does not assert anything. Based on this assertion, only the statements (namely declarative sentences) that can be judged as true or false are propositions, while questions, exclamations, imperatives, etc., are not propositions in the standard sense. In other words, the expressions of various sentence patterns, including interrogative sentences, exclamatory sentences, imperative sentences and unverifiable declarative sentences, are excluded from the scope of proposition.

However, from the perspective of information, whether it is a declarative sentence, an interrogative sentence, an exclamatory sentence or an imperative sentence, whether it can be judged as true or false, whether it directly expresses a proposition or not, it can be a kind of transmitted information.

In this way, proposition and information differ in the criteria of identification, which brings hidden trouble to logical information model. For example, in the model, it is reasonable when the content of the proposition object is "pandas eat bamboo". But if the content is "go and watch pandas eat bamboo", it obviously does not accord with our determination of the category of proposition. This will lead to the contradiction of the model setting between the form and internal, resulting in the collapse of the whole system.

To solve this contradiction, we can start with the extension of sentence patterns. Propositional statements, including definition statement and narration statement, all belong to **statement**. In addition to statements, commonly used sentence patterns, such as questions, exclamations or imperatives, cannot be directly applied to arguments as propositions, but can be used as a part of the information content in an information network in the form of "**sentence**". "Sentence" here becomes a kind of object in logical information model. Statement, question, exclamation and imperative can be its sub-objects, while propositional statement, definition statement and narration statement are all sub-objects of statement. In this way, the categorical contradiction between proposition and information can be resolved.

Of course, in fact, in some cases, those non-statements can be incorporated into an argument in a special form. If the imperative sentence "Go and watch pandas eat bamboo" is combined with its proposer A, as "(just now) A said: 'Go and watch pandas eat bamboo'", and its content becomes an expression of the proposer, then a declarative sentence can be formed. Such content also has the nature of assertion and can be considered as conforming to the category of propositional statement.

This is actually a clever and simple way to form all sentence patterns including questions, exclamations and imperatives into the object of propositional statement. Moreover, such a treatment is not uncommon. On many occasions, we can see that the remarks of authorities, professionals and stars are used as evidences in arguments. For example, Einstein's letter is quoted in Example 15 to assert the academic debate between him and Bohr.

Another example is the following paragraph in the 72nd chapter of *Three Kingdoms*:

"...... Cao Cao held his forces at the gorge for many days, unable to advance for fear of Ma Chao, unwilling to retreat for fear of exciting the scorn of the western army. Cao Cao was in a state of indecision. At this moment the chief cook brought in chicken broth for Cao Cao, who noticed pieces of ribs in the bowl. The sight gave rise to a thought. As he was musing, Xiahou Dun entered his tent to ask what the password would be that night. 'Chicken ribs. Chicken ribs.' Cao replied unthinkingly. Xiahou Dun passed the information to the officers. First Secretary Yang Xiu heard the words and instructed the soldiers assigned to him to pack up and prepare for the journey home. This was reported to Xiahou Dun, who in amazement invited Yang Xiu to his tent and asked why he was preparing to leave. Yang Xiu replied, 'I knew by the night signal that the king of Wei would be returning in a few days. You see, chicken ribs have no meat on them, yet one relishes them for the flavor. If we advance, we cannot prevail. Retreat will earn us men's contempt. There's no advantage either way, so a quick return home is the best choice. Tomorrow His Highness will order us home to the capital; I thought I'd better put my things in order and avoid the last-minute rush.' " *[25]

Here, Cao Cao said "chicken ribs" first, and then Xiahou Dun passed the order "chicken ribs" to the other officers, so that Yang Xiu heard about this order. The word "chicken ribs" is not an assertive statement or even an imperative sentence. However, Yang Xiu inferred the conclusion that the army was about to withdraw, based on Cao Cao's order and the war situation at that time.

4.2 Correspondence

Correspondence is the relevance, which is the association between two basic objects in logical information model. This kind of association is different from the information relations. It is the association of information structure rather than information content.

[25] This paragraph comes from *Three Kingdoms : A Historical Novel*, First Edition., Luo Guanzhong, Foreign Languages Press, Beijing, 1994, Page 860, 861.

4.2.1 Correspondence between Conceptual Connotation and Words

Generally speaking, the connotation of concept is always associated with words, because concept needs to express its connotation through words as external. However, conceptual connotations and words are not completely one-to-one correspondence. One same word can express different conceptual connotations in different contexts, and one same conceptual connotation can also be expressed by different words. For example, "taxi" and "cab" can express the same concept. The words "laptop" and "笔记本电脑" can also mean the same thing. And "bugs" can refer to either insects or loopholes in computer programs.

Two words expressing the same conceptual connotation are in synonymy relation from the perspective of information relation. However, even in the case of synonymy relation, there are always differences between different words. Without considering the connotation of the different concepts other than the two synonymous concepts, the biggest difference between them should lie in their usage habits and usage scenarios. "Taxi" and "cab" are idioms in different regions, "laptop" and "笔记本电脑" are used in different language environments, and "compound of chemical formula H_2O" and "water" are respectively used in the professional domain of chemistry and general daily communication, etc. These differences can exist as the attributes of different words, or the conditions of words in synonymy relation, and be used for remarks.

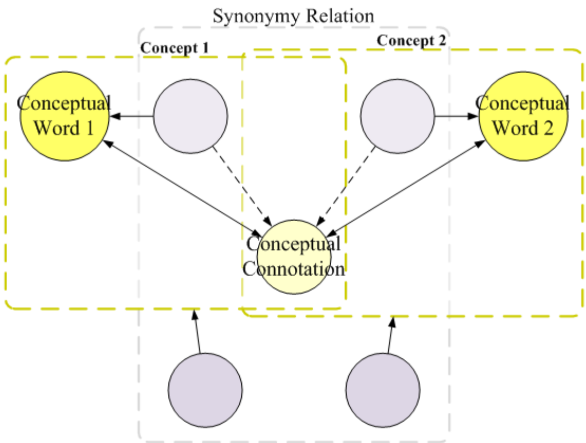


Figure 30: Diagram of the correspondence between different words expressing the same conceptual connotation.

On the other hand, when there is a word that can express different conceptual connotations, in order to distinguish the differences, it is necessary to use multiple groups of other words to make definition statements for their different conceptual connotations. For example, "physicist" and "electric vehicle company" are suitable definition statements for the word "Tesla" *[26], which respectively correspond to two different conceptual connotations.

But there is a problem ① here, that is, how to judge which connotation is exactly adopted by the word "Tesla" in a sentence? One approach we can take is to add some appropriate restrictive conditions to the various definition statements so as to make them better suited to the context in

[26] Nikola Tesla (1856 - 1943) was an inventor, physicist, mechanical engineer and electrical engineer. In 1960, in honor of his important contributions to the domain of electromagnetism, *General Conference of Weights & Measures* (French: Conférence générale des Poids et mesures, CGPM) adopted his surname "Tesla" (symbolized by T) as the international unit of magnetic flux density or magnetic induction intensity. In 2003, the electric vehicle and energy company named "Tesla" was established in California.

which the words are used. For example, it might be possible to add conditions, such as "in the category of 'human'" and "in the category of 'company'", to the definition statements of the two different concepts of "physicist" and "electric vehicle company". Then these two definitions can be stated as:

"In the category of human, Tesla is a famous physicist"

and

"In the category of company, Tesla is a well-known electric vehicle company".

When understanding the sentence ② "In 1882, Tesla successfully designed the first model of induction motor", it can be seen from the context that "Tesla" here should refer to a human, so we can at least exclude the option of "electric vehicle company" and focus on whether it conforms to the option of "physicist".

"Human" and "company" are the restrictive conditions of the two connotations of "Tesla" respectively, and they are also the attributes of the two connotations. Compared with "physicist" and "electric vehicle company" both of which are also attributes, they happen to be the concepts with greater denotation. From this, we can analyze that another way to answer question ① is to constantly adjust and enlarge the denotation of the definiens in the definition statement, so as to find the concept matching the context of the definiendum word and take it as the attribute of the definiendum. The denotation of "physicist" can be "human", or "scientist", or some other appellations. According to the context of sentence ②, it can also be roughly inferred that the word "Tesla" may correspond to the roles of "designer", "engineer", "inventor", etc., but none of these characters can be matched with "physicist". However, these roles all share a common word that can form an affiliation relation with them, which is "human". Coincidentally, "human" can also form an affiliation relation with "physicist", so that "physicist", one of the various connotations of the word "Tesla", can be corresponding to the context in sentence ②.

It is thus seen that a concept contains multiple connotations, each of which may be associated with different attributes and unique restrictive conditions. These attributes and conditions associated with particular connotations may help to identify the connotation of a concept in a specific context.

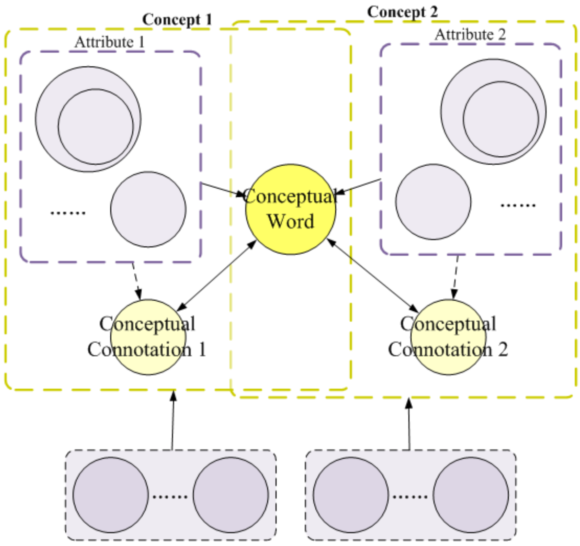


Figure 31: Diagram of the correspondence between different conceptual connotations expressed by the same word.

4.2.2 Correspondence between the Keys and Values of Attribute

There is a complex many-to-many correspondence between the connotations and expressing words of concept, and there is also a certain correspondence between the attributes affiliated to concept.

What is attribute? "**Attribute**" is a general term for the natures, characteristics, behaviors of concept objects, as well as the relations between objects, and so on. *[27] Attribute and concept are relative and inseparable. Concepts are concepts with attributes, and attributes are attributes of concepts. What attribute means to concept is equivalent to that evidence means to argument. The former is one of the components of the latter, and an essential part. Attribute comes with concept, and an attribute must have its corresponding concept.

In the epistemological point of view, concepts themselves are used to reflect the unique attributes and connotations of objects. In other words, the connotation of concept is not only the connotation of object, but also the unique attribute of the object. This is the most special and essential part of many attributes of the object. To distinguish one object from another is to judge whether the attributes of these objects are the same, which is like the pre-work required before making attribute mapping in analogical reasoning. Objects with the same attributes form one category, and objects with different attributes form different categories, thus constituting the classification of various things in the objective world.

A concept has its corresponding attribute, so the "concept" as a concept can also have its corresponding attribute, that is, "attribute". This statement seems like a mouthful and worthless, but it is actually a paradigm that can be generalized to other logical concepts. For example, "truth-value" is an attribute of the concept of "proposition", and "evidence", "conclusion" and "validity" are attributes of the concept of "argument", all of which conform to this paradigm.

The function of this paradigm can also be fully reflected in logical information model. In addition to these information elements corresponding to the logical concepts, there are also: "declaration" which is an attribute of proposer, "response" and "feedback" which are attributes of observer, "explanation" which is an attribute of doubt, "information relation" which is an attribute of several related types of information elements, and so on.

Attribute is usually divided into attribute name (namely key) and attribute value, that is, the so-called "key-value pair". Attribute names and attribute values are usually composed of one or more concepts, just as evidences and conclusions are composed of one or more propositions.

In terms of data type, the value of attribute name is generally based on character type, including natural language characters and symbolic language characters. The value types of attribute value are more diverse. For example, "Human is an animal with walking ability and no flying ability", in which "with ..." or "with no ..." (which can also be "yes" or "no") are one type of value; "Human is an animal with four limbs and five fingers at the end of limbs", in which "four" and "five" are one type of value; "Human is a gregarious and communicative animal", in which "gregarious" and "communicative" are also one type of value; "Human is an animal with emotions such as joy, excitement, sadness, anger, surprise and fear", in which "joy", "excitement",

[27] In *Dictionary of Logic* (Jilin People's Press, 1983), it is pointed out that attribute is "the nature of things and the relationship between them". The term "object" here covers all things and entities.

"sadness", "anger", "surprise" and "fear" are all one type of value. The data types of these values can correspond to the common data types in the domain of informatics, such as boolean, numeric, character and enumeration.

This form of attribute's key-value pair is a very common data structure in various software languages, and it is also very reasonable in natural language logic. This is also similar to the basic data structure of Knowledge Graph *[28], which is the current industry-leading knowledge repository model.

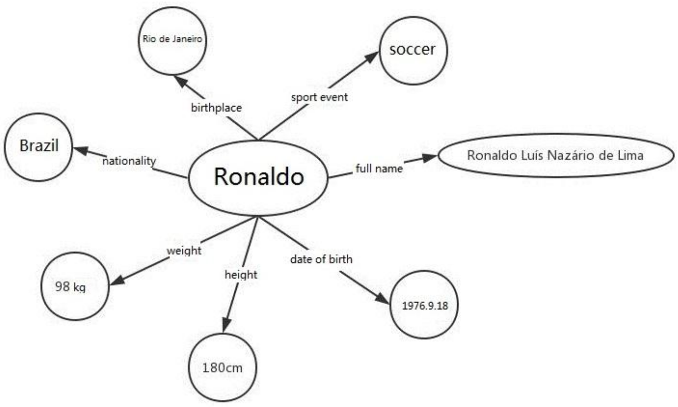
The logical structure of Knowledge Graph is composed of node and edge, which respectively represent "entity" and "relation" between entities. In its physical storage structure, it is more used in the form of triple such as "<entity, relation, entity>".

For example, "<Ronaldo, nationality, Brazil>" indicates that the "nationality" of "Ronaldo" is "Brazil" (Figure 32a). It can be seen that "<nationality, Brazil>" here is one of the many attributes of the object "Ronaldo". "Nationality" is the attribute name, and "Brazil" is the attribute value. This form is consistent with the characteristics of the type "attribute" in logical information model.

However, in practical application, the "relation" in the triple of Knowledge Graph usually does not purely refer to the subordinate relationship between concept and attribute. Instead, it forms an SPO triple of "subject-predicate-object" structure with the other two "entities", in which the "relation" actually plays the role of "predicate". For example, "<person, AtLocation, restaurant>" and "<restaurant, UsedFor, satisfy hunger>" respectively mean "The person is in the restaurant" and "The restaurant is used for satisfying hunger" (Figure 32b).

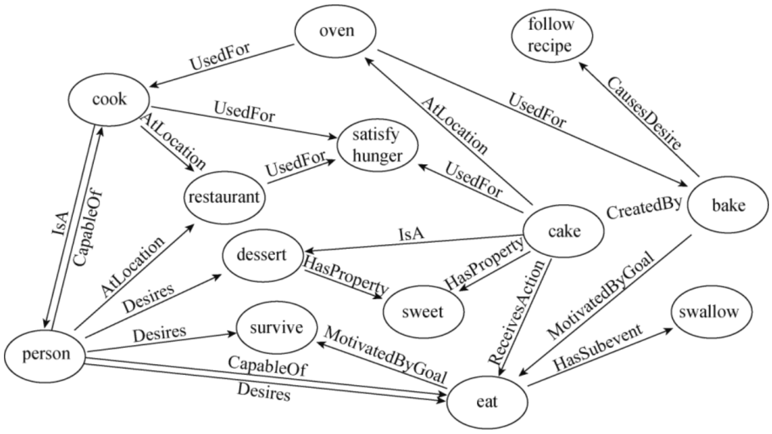
It is not difficult to understand that the triples of this structure more reflect the main components of propositions that can satisfy the paradigm of predicate logic. In other words, it can be used to express some propositions with relatively simple structure and some formal characteristics, but it cannot do anything about more complex propositions.

Meanwhile, it can be mixed with the relationship between concept and attribute, which makes the structure of the Knowledge Graph logically complex, confusing, uncontrollable and unreasonable. Comparatively speaking, the propositions and concepts in logical information model can be explicitly distinguished, and concepts and their attributes also have clear subordination order, so they are more precise in logical expression.



(a)

[28] The concept of "Knowledge Graph" was put forward by Google in 2012, which is essentially considered as a kind of semantic web, and its goal is to improve and enhance the function of search engine.



(b)

Figure 32: Example diagram of logical structure of Knowledge Graph. The pictures come from the network.

4.3 Conversion

Conversion refers to adaptation. On the basis of certain relevance, a matching mapping rule is established to facilitate the subsequent use of the rule, and output corresponding content in combination with relevant algorithms, or carry out appropriate operation and analysis.

These conversion behaviors can play a crucial role in the future human-computer interaction or the interpretability of model content.

4.3.1 Serialization

As an object in logical information model, a single information element can describe its connotation through a piece of text, which is a visible part of this information element. However, when multiple information elements are combined into an information element group, the visible text of each information element is not enough to reflect the connotation of the whole group by itself.

How to deal with this problem? Fusing is a solution, in which the proposer selects a group of source information elements, establishes the fused target information element on this basis, and declares the equivalence relation between them as the association. Based on the equivalence declaration of the proposer, the target information element after fusing can reflect the connotation of the group of source information elements before fused through its own text description.

Then, how is the text description of the target information element generated in the process of fusing? There are two possible approaches. The first is to completely declare it by the proposer. It is highly flexible in this approach that the expression and connotation of the target information element can be freely arranged without the restriction of the source information elements.

However, correspondingly, there will also be high equivalence risk in this approach, that is, the confidence level of the equivalence relation declared by the proposer is low.

The second is to use serialization to assist its generation. "**Serialization**" means that the proposer sets serialization rules for the information element groups and text language in advance, and when serializing is required, the rules are applied to the specified information element groups to obtain the text language after serializing. Serialization rules are not simply applied to superimpose the contents of source information element groups. They can be used in the process of producing fused information elements, or directly used for the mapping text expression output of the connotations of information element groups.

In general, we can serialize the information element groups of several specific relations.

4.3.1.1 Serialization of Argument

In logical information model, an argument can be a single information unit, a group of information units of proposition that serve as arguments and conclusion in an argument, or some other types of information elements can be added. Except for individual information elements, any other forms of arguments that need to be expressed in natural language must resort to serialization.

The ways of expression in natural languages are ever-changing. For a same thing, we can not only introduce it in simple and popular words, but also elaborate it through unusually complex or even obscure words. And for a complete argument described in natural language, no matter how it varies, no matter what terms are used in it, simply saying that it is actually expressing the causal connotation that can be described in the form of "because ..., (so) ...". Whether the one in front is conclusion or evidences, such as "because A, (so) B", "(conclusion)B, because A", etc.; Or different connectives of causality are used, such as "therefore", "thus", "so", "hence", "consequently", "proves that", etc., which are just different forms of expression. For example, "because birds have wings, they can fly", "birds can fly, because they have wings", "birds have wings, so that they can fly", and so on. These different expressions are all describing the connotations of arguments that are equivalent to each other.

No matter how complex an argument is, even a professional paper that runs to tens of thousands of words can be broken down into a certain number of combinations of arguments. Of course, the number may reach thousands or even more. In the final analysis, each of these arguments is a deformation of the form of "because [evidences], (so) [conclusion]".

Thus, we can set appropriate connectives of causality as standardized forms of argument expressions, such as "because ..., (so) ...", regard them as serialization rules in advance, and then apply the corresponding rules to the evidence elements set and conclusion element in the information element group belonging to the same argument, so as to produce the serialized text language.

Of course, the serialization rules used to produce text language are not invariable. Different proposers can customize different expression rules for connectives of causality and sentences according to their own needs.

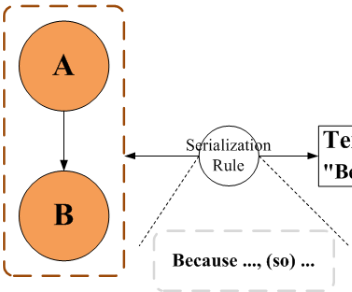


Figure 33: Diagram of the comparison and conversion between information element group of "argument" and text language expression.

Furthermore, not only evidence elements set and conclusion element, serialization rules can also cover other types of relevant elements in arguments, such as the conditions of argument or proposition.

Example 17:

"At standard atmospheric pressure, when the temperature drops to 0 ℃, water will gradually condense, so then water will go from liquid to solid."

The argument of Example 17 can be divided into two parts, which are the proposition of evidence and the proposition of conclusion. The proposition of evidence is "at standard atmospheric pressure, when the temperature drops to 0 ℃, water will gradually condense", in which the main part of the evidence is "water will gradually condense", and the relevant conditions are "at standard atmospheric pressure" and "the temperature drops to 0 ℃". The proposition of conclusion is "water will go from liquid to solid", the main body of the conclusion is itself, and it also implies the same conditions as the evidence.

We can set the serialization rule as: "because ... (under the condition of ...), (so) ...". By substituting the evidence, conclusion and conditions into the rule, we can get the statement: "Because water will gradually condense when it is at standard atmospheric pressure and its temperature drops to 0 ℃, water will go from liquid to solid."

It can be seen that the text statement obtained after applying the serialization rule has the same meaning as the statement in the original example.

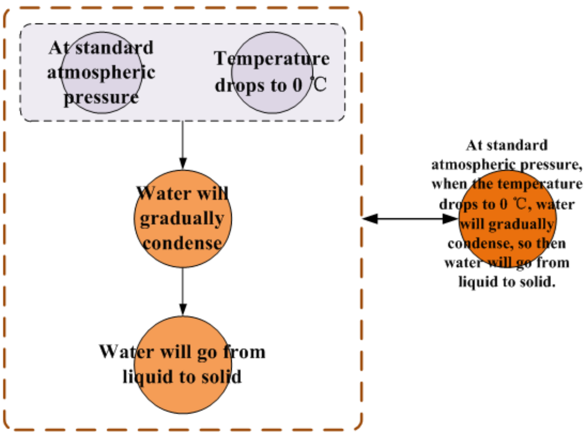


Figure 34: Model diagram of the information element group mapped by the argument of Example 17.

4.3.1.2 Serialization of Doubt

The connotation of an argument, a proposition or a concept can be embodied by a group of information elements. Similarly, what is related to a doubt can also be a group of information elements. In addition to the information unit of doubt itself, there will also be the target object of the doubt. When this group of information elements need to express their overall meaning in natural language, serialization is also necessary to be used.

When a doubt is expressed through a sentence (i.e. interrogative sentence, or question), due to the richness of language, the way of its elaboration can be diverse. To this end, it is necessary for us to briefly analyze the expressions of doubt.

In linguistics, we know that interrogative sentences are usually considered to have several different types, such as yes-no, alternative, special, disjunctive, rhetorical and so on. Except that the key point of rhetorical question and disjunctive question is not the internal doubt but to emphasize their tones, yes-no question, alternative question and special question are all doubt forms suitable for D&E relation. Yes-no question is used to inquire about "yes or no"; Alternative question asks responders to choose one of two or more options. Both kinds of questions are easy to understand. And what special question aims at is usually some specific content or a particular element of a sentence.

Here we will analyze the interrogative words which refer to the interrogative meaning in interrogative sentences.

Since doubt is a common thinking mode of human beings, interrogative sentences as its external expression have good language compatibility, and the corresponding interrogative words also exist in various natural languages, so it is unnecessary to worry that they are unique to a certain language.

Referring to the famous "5W2H method", it focuses on seven common special interrogative words (WHAT, WHEN, WHERE, WHO, WHY, HOW and HOW MUCH) as its core. In addition, there are WHICH, WHOSE, HOW MANY, HOW OLD, HOW LONG, HOW FAR and so on, which are also commonly used interrogative words. The referential content of these special interrogative words covers almost all sentence elements, including thing, time, place, person, reason, degree, quantity, choice, and other conditions.

According to this, we can further sort out these interrogative words. In the case of unchanged semantics, we can make some deformation and adjust them to the form based on the interrogative word "WHAT". For example, "WHEN" can be changed to "WHAT THE TIME"; "WHERE" can be changed to "WHAT THE PLACE", etc. The details are shown in Table 2.

Table 2: Mapping relation between interrogative words and their serializations of the connotations.

Interrogative Words	Conversion	Corresponding Target Objects
WHAT	WHAT THE THING	THE THING
WHY	WHAT THE REASON	THE REASON
WHEN	WHAT THE TIME	THE TIME
WHERE	WHAT THE PLACE	THE PLACE
WHO/WHOM	WHAT THE PERSON	THE PERSON
WHOSE	WHAT THE OWNER[OF SOMETHING]	THE OWNER
WHICH	WHAT THE CHOICE[OF SOMETHING]	THE CHOICE
HOW	WHAT THE DEGREE[OF SOMETHING]	THE DEGREE
HOW MUCH	WHAT THE PRICE[OF SOMETHING]	THE PRICE
	WHAT THE QUANTITY[OF SOMETHING]	THE QUANTITY
HOW MANY	WHAT THE QUANTITY[OF SOMETHING]	THE QUANTITY
HOW OLD	WHAT THE AGE[OF SOMETHING]	THE AGE
HOW LONG	WHAT THE LENGTH[OF SOMETHING]	THE LENGTH
HOW FAR	WHAT THE DISTANCE[OF SOMETHING]	THE DISTANCE
……	……	……

Then, we come back to the alternative question and yes-no question. Obviously, alternative question has the same expression effect as "WHICH", and can be considered equivalent to "WHAT THE CHOICE". And yes-no question is used to inquire about "yes or no", which in general can be understood as an inquiry about the truth-value of some proposition or the validity of some argument. For example, the questions "Do gravitational waves really exist?" and "Can humans dive to the bottom of the Mariana Trench?" maybe respectively inquire about the propositions "Gravitational waves exist" and "Humans can dive to the bottom of the Mariana Trench".

It can be seen from Table 2 that the specific interrogative words, including but not limited to which listed in the table, are all used to inquire about "WHAT" a piece of certain content is. These contents are either propositions and arguments themselves, or conditions in propositions and arguments, or conceptual terms in propositions and arguments, or relations between multiple propositions and arguments, and so on. As the target objects of doubt, these contents are related to the doubt object itself, and jointly determine the statement form of the doubt. Each interrogative word determines a category of doubt objects, and the doubt object of each category can be serialized into a specific statement form of natural language.

For example, in response to the argument of Example 2 in the preceding text, we can raise the following questions: "What is mitochondria?", "Where is Africa?", "How long does African people have their evolutionary history?", "Who concluded that African people had the longest evolutionary history?", "Why is it a probable African origin for modern humans?", "Did the greatest mitochondrial variations occur in African people?", etc. These interrogative statements respectively correspond to the types of doubt objects such as thing, place, time, person, reason, and truth-value of proposition and so on.

From the perspective of linguistics, such interrogative statements can undoubtedly be summarized into some standardized statement forms, such as "WHAT BE ...?", "WHERE BE ...?", "WHO BE ...?", "WHY DO ...?", "..., ISN'T IT?" etc. (Table 3). Targeted semantic analysis can help us determine the expression of interrogative word and rules of sentence structure.

Table 3: Mapping relation between interrogative words and serialized expression rules of text languages.

Interrogative Words	Expression Rules of Text Languages
WHAT	WHAT BE ...... ?
WHY	WHY DO ...... ?
WHEN	WHEN DO ...... ?
WHERE	WHERE BE ...... ?
WHO/WHOM	WHO BE ...... ?
WHOSE	WHOSE BE ...... ?
WHICH	WHICH ...... DO/BE ...... ?
HOW	HOW ...... DO/BE ...... ?
......	......

Of course, in practical application, different sentences have different rules of structure in different scenarios, which requires extremely complex language grammar rules to support.

Moreover, the expression of these interrogative words and the rules of sentence structure can also be adjusted by the proposer according to the actual scene and language habits. For example, "WHAT IS ...?" can be replaced with "WHAT'S ...?".

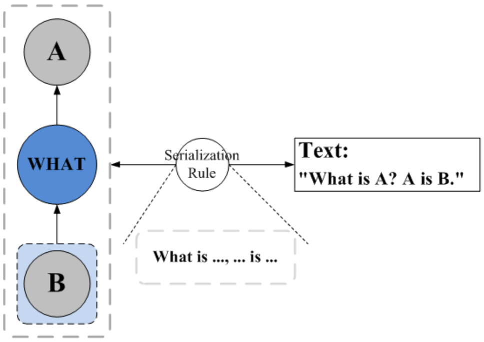


Figure 35: Diagram of the comparison and conversion between information element group of "doubt" and text language expression.

4.3.1.3 Other Serializations

In addition to argument and doubt, there can also be some other serializations of common information element groups in the model, such as the information unit combination between proposition and truth-value of proposition, the information unit combination between argument and validity of argument.

Truth-value of proposition is always associated with proposition, and when describing the truth-value of a proposition, it is naturally inseparable from the proposition. The information element group combined by the information unit of truth-value of proposition and the information unit of proposition can be serialized into sentence expression rules of text languages, and the rules can be very intuitive, just like **"The truth-value of the proposition '...' is ..."**.

Similar to truth-value of proposition, validity of argument is closely related to argument. The information element group combined by the information unit of validity of argument and the information unit of argument can also be serialized into text language by sentence expression rules in the form of **"The validity of argument '...' is ..."**.

If the conditions of proposition / argument are added, the combination of information unit groups such as "condition + proposition + truth-value" and "condition + argument + validity" can be formed. The sentence expression rules for their serialization into text languages can be as follows:

"condition + proposition + truth-value": **"Under the condition of ..., the truth-value of the proposition '...' is ...";**

"condition + argument + validity": **"Under the condition of ..., the validity of argument '...' is ...".**

Then if we add proposer and observer, we can form the combinations of various information unit groups, such as "proposer + proposition", "proposer + argument", "observer + proposition + truth-value", "observer + argument + validity", "proposer + proposition + observer + truth-value", "proposer + argument + observer + validity". The sentence expression rules for their serialization into text languages can be as follows:

"proposer + proposition": **"(the proposer)... says: (the proposition)'...', or "(the proposer)... states that (the proposition) '...' [is true]";**

"proposer + argument": **"(the proposer)... says: (the proposition)'...', or "(the proposer)... states that (the argument) '...' [is valid]";**

"observer + proposition + truth-value": **"(the observer)... considers that, [the truth-value of the proposition] '...' is (the truth-value)...";**

"observer + argument + validity": **"(the observer)... considers that, [the validity of argument] '...' is (the validity)...";**

"proposer + proposition + observer + truth-value": **"(the proposer)... says: (the proposition)'...', and (the observer)... considers that, [the truth-value of] it is (the truth-value)...";**

"proposer + argument + observer + validity": **"(the proposer)... says: (the proposition)'...', and (the observer)... considers that, [the validity of] it is (the validity)...".**

4.3.1.4 Deserialization

Since there can be "serialization" behavior of converting the content of information element group into text, in principle, there can also be "**deserialization**" of converting text content into information element group. Similar to serialization, deserialization also needs to rely on the declaration of proposer or apply the deserialization rules set in advance, but the method of setting deserialization rules should be more complex.

Either serialization or deserialization is a form of information element variation in logical information model. They are conducive to associating the element objects in the model with the natural language expression, so that the model content can be observed in an expression way that is easy to understand, and it is also convenient to flexibly convert the natural language introduced from the outside into the objects in the model. This will be very helpful for further understanding, presenting, expanding the model, and applying various model capabilities.

4.3.2 Symbolization

Serialization is the conversion between information element group and text language, while "**symbolization**" is the conversion between natural language and artificial language in the text content of information element.

Mathematical logic is a system of logic that uses a lot of symbols, and the phenomenon of symbolization has long been quite common in mathematical logic. One of the most common, in addition to the symbolization of quantifiers in first-order logic, is the symbolization of connectives in propositional logic. The artificial language symbols "¬ (or ~)", "∧", "∨" , "→", "↔" are used as Symbolized logical connectives to respectively map the words "negation", "conjunction", "disjunction", "implication (or conditional)" and "biconditional" in natural language.

Artificial language symbols are mainly used in propositional expressions, and then participate in propositional truth-value calculus. Compared with artificial language, natural language has more diverse ways of expression, which is more conducive to be understood and appropriate for communication.

Similarly, there can also be symbolized mapping relations in logical information model.

4.3.2.1 Symbolization of Truth-Value of Proposition

In most cases, we are used to expressing the truth-value of a proposition in terms of "true or false" in two-valued logic. "True and false" is the true-value connotation of binary logic, but it is not the only way in expression.

In Boolean logic, which was proposed in the 19th century by the British mathematician George Boole, "1" represents that the proposition is determined to be true, and "0" represents that the proposition is determined to be false. This way of expressing the truth-value of proposition with {0, 1} numeric set, combined with various equivalent calculus formulas, is convenient for combining a large number of functional propositions for substitution and calculation, and finally can calculate the result of complex propositional function, i.e. the numerical truth-value of proposition. This series of creative changes brought great breakthroughs to the development of mathematical logic and other disciplines based on it. Nowadays, in most computer programming languages, "0" and "1" (or "0" and "non-0") are used to represent "TRUE" and "FALSE" in Boolean values.

Three-valued logic which is derived from two-valued logic generally uses a set of three elements similar to {0, 1, u} as its true-value set, that is, another element is added in addition to "0" and "1". Different systems of three-valued logic have different understandings of the true-value "u", resulting in different stipulations of truth-value. Kleene's three-valued logic interprets the third truth-value "u" as a gap between true and false, an "unknowable" truth-value, which is a conclusion from the perspective of "computability". Lukasiewicz's three-valued logic regards the truth-value "u" as the truth-value of a proposition that has neither reason to be determined as true nor reason to be determined as false. This approach can be understood as putting aside true or false (namely the truth) of such propositions without distinguishing them, but only giving them a value "u" to indicate their difference from the truth-values of "0" and "1". Bochvar's three-valued logic holds that "u" is the truth-value agreed upon the meaningless propositions, such as the semantic paradox "This sentence I wrote is a lie".

Different from three-valued logic, infinite-valued logic usually refers to the system of logic that takes the interval of real numbers [0, 1] as the truth-value set, in which the typicals are "Lukasiewicz's infinitely valued logic" ($L\infty$), and "Rescher's probabilistic logic" (RPL).

The different claims of these systems of logic on truth-value lay a foundation for the definition of the value range of truth-value object in logical information model. For a proposition in the model, we can use "TRUE", "FALSE" or "0", "1" to represent its truth-value, or we can also use "true-false gap" (Kleene), "no reason to be determined as true or false" (Lukasiewicz), "meaningless" (Bochvar), and the interval set of real numbers [0, 1] in infinite-valued logic, etc., or even new definitions of truth-value that may appear outside these existing systems of logic, to reflect the truth-value connotation of what it is mapping.

"TRUE" and "FALSE", "1" and "0" of two-valued logic represent the most common description of truth-value in natural language and artificial language respectively. In many-valued logic, although truth-value is mostly described in the form of artificial language, it can also be described by corresponding natural language. Natural language symbols and artificial language symbols can correspond to each other one by one, just as different natural language systems can translate each other.

The artificial language that uses number "0" and "1" and the interval set of real numbers [0, 1] to represent truth-value is mainly to facilitate doing the truth-value calculus in mathematical logic. The value got in the interval of real numbers [0, 1] depends on probability and statistics. Currently, probability and statistics are primarily considered mathematical disciplines, but they are also one of the important parts of inductive logic. The significance of combining probability theory within inductive logic is that we can use quantitative methods to study probabilistic logic. Coupled with the abundant achievements of probability acquired in the domain of mathematics, these study methods are made more efficient. And it also helps to provide corresponding logical theoretical support for the research of other probabilistic scientific domains. Natural language is mainly used for expression, which is more convenient for others to understand the truth-value of proposition than artificial language. When truth-value cannot be determined by accurate probability value, it is more appropriate to use natural language for approximate description.

In logical information model, we can declare the truth-value of proposition, as well as the dataset used for the truth-value of proposition. The data in the dataset can be based on natural language, or contain both natural language and artificial language that map to each other. As shown in Table 4, each artificial language expression of probability value corresponds to a natural language expression. Of course, this is just an example. Each proposer is free to declare an independent standardized truth-value set, rather than completely following the contents in Table 4.

Table 4: Example table of mapping relation between the descriptions of the truth-values of proposition.

Artificial Language Expression	Natural Language Expression
--	meaningless
1 / 100%	determined to be true
0%≤u≤100%	not sure whether true or false
u<100%, u→100%	almost true
75%<u<100%	more likely to be true
50%<u<75%	tend to be true
50%	half true, half false
25%<u<50%	tend to be false
0%<u<25%	more likely to be false
u>0%, u→0%	almost false
0 / 0%	determined to be false

For another example, we are also able to use a series of degree modifiers to describe the degree about the content of a statement in daily practical application scenarios, which is equivalent to limiting the truth-value of the proposition statement itself. Just like that in Figure 36, we can map a number of modifying adverbs from "never" to "always", to the probability value range from 0 (0%) to 1 (100%). While filling the corresponding adverb into the example sentence "We ___ go there.", it is equivalent to expressing a numerical reflection of the truth-value of the proposition "We (always) go there."

Figure 36: Diagram of mapping relation between the descriptions of the truth-values of proposition. The picture comes from the network.

4.3.2.2 Symbolization of Validity of Argument

Likewise, the validity of argument can also be symbolized between natural language and artificial language, which is similar to the truth-value of proposition. Moreover, from the two aspects of deduction and induction, the validity of argument is also many-valued.

As we all know, the goal of deductive logic is to distinguish between valid argument and invalid argument, that is, a deductive argument must be "valid" or "invalid", which can also be said to be a "completely tenable" or "completely untenable" argument.

The argument in inductive logic is only probabilistically "valid" or "invalid", and its premises do not necessarily support the conclusion. To describe the validity of inductive argument qualitatively, words such as "better" or "worse", "stronger" or "weaker" are usually used. If we want to describe the validity quantitatively, we also need to rely on the method of probability and statistics. Usually the probability value is also based on the interval of real numbers [0, 1]. According to the size of the probability value, we can also describe it in the corresponding natural language. (As shown in Table 5)

Table 5: Example table of mapping relation between the descriptions of the validity of argument.

Artificial Language Expression	Natural Language Expression
1 / 100%	valid / completely tenable
u<100%, u→100%	almost valid / almost tenable
50%<u<100%	more likely to be tenable / better / stronger
50%	half valid / half tenable
0%<u<50%	more likely to be untenable / worse / weaker
u>0%, u→0%	almost invalid / almost untenable
0 / 0%	invalid / completely untenable

4.3.3 Conversion between D&E and Inference

In essence, each conversion is actually based on some kind of mapping relation. Serialization is based on object-expression mapping, and symbolization is based on natural-symbolic language mapping.

In addition, we can also see the mutual mapping between some information unit group of D&E and information unit (group) of argument. For example, in the interrogative sentences of natural language, the basic expression form of the "WHY" question, which doubts the reason (or cause) of things, can be simplified to "Why A? Because B". If it is converted into a form to describe the relation between A and B, it could be "Because B, so A", which is a typical expression of argument.

Such form conversion will not bring ambiguity or metamorphism of connotation. In other words, if the two things can be used as evidence and conclusion in an inference to form a naive argument, the evidence in them can also be used to answer the question of cause for this conclusion, and vice versa.

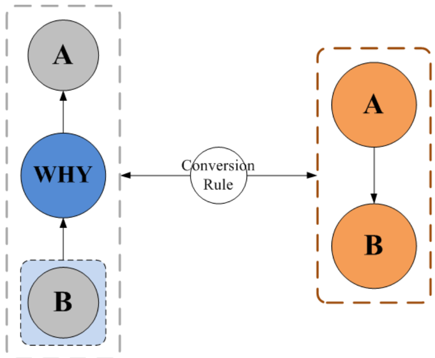


Figure 37: Diagram of the comparison and conversion between information element group of "D&E" and information unit group of "argument".

5. Logical Information Network: Characteristics

The previous chapters focused on the basic structure of logical information model. After the model is formed, and a large number of model elements are constructed according to this model, a network of information elements of a certain scale, combined with the relations between them, can be organized. As the scale of information network becomes larger and more complex, many unique characteristics that fit complex network may be derived accordingly.

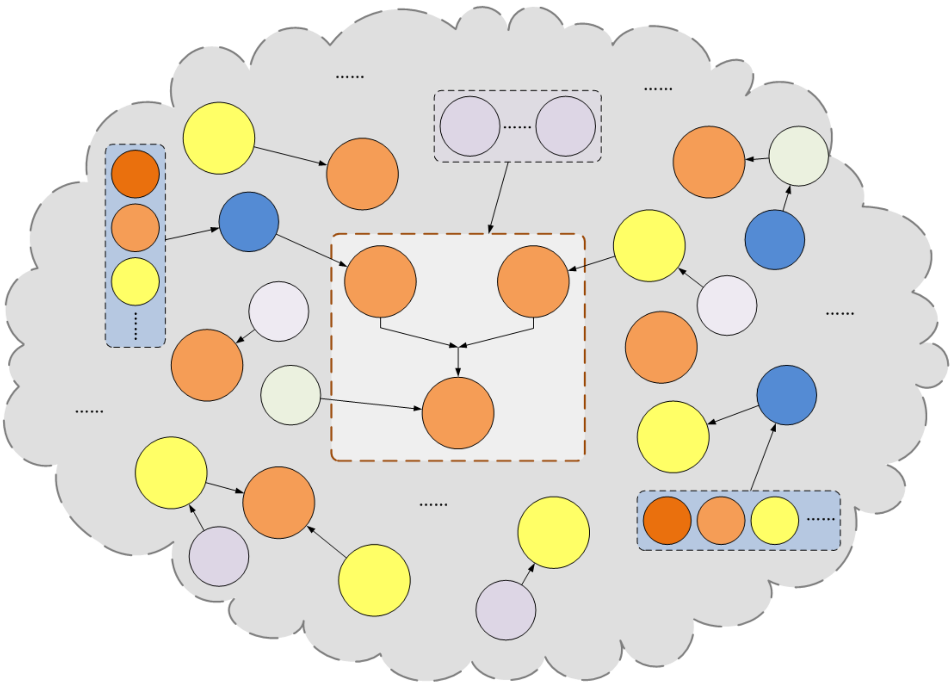


Figure 38: Diagram of logical information network.

5.1 Fragmentization

In a logical information network, the acts fusing and separating between information elements can be used to produce more information elements. If an article of about thousand words is regarded as an information section in the logical information network, there may be hundreds or even thousands of new elements that can be separated from it. Predictably, when there occurs a large number of acts of fusing and separating, it will inevitably lead to a lot of **fragmentary elements** flooding the logical information network.

In addition to fusing and separating, as a proposer within a certain authority, each network visitor can create independent information elements in the form of single entity, which is also an important way to produce fragmentary elements.

Obviously, **fragmentization** is an inevitable trend in the actual operation of logical information network. It can be used to produce larger or smaller elements.

It is noteworthy that more and smaller fragmentary elements are produced in the process of separating the larger fragmentary elements, which usually contain smaller connotation and less information. Such fragmentization tends to make the information connotation in larger fragments more precise and detailed. In the process of gradual fragmentization, a large number of compound and complex information will be discarded, while the interference caused by it will be reduced. Smaller and more detailed information units help observers focus on those tiny and independent points of information and grasp the deeper details of object.

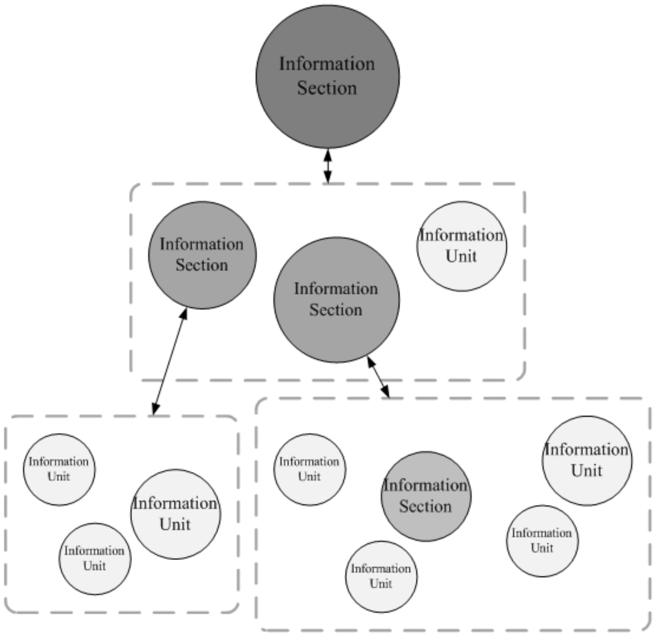


Figure 39: Diagram of the fragmentization of information elements.

5.2 Hierarchicalization

In the process of fragmentization, the source and target information elements of an act of separating are single information element with large connotation and multiple information elements with small connotation respectively. If one of the target information elements is further separated, multiple information elements with smaller connotation can be obtained again. In this way of continuous separating, we can obtain a sequence of information element sets with continuously decreasing connotation size. Correspondingly, the same goes for the act of fusing.

By expanding the set of information elements in the sequence, a tree diagram composed of information elements can be obtained. The root node of the tree is the source information element of the first act of separating, or the target information element of the last act of fusing. In brief, this is the information element with largest connotation in the sequence.

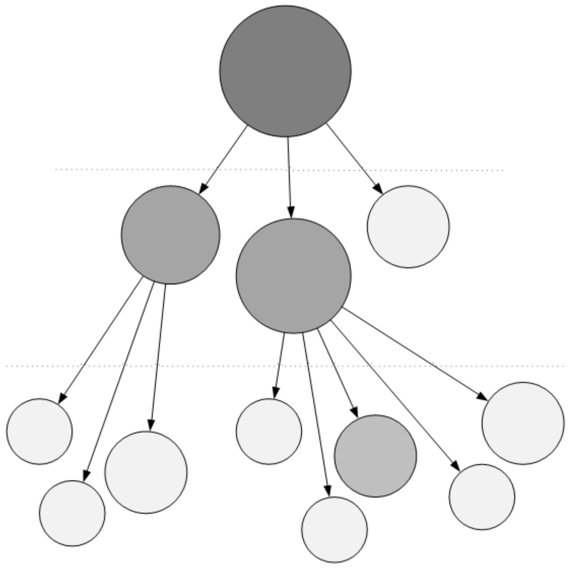


Figure 40: Diagram of the hierarchicalization of information elements.

It is clear from Figure 40 that different levels can be clearly distinguished by dividing the fragmentary elements produced by each act of separating or fusing.

Since all the fragmentary elements produced by fusing and separating are independent but not isolated, and their connotations are derived from the relevant source information elements, so there must be overlapping parts between the two connotations. Because of these overlapping connotations, there is a natural relation between these information elements. This connection is not only the relation between the source information elements and the target information elements in each act of separating or fusing, but also the relation between adjacent levels. So it is called "**hierarchy relation**".

Compared with the information in pure text form, **hierarchicalization** can provide observers with a multi-level perspective that is different from the flat text form to learn its connotation more comprehensively. We can break it down and divide the hierarchy in different ways. Perhaps the most convenient and intuitive one is to divide it into several levels, such as article, paragraph, sentence, phrase, word and character, according to our current understanding of the structure of articles. Of course, this division can also be adjusted according to different language characteristics. For example, the levels of word and character are feasible in Chinese language families, while in mainstream Western language families, they may need to be modified to the levels of word and letter.

5.3 Networking

The proposer's original information elements are another important way to produce fragmentary elements in addition to the acts of fusing and separating, including completely independent elements and some elements derived from other information elements. For example, establishing new arguments; adding more evidences to the conclusion of an argument; setting conditions for a proposition; adding a new definition for a concept; doubting about an information unit, then creating propositions as an explanation, and so on.

Different from the fragmentary elements set produced by fusing and separating with distinct structural characteristics of layers, what is more reflected between these original elements is that the topological network structure without specific order or with complex order. When the two network structures, ordered hierarchicalization and disordered **networking**, are combined together, a complex network form is formed. Once a logical information network of certain scale is built, the information elements in it will inevitably develop in the direction of hierarchicalization and networking in the meantime, and it is difficult to make the situation directly happen, in which the two network structures are separated completely or there is a simpler network structure.

The topological structure of this complex network conforms to the category of "network" studied in the domain of mathematical graph theory in essence. In a logical information network to be deeply researched, the information elements are nodes, and the relations between elements are edges connecting nodes. Some relations have tendencies, which set directions for the edges. They could be the direction from cause to effect, or the direction in which the information elements are continuously separated and refined. Some edges can be assigned with real weights to form a weighted graph, and the weights can be the symbolized truth-value of proposition, or the symbolized validity of argument, etc. After identifying these partial features in the model, we have the basis for in-depth analysis and research of the complex characteristics of the network which is based on the model.

However, if we want to apply mature graph theory research methods and algorithms to analyze and study a potentially huge complex network structure, it will be a suitable way to select a limited set of local network elements, or a set of information elements for a particular aspect, by proper means of slicing and dicing. For example, selecting all the direct information elements of proposition in an argument, or selecting all the information elements of concept related to a proposition, or all the information elements of concept that conform to a keyword retrieval, and so on.

The selected local network may be an information element group, or a group of information elements that are unrelated to each other. We can call this group of information elements an "**information cluster**".

A large-scale logical information network must also be an information network within the scope of complex network theory. Although there has not been any complete example of logical information network, it is not difficult to predict that in the near future, once logical information model is popularized and logical information network can develop rapidly, the massive information contained in it will be very worth observing its statistical characteristics. Whether it exhibits the statistical characteristics such as "small-world" or "scale-free" possessed by classical complex networks, or there are some other characteristics different from this. Such research is of positive significance not only to the development of logical information network, but also to the further exploration of complex network theory.

5.4 Quantifiability

5.4.1 Quantifiability

The information elements in logical information network can be separated, and the information contained in its connotation can be continuously dispersed into the connotations of smaller elements in the process of fragmentization.

Assuming that there is such a kind of monomeric information, whose connotation as information element is inseparable, and all information can be combined (or fused) by several monomeric information, this monomeric information can be called "**quantum information**". *[29] It can be predicted that the ultimate separation of an information element is the emergence of an information element with quantum information as its connotation, or called "**quantum information element**". This also means that, theoretically speaking, in a logical information network with positive information production orientation, the overall situation will gradually tend to be that the connotations of all information elements can be combined by the connotations of quantum information elements within the network. The logical information network that achieves this state can be called "**quantum information network**".

For us, the significance of quantum information network lies in the **quantifiability** of information.

In daily written communication, information is the connotation of what is conveyed, and text is its extension. Text can be easily quantified by the number of characters, which is an important index to measure the information contained in it. However, there is no evidence to show that there is a strict positive proportional linear relationship between the length of text and the amount of information it contains. It can be said that there is only a certain positive correlation between them. In other words, text describing the same thing can be long or short, or text of the same length can convey information that varies greatly in measure. Therefore, it is difficult to accurately quantify the amount of text information at present. However, as a special logical information network, the information elements in quantum information network are discrete and countable. Obviously, this can be through some effective and efficiency controllable technical means, to its non-dynamic changes in the number of information elements for a variety of counting, statistics and other operations. This will be a major technological change for the existing fields of statistics and measurement.

[29] "Quantum" is the smallest indivisible unit of matter or energy in theory. In the domain of physics, the term "quantum information" refers to the physical information contained in the "state" of quantum system, which has nothing to do with what is referred to in this article.

5.4.2 Redundancy

In hierarchicalized networks, there are overlapping connotations between the source and target information elements of the acts fusing and separating, which makes these connotations convey repeated information. In other words, the acts of fusing and separating will objectively produce a lot of redundant information.

Redundancy will occupy more storage space for information, but redundancy does not mean uselessness. In the current computer technology, it is often used to increase redundant data in the process of data persistence to improve the query performance of the system or application. This method is a very effective means for the current situation that the development of storage hardware technology is much faster than that of computing hardware technology. On the other hand, there is a hierarchy relation between these redundant information elements. Being maintained on the same relation makes it easy to establish data indexes in the data storage phase. Therefore, redundant information will be beneficial to various daily operations for information systems like logical information network, such as responding to users' high-frequency access requests, and doing massive data mining.

5.4.3 Knowledge Measurement

Knowledge comes from the refinement of information and is information of public value. If information can be quantified, knowledge is no exception.

In addition to counting the quantity of knowledge, we can also measure the complexity of knowledge. The complexity of knowledge in atomic information network can be expressed from two dimensions: breadth and depth.

A knowledge point usually refers to a concept or argument. Its breadth mainly refers to "what it is", which is usually related to the definition of concept, attribute, condition or condition of argument and proposition, etc. The associations between these information elements tend to be flat, so they are primarily based on horizontal measurements. And its depth mainly refers to "why it is", which is related to the argument of conclusion, including the evidences corresponding to conclusion, etc. A complete argument usually requires multi-step cascade inference, so most of the information elements within it present a trend of vertical correlation.

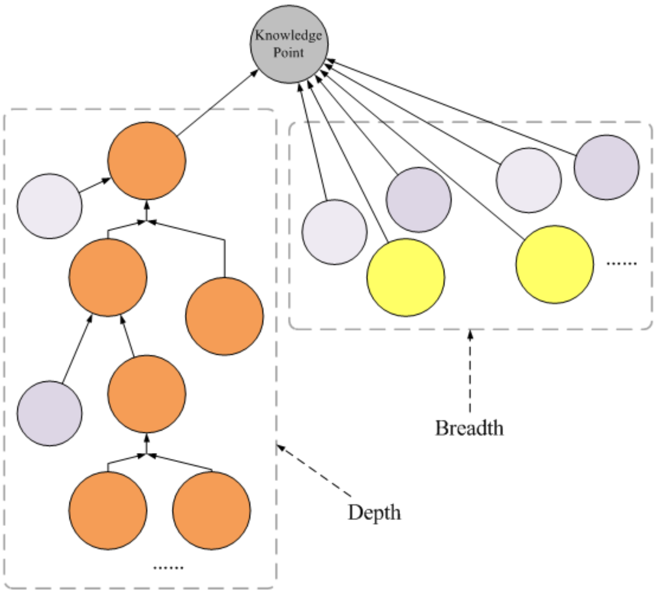


Figure 41: Diagram of the breadth and depth of knowledge complexity.

5.5 Visualization

When the data of any form of information network reaches a certain level, it is difficult to intuitively present the intricate data relations and complete information of connotation simply by relying on text expression, and there is no exception for logical information network. **Visualization** technology, which has been gradually developed in recent three or four decades, is the most direct and effective way to show the topological relationships among many elements in a network in order to cope with the increasingly complex network structure.

Visualization technology can transform a great deal of abstract and complex data information into intuitive graphics. In the form of visual interaction, users can more easily explore and discover the characteristics, relationships and laws implied in the data, promote their understanding of things and the formation of their overall concept, and effectively improve the creation and transfer of information or knowledge among many people.

At present, the commonly used network visualization tools can be roughly divided into two categories: one is the graphical interactive software that is easy to operate and understand, such as Gephi, UCINET, Cytoscape, etc.; The other one is the applications or plug-ins based on programming language that require coding or scripting, such as NetworkX (based on Python), networkD3 (based on R), iGraph (based on Python, C and R), Graphviz (based on DOT), JuliaGraphs (based on Julia), etc.

These visualization tools are designed for complex networks in a broad sense. A network of any form, whose elements can be abstracted into two types, nodes and edges, fits the category of "complex network", and these tools can be applied. Therefore, the related functions and algorithms of visualization, such as appearance, layout, statistical analysis, data filtering and so on, are also completely carried out around these two element types.

However, they are not appropriate for logical information network. In other words, they are difficult to be applied directly. Although from the perspective of graph theory, the information elements in logical information network can also be roughly classified as nodes and edges, the basic model of logical information network is more complicated than the general complex network consisting of only nodes and edges. As can be seen from the previous text, there are dozens of node types of logical information model alone, and the types of edges (namely relations) can also be defined by proposer, and the number is not limited. This will lead to the traditional rendering algorithm of complex network cannot fully meet the requirements of the visualization function of logical information network. It is necessary to target to expand and optimize the existing algorithms or customize special tools.

Furthermore, in terms of purpose, most of the current visualization is used to provide enterprise users with data analysis and assist in decision-making and planning, or provide scientific researchers to study the macroscopic properties of specific complex networks, and then summarize general laws. Besides the above functions, the visualization of logical information network should also provide the networked presentation of personal information for individual users to analyze their own information data. In addition, the study of different types of logical relations between information elements in local logical information network can also use the help of visualization.

6. Logical Information Network: Advanced Capabilities

The model structure of logical information network integrates the basic concepts of logic and informatics. It can not only meet the existing laws of logic, but also serve as a container of huge amount of information. Due to the characteristics of these model structures, the information network constructed by these models can fulfill some complex logic and information capabilities.

6.1 Logic Capabilities

6.1.1 Logicality

The reason why logical information model is called "logical" information model is that compared with other information models or models of information system and knowledge repository, the biggest difference lies in its "**logicality**". Logicality means that we can make the data in logical information model follow the most basic laws in logic.

Throughout the development history of logic, Aristotle, who is widely regarded as the "father of logic", established the first rigorous deductive logic system with categorical syllogism as the core. Syllogism plays an extremely important role in the research and development of logic, mathematics and even all other natural sciences. As the basic part of mathematical logic, restricted predicate logic evolved from syllogism. On the premise of 23 definitions, 5 postulates and 5 common notions (namely axioms), Euclid deduced 465 propositions (namely theorems) in *Elements of Geometry* with syllogism, forming the logical system of Euclidean geometry. Since then, all kinds of more common scientific theoretical systems have basically adopted a similar axiomatic approach based on syllogism. Syllogism has far-reaching influence.

In general, syllogism theory covers all the elements of deductive logic. It deals with the forms study of proposition and reasoning, i.e. all the forms and laws from premises to conclusions in the reasoning process. The reasoning form of syllogism, usually called major premise, minor premise and conclusion, is essentially a deductive argument that deduces a conclusion from two premises. This form is consistent with the naive argument-proposition model in logical information model.

Syllogism has some specific rules. Taking categorical syllogism as an example, it is currently considered that there are 15 valid forms of categorical syllogism, which are distinguished by different types of the form of their categorical propositions. According to their quality and quantity, these categorical propositions can be divided into four types: universal affirmative propositions (A), universal negative propositions (E), particular affirmative propositions (I) and particular negative propositions (O). The concepts of "quantity" and "quality" here can both exist as the conditions or attributes of proposition object in logical information model. These valid forms of syllogism can be determined by definition, and then they can be taken as conditions to declare the validity of the argument object of syllogism.

For example, argument ① of Example 9 is a typical categorical syllogism of the form AAA-1. Categorical syllogism of the form AAA-1 can be defined as: "This is a syllogism in the form of 'all M is P, all S is M, so all S is P'". We can break the content of this example into the following element types:

① The argument: i.e. the syllogistic argument itself;

② The propositions: "All mammals have lungs", "All whales are mammals", "All whales have lungs";

③ The concepts: "mammal", "whale", "have lung", "lung", "all";

The form of their relationship in logical information model can be seen in Figure 42.

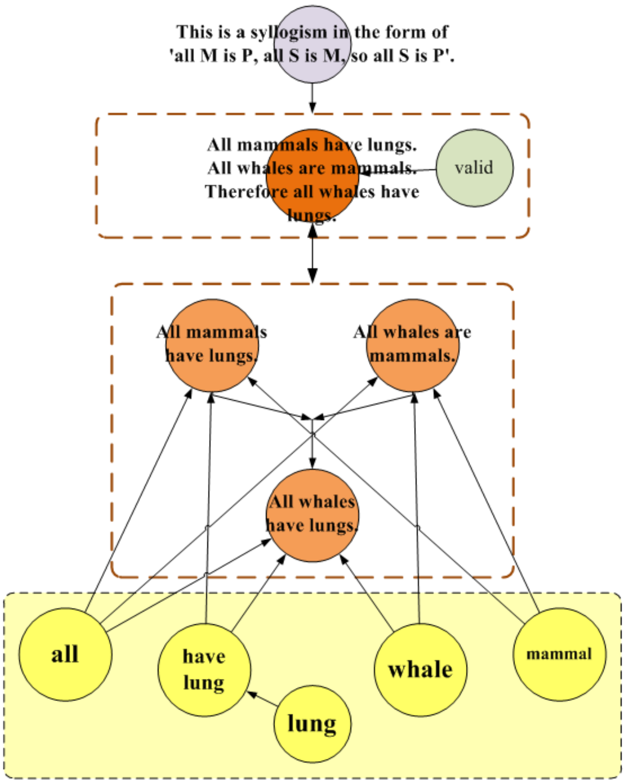


Figure 42: Model diagram of the broken content of argument ① in Example 9.

For another example, argument ② of Example 9 is a categorical syllogism of the form EIO-2, which can be defined as: "This is a syllogism in the form of 'no P is M (or all P is not M), some S is M, so some S is not P'". We can break the content of this example into the following element types:

① The argument: i.e. the syllogistic argument itself;

② The propositions: "All soldiers who want to be generals are not cowards", "Some soldiers are cowards", "Some soldiers don't want to be generals (i.e. Some soldiers are not the soldiers who want to be generals)";

③ The concepts: "want to be general", "general", "soldier", "coward", "all", "some", "no / not";

The form of their relationship in logical information model can be seen in Figure 43.

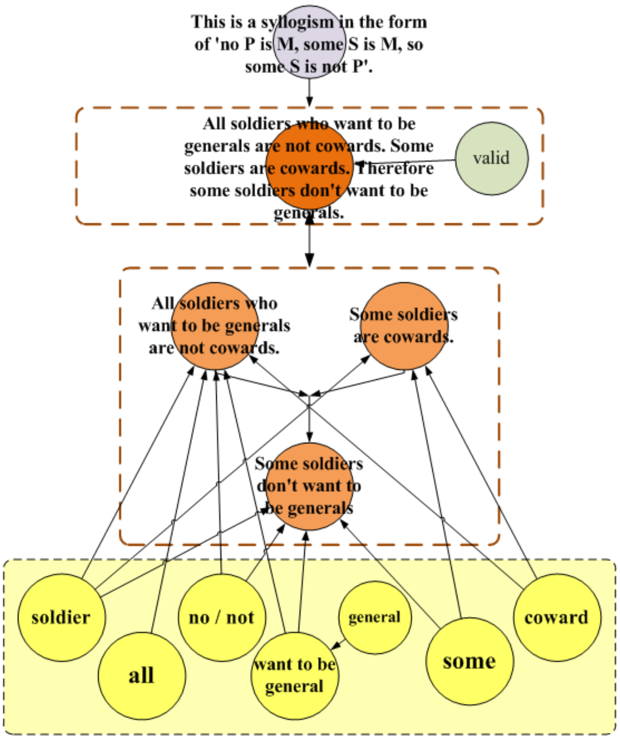


Figure 43: Model diagram of the broken content of argument ② in Example 9.

By analogy, 15 valid forms of categorical syllogism can be completely presented in logical information network. Furthermore, besides categorical syllogism, it is not difficult to see that the syllogism forms composed of other types of propositions, such as disjunctive syllogism and hypothetical syllogism, are also applicable to this presentation mode.

In this way, after improving the realization of syllogism in logical information network, all axiomatic scientific theoretical systems based on syllogism theory can be reformed and presented in logical information network.

6.1.2 The Risk of Reasoning Paradox in Scientific Axiom System

Aristotle's syllogism is a typical and generally accepted meta-logic rule, which provides a very important solid foundation for building a formal logic system. However, this point was criticized and doubted by the skeptikos of the same period, who thought that Aristotelian logic is not a "dela" *[30] rule of logic, and does not conform to the human instinct.

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[30] Ancient Greek skepticism divided everything into two kinds: one is the "dela" (namely obvious) or the "prodela" (namely self-explanatory), that is, what is directly presented to the senses or reason through itself, namely phenomenon. The other is the "adela" (namely non-obvious), which cannot be revealed by itself, and is not directly recognized by sense and reason.
Dogmatike philosophers held that philosophy should and must infer the adela through the dela, and reveal the essence of the other world through the veil of the phenomenal world. Only such kind of knowledge has the nature of inevitability. For in their view, "phenomenon is the representation of non-obvious things", that is, obvious things can be used as signs and evidence to prove the reality of non-obvious things.
Skepticism investigates and criticizes these dogmatic propositions and inferences of dogmatism, and explores the basis of their propositions and inferences about non-obvious things and what reliable means they depend on to ensure the inevitability of these knowledge.

After gathering the skeptical views of predecessors exploring meta-philosophy, Sextus Empiricus, the representative of skepticism in late Ancient Greece, summarized five "tropos" *[31] , which are: **1. discrepancy; 2. regress ad infinitum; 3. relativity; 4. hypothesis; 5. circular reasoning.** **[32] These tropos not only exerted great influence on the development of logic and philosophy at that time, but are still of great significance even today.

We can see that, compared with the budding of the Renaissance and the Enlightenment in Europe, the current whole system of natural science has grown into a towering tree with clear veins and luxuriant foliage. In the process of growing up all the way, through unremitting exploration, different kinds of possible facts are sought. In the face of the same thing or phenomenon, many different viewpoints are often put forward, which can reach no agreement. For example, there have been different theories about the movement law of celestial bodies, such as the geocentric theory, the heliocentric theory and the modern cosmology. And for the interaction and motion law of objects, there have been various theories such as Newton's law of motion, the relativity theory, and the quantum mechanics and so on. This is called "discrepancy".

In this complicated scientific system, logic and mathematics can be said to be the absolute foundation. At present, logic and mathematics are generally regarded by the scientific community as a part of formal sciences rather than natural sciences. They are used to analyze and think about abstract problems, research definitions, laws and methods, and emphasize strict reasoning. All these are different from the natural sciences that are based on real evidences and observe the real world. But meanwhile, they can provide research basis for those disciplines, which make their construction on a rigorous cornerstone. However, in fact, we can also see that the bases of logic and mathematics themselves are not as rigorous as ideal.

The concepts, propositions and arguments mentioned in Chapter Two are the basic concepts in logic. In addition, the laws of identity, contradiction, excluding middle and so on are considered to be the basic laws in logic. These basic concepts and laws are the prerequisites for building a complete logical system, but they do not come from rigorous logical derivation.

In the domain of mathematics, there are some corresponding axioms in different branches, such as five axioms and five postulates of Euclidean geometric system in geometry, five axioms of

[31] * There are also views that the five tropos of skepticism was put forward by Agrippa of ancient Greece, It's just that his points of view are passed down till now through Empiricus' narration in his works *Pyrrhoniae Hypotyposes* (namely *Outlines of Pyrrhonism* for English Translation) and *Adversus Mathematicos*.

[32] ** According to Empiricus, the five tropos (also called "modes" in English Translation) are "the first based on discrepancy, the second on regress ad infinitum, the third on relativity, the fourth on hypothesis, the fifth on circular reasoning".
First, that based on discrepancy leads us to find that with regard to the object presented there has arisen both amongst ordinary people and amongst the philosophers an interminable conflict because of which we are unable either to choose a thing or reject it, and so fall back on suspension.
Second, the mode based upon regress ad infinitum is that whereby we assert that the thing adduced as a proof of the matter proposed needs a further proof, and this again another, and so on ad infinitum, so that the consequence is suspension, as we possess no starting-point for our argument.
Third, the mode based upon relativity is that whereby the object has such or such an appearance in relation to the subject judging and to the concomitant percepts, but as to its real nature we suspend judgment.
Fourth, the mode based on hypothesis is when the Dogmatists, being forced to recede ad infinitum, take as their starting-point something which they do not establish by argument but claim to assume as granted simply and without demonstration.
Fifth, the mode of circular reasoning is the form used when the proof itself which ought to establish the matter of inquiry requires confirmation derived from that matter; in this case, being unable to assume either in order to establish the other, we suspend judgment about both.
Therefore, the conclusion can only be: "in all cases, we are compelled to suspend judgment concerning the object presented".
These paragraphs come from *Outlines of Pyrrhonism*, Empiricus S., translated by Bury, R., 1933, BOOK I, CHAPTER XV. OF THE FIVE MODES.

Peano's natural number system in algebra, and so on. These axioms and postulates, which are the basis of a vast mathematical axiom system, have also not been rigorously deduced and proved.

This means that once one of these basic concepts, laws or axioms is falsified, the corresponding logical system or mathematical axiom system may be overthrown and started all over again. It is like a mansion built on sand, which may topple down in an instant once there is any mistake with its support.

So where do these basic concepts, laws or axioms come from? Although in philosophy, there has been a point of view that axioms are innate ideas or priori knowledge of human beings, the more common view tends to be that the emergence of axioms comes from thinking, analysis, summary and induction of the facts in the objective world, rather than priori knowledge. Inductive method is different from deductive method. Inductive method is not completely effective, and the conclusion derived from induction is not absolutely true. Therefore, no one and method can guarantee or strictly prove the correctness of axioms. So this is called "hypothesis".

However, in the reasoning rules of formal logic, any reasoning, whether it is deductive or inductive, needs at least one starting point, which is the basis for the beginning of reasoning. And axiom systems rely on reasoning rules, which must be constructed from a few basic, unproved propositions. For example, assuming that proposition A is deduced from proposition B, and then proposition A takes Proposition B as the starting point of its inference. If proposition B is not proved (or cannot be proved or falsified), it can play the role of a cornerstone in an axiom system including proposition A, then it is called the "axiom". If a proposition C can be found that can prove or deduce proposition B, then proposition B cannot be or is no longer an "axiom", but a "theorem" or "inference". And meanwhile, proposition C may take over the role of "axiom" from proposition B. Now that proposition C can deduce proposition B, proposition D also can deduce proposition C. In this way, it will fall into "regress ad infinitum". If it is compulsory to "prove" the cornerstone axiomatic proposition and avoid regress, it will probably constrain the arguer to seek the reasoning basis inside the system, which will make it fall into the vicious circle of "circular reasoning".

For an axiom system to take shape, however, it must eventually have a starting point; otherwise the regress would be endless. The role of the starting point determines that the propositions ultimately defined as "axioms" can only be cited as evidences without proof. Thus, on one side, its correctness cannot be ensured; And on the other side, it must be cited without proof. That is which brings a question mark to the rationality of these logical systems and axiom systems. How to face the dilemma, which is difficult to prove itself and necessary to be used to prove other propositions, and the paradox risk it brings? The "declaration of proposer" in logical information model is an appropriate solution.

Defining axioms or a complete axiom system should be the declaration of the proposer of the axioms or axiom system. The definition declaration of axioms can temporarily ensure that the axiom system can achieve logical self-consistency from the basic level within a certain range. It's like painting a magical thin-film on the bottom of a sandy building to temporarily solidify its foundation and prevent it from collapsing. The basic concepts and axioms declared are such a thin-film, which holds up the foundation of the whole axiom system, and meanwhile becomes the scope condition that affects the validity of the system.

The scope of direct influence by the declaration of definition is limited to the proposer's own subjective will. The declaration of proposer represents a kind of systematic condition based on hypothesis and restriction. It indicates that all arguments, propositions and concepts accepted under this condition, and any composite forms of information (or knowledge) constructed by these elements, including axiom system of course, all reflect the proposer's subjective will, or at least are approved by the proposer's subjective will. The premise of establishing such condition should be to admit the difference and correlation between subjective will and the objective world, and accept their "relativity". (Figure 44) After observation, other observers can agree with these axioms or axiom system, or doubt them, or even redeclare their own different axioms or axiom system with the role of proposer.

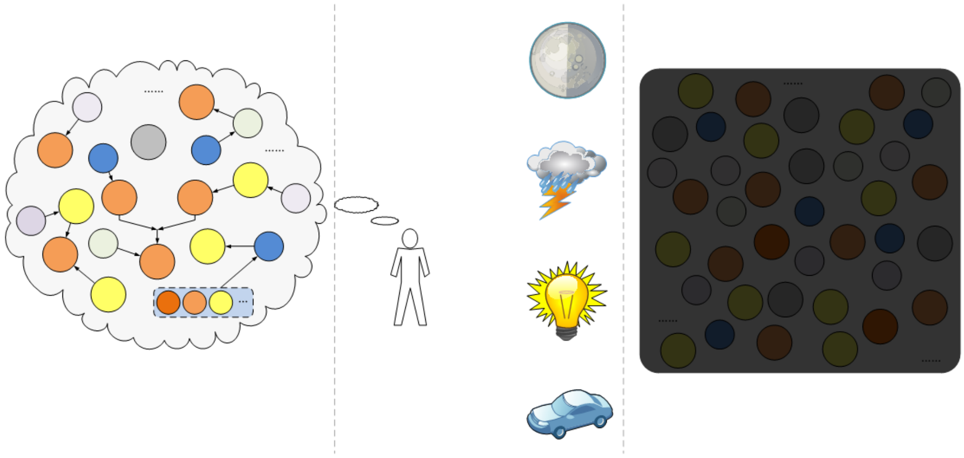


Figure 44: Diagram of the difference between subjective will and the objective world.

If there is an axiom system in which the axioms are doubted, proved or falsified, one of the following situations may occur:

1). Modifying the underlying axioms for the existing axiom system.

For example, in 1908, The German mathematician Zermelo, E.F.F. proposed seven groups of set axioms, creating the axiom system of set theory. After that, Fraenkel, A.A. and Skolem, A.T. pointed out the shortcomings of the axioms, proposed to improve and supplement new axioms, and gradually formed the ZFC axiom system of set theory consisting of 10 groups of axioms, which is generally accepted at present.

2). Establishing a new axiom system on the condition of the different forms of the doubted axioms.

For example, parallel postulate is an important basis for the establishment of Euclidean geometry, but many people have put forward different views on this postulate, based on which a variety of axiom systems of non-Euclidean geometry have been developed. The focus of controversy is, "how many lines are there passing a point outside a line, and parallel to the line?" Someone posited that there could be none, which led to Riemannian geometry (also known as elliptic geometry). And it was also suggested that there could be at least two such parallel lines, which in turn derived Lobachevskian geometry (namely hyperbolic geometry).

3). Abandoning the original axioms, starting a new one, and rebuilding the axiom system.

For example, Euclid of ancient Greece is regarded as the first person who applied axiomatic method to the domain of geometry for his "*Elements of Geometry*". However, in the later research process, many flaws were gradually found, and the elaboration of part contents was completely dependent on intuition, which was farfetched. In 1899, David Hilbert re-proposed 20 axioms of 5 groups through formal methods in his published *Grundlagen der Geometrie*, reconstructing the axiom system of Euclidean geometry and making the logical structure of Euclidean geometry more clear.

It can be seen that the way of proposer's declaration cannot help us find the absolute truth of the objective world at one stroke, and promote an unchangeable and static perfect axiom system. However, this is a moderately dynamic balance. The axiom system that is temporarily stable and "adequate", coupled with the form of sustainable improvement, provides a fulcrum for each step forward of the axiom system model so as to ensure its steady development. After all, the information and knowledge in the world are too vast to be mastered in a short period of time by human beings with a civilization history of only thousands of years.

6.1.3 (General) Validity of Argument

In Aristotle's system of deductive logic, reasoning is an idealized argumentation process that can lead to valid or invalid judgment, which is the judgment of dualistic validity of process. However, in the real world, not all reasoning conforms to dualistic validity. One of the reasons is that it adopts the reasoning method in inductive logic which is not complete induction, rather than deductive method or complete induction method. And another important reason is that parts of the conditions of argument are ignored in the process of reasoning.

All the reasoning conforming to dualistic validity must be built in some ideal situation. Usually, deductive reasoning needs to get rid of those factors that may affect the validity of reasoning, so as to achieve the purpose of dualistic reasoning. Therefore, a strict context is usually set up for it in advance, which can be realized through certain assumptions, hypotheses and other conditions. Or it is just existed in some paragraphs of a non-idealized complete argument. The conditions of these paragraphs are generally consistent in each segment of them, so as to ensure that the part of deductive reasoning in these paragraphs is not affected by the changes of various conditions.

Complete induction can also achieve dualistic reasoning because it sets the conditions that all objects of the types involved in the reasoning process are included in the argument. When this condition does not exist or fails, the inductive reasoning is no longer complete induction but incomplete induction, and the validity of reasoning is no longer a dualistic result.

Of course, in incomplete inductive reasoning, even if the result of dualistic validity cannot be obtained, it may also be suitable to use the method of probability and statistics to obtain an explicit value of validity. However, this can only be implemented in the ideal case where there are certain quantifiable conditions. For example, we can often see math exercises like "In a closed box, there are N small balls of the same size, color and shape, ...", or "In a plane rectangular coordinate system, ...", "Given the right angle △ABC...", and so on. In fact, this kind of setting is to create an idealized scene without too much interference from other complicated factors.

Even so, strictly speaking, in reality, it is usually difficult to meet the ideal state of dualistic validity reasoning, and it is only some cases approximate to the ideal. Most of the arguments in the world are also difficult to reach the conclusions that meet absolute dualistic validity or exact probability values of validity.

So how do we bring a more realistic judgment of validity to an argument? It is a feasible way to force the declaration by proposer, but if there is only the declaration without enough and strong evidence to support it, the result should be opposed by most observers.

For example, as early as 1803, the British scientist John Dalton proposed the first atomic model, i.e. the Dalton's "solid sphere model". His basis, which was learned from chemical experiments, is that: ① Atoms are chemically indestructible particles of matter; ② Atoms of an element share common properties and same atomic weight; ③ Atoms are tiny solid spheres. However, after Thomson, J.J. discovered electrons in 1897, he denied Dalton's "solid sphere model" and proposed the "plum pudding model" several years later. His model is based on the following: ① Electrons are evenly distributed over the whole atom, just as scattered in an ocean of uniform positive charges, and their negative charges cancel out those positive charges; ② When excited, electrons will leave the atom, and cathode rays will be produced. Later, Ernest Rutherford denied the "plum pudding model" and proposed the "planetary model" in 1911. His theoretical basis comes from the analysis results of the famous α-particle scattering experiment: ① Most of an atomic volume is empty; ② An atom has a very small nucleus at its center; ③ All the positive charges of an atom are in its nucleus, and almost all the mass is concentrated in the nucleus; ④ Negatively charged electrons move around the nucleus in nuclear space. After that, Bohr model and electron cloud model appeared respectively, and some different opinions were put forward mainly on the layout and motion mode of extranuclear electrons though these models.

Each theory or model that has appeared in the history of science is a set of complicated arguments, and there are some reasons and basis for its existence more or less, but this does not mean that it will be accepted for a long time. If there is no sufficient factual evidence for support, or some phenomena contrary to the theory or model are found, it may shake the confidence of its supporters, and then there will be doubts or even opposition.

In addition to the declaration of proposer, another way that can be used to bring a more realistic judgment of validity to an argument is **to break the argument down into multiple steps, separately determine or declare the validity of each single step of reasoning that leads from evidences to conclusions, and then superimpose them to form the overall validity of the complete argument**. Such a process of breaking argument down may not be completed at one time, but continuously separated and refined, which finally make each intermediate process be an inseparable inference process.

For example, (Example 18) to prove that the root of the univariate quadratic equation $ax^2+bx+c=0$ is $x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$, one side of the equation should be configured as $x^2+2kx+k^2$, and the remaining constants should be transferred to the other side of the equal sign. Because

$x^2+2kx+k^2=(x+k)^2$, a square of the sum of a variable plus a constant is pieced together. And take the square root of it together with the constant on the other side of the equal sign, and then the solution of X in the equation can be easily obtained. (Figure 45a) In this process, the derivation of each step is a small inference process, and each inference process has its own validity. Superimpose all these validities, and it forms global validity, or we can call it "**general validity**". (Figure 45b)

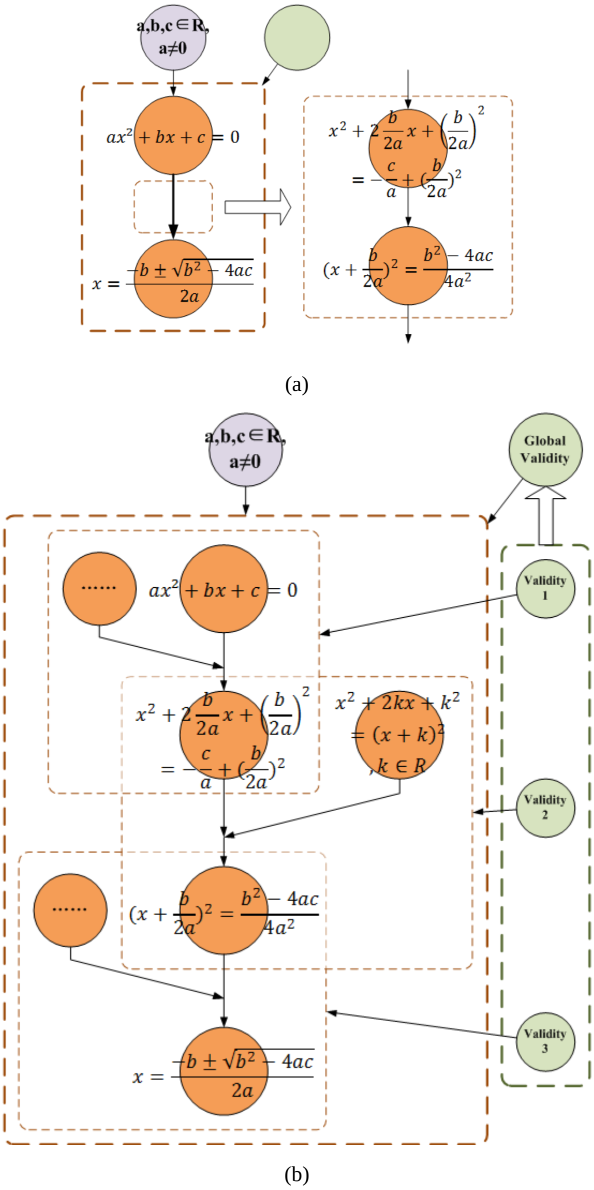


Figure 45: Diagram of Example 18.

The continuous separation and refinement of argument process is indeed beneficial to determine the validity of argument in each step, but it is also more difficult to evaluate the overall validity of argument with multiple steps. After rigorous separation and analysis of an argument, if all the branch arguments used to prove the final conclusion are regarded as a continuous argument chain, from the perspective of probability theory, the branch arguments with each other in the chain basically exist in the relationship of intersection. If the validities of every branch arguments are measurable probability values, the overall validity of the argument chain can be easily calculated by multiplying the probability values of these branch arguments. However, there are only a small number of arguments that can be quantified through probability and statistics without loss of any conditions. More arguments may be difficult to be quantified directly and their probability of validity can only be described in ambiguous words. Considering that the branch arguments which are difficult to measure the probability of validity and the branch arguments which are easy to measure the probability of validity may affect the overall validity of the same argument chain together, the problems we are facing will become much more complex.

In addition, there may be many factors or conditions that can affect the validity of a single argument, such as error, hypothesis, ambiguity or comprehension deviation, etc., which may not be considered thoroughly in the argument.

Moreover, there may be many different argumentation methods for a proposition. Different arguments may have different validity, even if the proposition is generally accepted as true. For example, since the Pythagorean Theorem came out, a large number of argumentation methods have been proposed by later scholars. *[33] However, some of these methods have been judged to have serious loopholes, or take assumptions as premise, even use irrelevant theories from other fields. Of course, such arguments cannot be considered valid.

Furthermore, once the validity of a branch argument in an argument chain changes, the overall validity of the whole chain needs to be reevaluated. For the main way of its presentation, namely oral statement or written text, it is a heavy workload to evaluate or reevaluate the validity of an argument, and it is easy to make subjective assumptions and misjudgments caused by ignoring part of the argument information. Logical information network, on the other hand, is more suitable for analyzing arguments, analyzing their details, and estimating their validity. In logical information network, the details of arguments can be presented more intuitively. Moreover, observer can directly locate any link in argument process to doubt and argue, and proposer can argue back or amend the content of argument accordingly. In addition, based on the symbolization of the validity of argument, the description of the validity in natural language which is difficult to be used for calculation can also be transformed into probability value in artificial language which can be used for calculation, so as to obtain the overall validity of argument more easily.

6.1.4 Expanding & Collapsing

Usually when we discuss the proof of a certain point of view, if some theorems are involved, generally speaking, we directly take the conclusions of the theorems as evidences to support our own point of view, rather than appending the complete argument process of the theorem. This is because those viewpoints called theorems are generally demonstrated and evaluated scientifically and professionally. Although there are some flaws occasionally, they are still highly reliable on the whole.

[33] *The American Mathematical Monthly* serialized more than 100 different proofs of the Pythagorean Theorem in the late 19th century alone. So far, there are no less than 400 or 500 kinds of argumentation methods publicly proposed.

However, this does not mean that we cannot delve into the degree of that the argument process of theorems supports our own point of view. Regardless of the fact that the theorems are not the "truths" in the ideal and may be flawed, even if the theorems that have not been falsified also have their application scopes or restrictive conditions. For example, Newton's classical mechanics is currently considered to be only applicable to the macro world and low-speed environment in our daily lives. It is ineffective in ultra-high-speed scenes close to the speed of light, or in the micro world.

Moreover, in the process of knowledge dissemination, the theorem may also be misread due to the reasons such as different expressions of media, and incomplete expressions of application scopes or restrictive conditions. That results in comprehension deviation or improper use, which leads to absurdities such as proving the Pythagorean Theorem (i.e. in a right angle $\triangle ABC$, $a^2+b^2=c^2$) with Einstein's mass-energy equation (i.e. $E=mc^2$).

In addition, improper use of theorems may also lead to circular reasoning. For example, the distance formula between two points in rectangular coordinate system is often used to prove the Pythagorean Theorem, just like that there are points A(a, 0) and B(0, b), then $|AB|=\sqrt{a^2+b^2}$, and $|AB|^2=a^2+b^2$. However, the distance formula between two points in analytic geometry is considered to be proved on the basis of the Pythagorean Theorem, which is a typical circular reasoning. Which come first, chickens or eggs? I am afraid that in many cases, it can be concluded only by opening the argumentation details of theorems for evaluation. And at this moment, visualization functions or tools can provide convenience for this.

In an argument chain, the most direct way to delve into a theorem in its evidences is to expand its argument process. "**Expanding**" is a kind of act in logical information network. Expanding an argument process is to turn the "inactive" information elements of argument to "active", so as to make them visible in the presentation of the argument chain.

Expanding an argument would present the details of the argument thoroughly and facilitate the discovery of hidden problems, but meanwhile, it will also make the presentation of the argument chain lengthy. When it is no longer necessary to go deeply into details, the argument process can be collapsed. **Collapsing** an argument process is to turn some "active" information elements in the process into "inactive", and then they no longer appear in the argument chain.

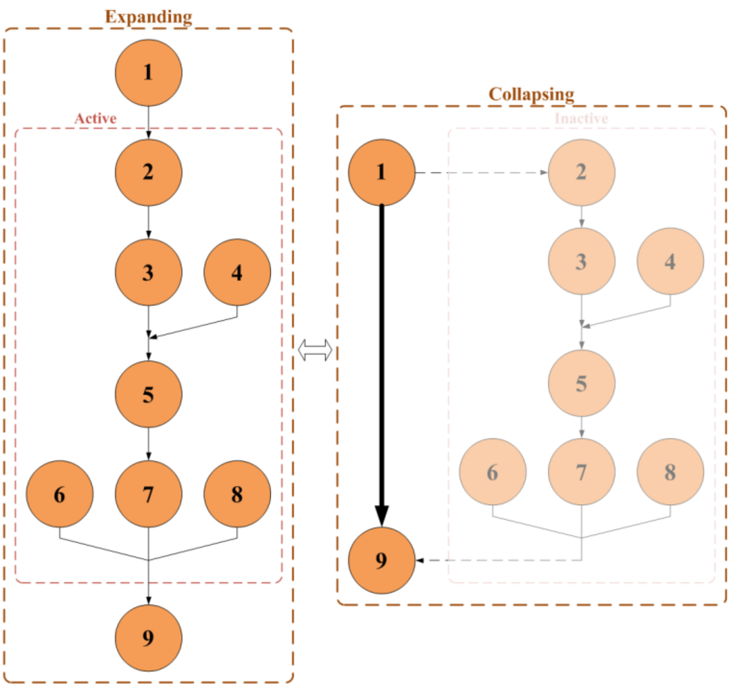


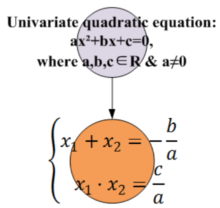
Figure 46: Diagram of expanding and collapsing argument.

Example 19:

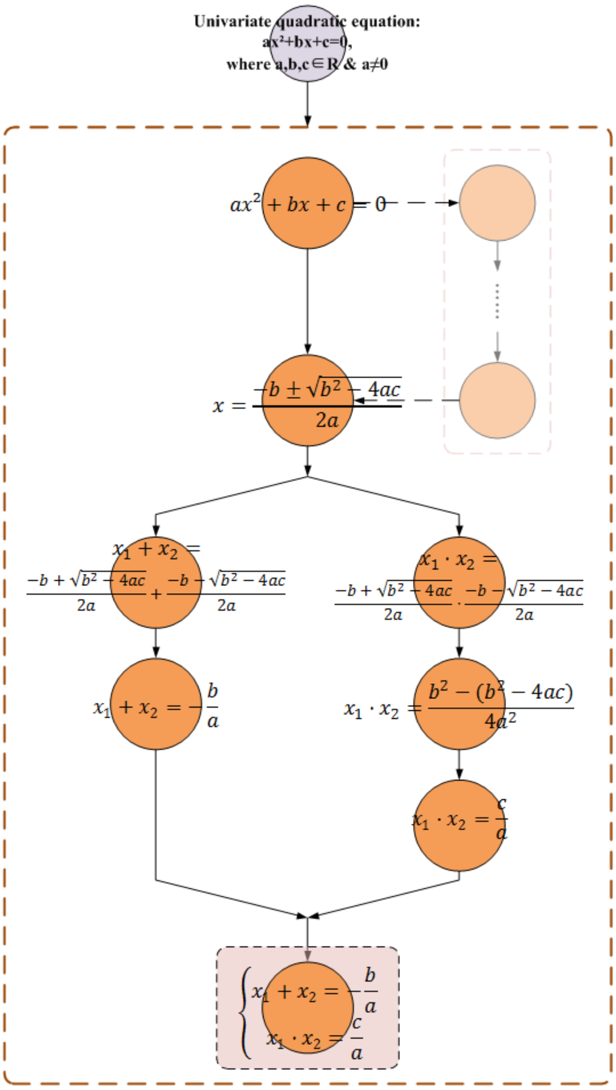
In the 16th century, the French mathematician François Viète discovered the relationship between the roots and coefficients of algebraic equations, namely the Vieta's Theorem. Its content reads as follows:

"① Let a univariate quadratic equation $ax^2+bx+c=0$, where $a,b,c \in R$ and $a \neq 0$, then ② the two roots of the equation, x_1, x_2, follow the relationships as below: $x_1+x_2=-b/a$, and $x_1 x_2=c/a$."

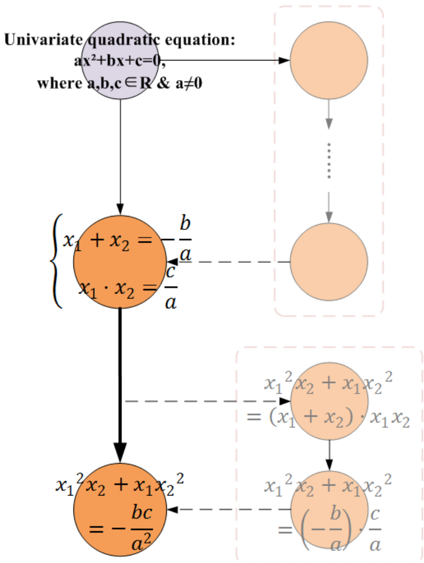
The content of the theorem can be regarded as a hypothetical proposition. Branch proposition ① provides hypothetical condition and branch proposition ② provides assertion. (Figure 47a) The argument process of the theorem is shown in Figure 47b. In this process, the conclusion of Example 18 can be directly used, so that parts of steps are collapsed and the length of the argument process is shortened. When it is necessary to use the conclusion of this theorem as the basis for other calculations or inferences, such as calculating $x_1^2x_2+x_1x_2^2$, the argument process of this theorem can also be completely collapsed, just as shown in Figure 47c.



(a)



(b)



(c)

Figure 47: Diagram of expanding and collapsing the argument of Example 19.

An ideal logical information network can theoretically contain a large number of information elements of argument, and most of these information elements can be connected together through different relations. Once all the details of an argument chain are displayed together, it may be an extremely large amount of information. It's going to be hard to accept, both in terms of efficiency and effectiveness. Therefore, the act of collapsing is bound to have very important practical significance in application.

6.2 Information Capabilities

6.2.1 Static Information

Logic is built on the basis of information. What all logical relations reflect is the connection between information.

From the perspective of cognitive science, we have been receiving the information around us since we were born, so as to understand the world. Anything can convey a variety of different information. For example, for a tree, we can see that it is "tall" and it is "green", which belong to the attributes of it, namely the particular concept "this tree". A tree can have many attributes, such as height, color, shape, tactile impression, etc. Each person may be exposed to only a few of these attributes. Even with the same attribute, different people may get different information contents. Some people see the tree during the day, while others see it at night. Some people see that it is very tall, taller than the wall next to it, while others see that it is not tall, shorter than the building on the other side. Some people see the trunk from under the tree, some climb to the tree top to see the leaves, and others see the whole lush tree from the sky through the drone.

These disparate attributes and their contents can constitute all the information conveyed by a concept entity in logical information network.

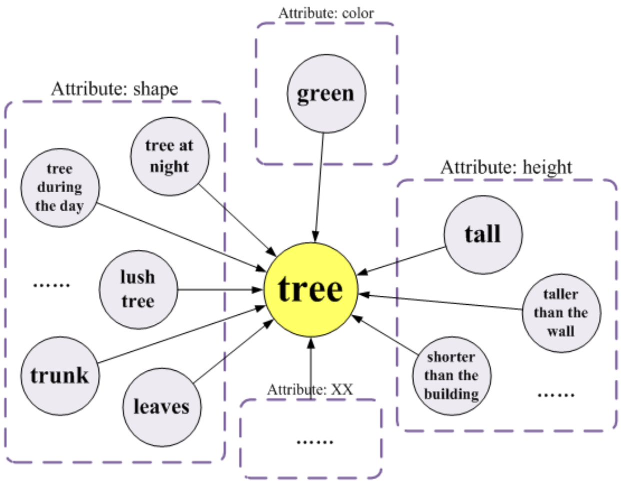


Figure 48: Example diagram of stereoscopic attribute information of a concept entity.

Our cognition of outside information is a progressive process from shallow to deep. This process is usually the process of advancing from presentative information to intrinsic essential information. Presentative information is the one that is readily perceived by our sensory organs all over the body, which can usually provide a simple and qualitative judgment. Is this tree taller than the wall? This can be seen at a glance. Did the bugs in the tree make a noise? We can hear it with our ears.

In order to obtain intrinsic essential information, there needs to be more premises, i.e. context information.

This tree is taller than the wall, how much taller? It requires the use of appropriate measuring tools. How loud is the noise that the bug made? Appropriate recording and observation equipment is also required. Being familiar with and knowing how to use these devices is a kind of context information. Why do the leaves of this tree turn red in autumn? How does that bug make a noise? These may require observation and biological experiments. These observation and experimentation methods are also context information.

What are the results after observations and measurements? "This tree is 2 meters taller than the wall", and "the noise of that bug is 50 decibels". The "2 meters" and "50 decibels" here are the required reserves of relevant knowledge, involving some contents in mathematics and physics. "The leaves of this tree contain anthocyanins", and "that bug makes a noise by vibrating its abdominal tympanal organ". The "anthocyanins" and "tympanal organ" here are also related concepts in biology. These are all context information.

Sometimes, in order to get intrinsic information, maybe we also need to set some conditions or hypotheses and establish some models.

A huge amount of context information is required to be as the premise, which determines that intrinsic essential information involves a greater amount of information and is more difficult to grasp than the presentative information.

Since these information belong to one specific concept, and not to another specific concept concurrently, we call them "**static information**".

6.2.2 Dynamic Information

It is worth noting that the statement "whether information belongs to different specific concepts" mentioned in the previous section is different from "whether the contents of different specific concepts are consistent". Just as we say, "this tree is green" and "that tree is green". From an object-oriented perspective, although the contents of "green" and "green" here are the same, they are different objects. The former is the attribute of "this tree" and the latter is the attribute of "that tree". The two should not be confused.

However, once the concepts of consistent attribute content increase, it will become miscellaneous and redundant when representing. At this time, we can combine them together, such as "all the trees on this street are green". The information represented in this way is a kind of "**dynamic information**". Because the "green" here is not only the attribute of the concept of "all the trees on this street", but also the attribute of "the first tree", "the second tree" ... and "the Nth tree" "on this street".

This representation is similar to the set method that we often use in mathematics. Representing objects by sets can not only list objects one by one by roster notation (such as {a, b, c}), but also describe the properties of objects in sets by set-builder notation (such as {x | f(x)}). Set-builder notation uses variables in expressions to refer to mutable objects, while we can also use dynamic information to represent the mutable objects in logical information model. The proposition "all the trees on this street are green" is a piece of dynamic information, which can correspond to N static information propositions, such as "the Nth tree on this street is green". The variable concept "all the trees on this street" is also dynamic information. It can also be associated with N static information concepts, such as "the Nth tree on this street", in accordance with specific relation. This relation is termed "**dynamic-static relation**".

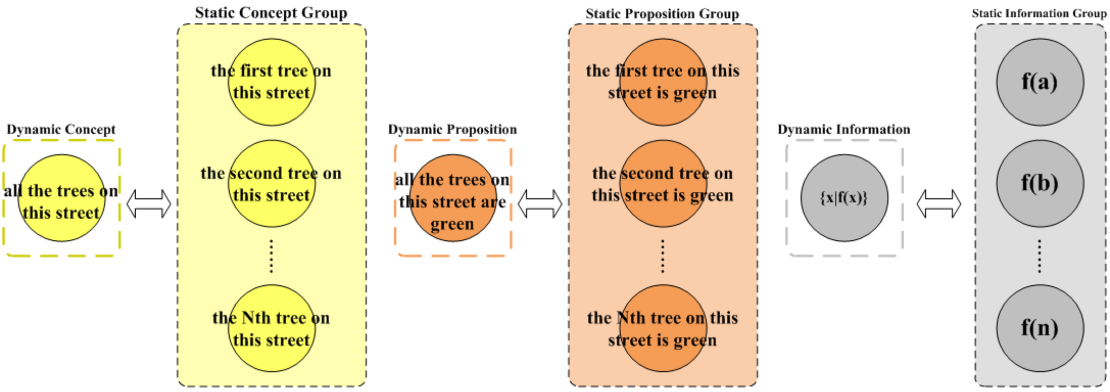


Figure 49: Diagram of dynamic information mapping static information.

The role of dynamic information is obvious. First of all, like set-builder notation, dynamic information is suitable for representing the objects of infinite sets, as well as the objects of finite sets, especially the finite sets of a larger order of magnitude. This is very beneficial for simplifying the expression of homogeneous objects.

Secondly, in the process of argumentation and reasoning, especially in complete inductive argument, we often encounter the objects of infinite sets or the finite sets of a larger order of magnitude as evidences or conclusions. In addition, in the concepts or propositions modified by universal quantifiers, or even arguments composed of them, there are also the objects of infinite sets or the finite sets of a larger order of magnitude. By using the correlation between the dynamic information representing objects of a large order of magnitude and relevant static information to split or merge arguments or propositions at an appropriate time, it can make the details of arguments clearer and easier to analyze.

Furthermore, the variables in dynamic information can also refer to indeterminate objects. For example, variables in formulas (whether mathematical formulas or propositional formulas) and variables in programming code all play such a role. Indeterminate objects mean that the variables in dynamic information can be substituted under appropriate conditions, so as to achieve the purpose of mapping them into determinable static information.

For example, "y=ax+b" is a general formula of linear equation in two unknowns, which can be used to represent the set of all linear equations in two unknowns. This general formula is a piece of dynamic information, in which a, b, x and y are all variables. When both a and b are given exact values, such as "y=2x+5", the formula is exactly a special case of linear equation in two unknowns. It is a piece of static information compared to the general formula. In addition, a linear equation in two unknowns can correspond to a definite straight line in Cartesian coordinate system. And x and y, as the variables of the linear equation in two unknowns, can refer to the coordinates of any point on this line. In other words, the linear equation in two unknowns, in which they are located, can represent the set of coordinates of all points on the line. From this point of view, this special case of linear equation in two unknowns can also be a piece of dynamic information.

Therefore, it is not difficult to see that dynamic information and static information are not absolutely invariable, but a pair of interdependent concepts. Whether a piece of information is dynamic or static depends on whether it takes more dynamic or static information as reference.

Different conditions can make the same dynamic information map to different static information, so that it has excellent adaptability. This form is suitable for content that is flexible and different from general static knowledge, such as algorithms.

In many cases, algorithm is considered as an instruction set suitable for implementation by computer program and constructed to solve particular problems. That is a narrow view. Because algorithm is not equal to program itself, and is not just programming code. In essence, algorithm is a scheme designed to achieve specific goals or functions. The core of this scheme is to accurately describe the detailed and executable operation steps formulated to achieve a goal. Language description is the main, and implementation code is the auxiliary. The description and code can correspond to each other. Both language description and program code are mostly presented in the form of text information, and most of them are flexible dynamic information. The more complex the algorithm is, the more flexible it is, and certainly the more dynamic information it contains.

Take the common and simple binary search algorithm as an example. (**Appendix B**) In **Appendix B**, both of which show the steps of binary search algorithm, whether Paragraph ① represented by easy-to-understand text description or Paragraph ⑤ represented by easy-to-execute code description, both can be disassembled to more detailed information elements, and can be made to correspond with each other one by one. Among them, the keyword (key), queue (array), middle position (mid) and comparison result (comparisonResult) are all dynamic information, whose specific values will change with the change of the object fed into the algorithm or the evolution of the algorithm execution. The existence of these dynamic information makes the algorithm widely adaptable to different scenarios, and ensures the flexibility of the algorithm in the face of various substitution conditions. Similarly, the same goes for other complex algorithms.

Dynamic information has different characteristics from static information, which can make a great difference in the purpose between the logical information network mainly composed of dynamic information and the logical information network mainly composed of static information. Static logical information network is suitable for the information of knowledge data, while dynamic logical information network is more suitable for the information of algorithms, operations and behaviors.

6.2.3 Hierarchy Dividing & Classifying of Domain Information

There is so much information throughout the world. It is countless and endless that no one can get all the information. So it is necessary to classify and manage the information appropriately, in order to effectively grasp as much information as possible. According to common sense, it is not difficult to understand that each independent concept can belong to a specific domain, which can be called the **domain information** or **domain knowledge** in this domain. The concept of different "domains" makes it easy to divide information or knowledge into smaller areas, so as to focus on a smaller and more controllable amount of information.

So, how to divide the domains? The most straightforward way is to divide according to our academic disciplines. At present, in terms of categories, domestic disciplines (in China) are mainly divided into more than ten categories, such as philosophy, literature, science, engineering, law, medicine, history, pedagogy, economics and so on. This is a good way of defining domains.

In logical information network, classifying information or knowledge by domains is a simple and effective method of information classification and management. Just define the domains in advance, and associate the domain information as an attribute of the corresponding information or knowledge.

Then, how to manage the domains? This can be inspired by the national standards of discipline classification. According to the national standard for classification and code of disciplines (GB/T13745-2009) issued in 2009, all disciplines are roughly divided into 62 first-level disciplines, 676 second-level disciplines and 2382 third-level disciplines. This is a multi-level discipline classification approach, which is now widely adopted in global academic circles. For example, *Classification of Instructional Programs* (CIP) in the United States adopts 2-digit, 4-digit and 6-digit codes respectively as the identification of its three levels of disciplines. And *the Joint Academic Coding System* (JACS) in The UK uses a combination of letters (representing discipline domains) and numbers (representing discipline codes) to reflect its obvious discipline hierarchy. Multi-level discipline classification helps to control the scope of domains, and there may be obvious differences in size between the domains of different level. In general, a high-level domain contains all the information or knowledge in the low-level domains which only belong to it.

Of course, the way of defining domains is not fixed, and the division of disciplines has been changing and developing. As the origin of the university degree system in today's various countries, the European medieval universities opened only four categories of liberal arts (covering grammar, logic and dialectic, rhetoric, arithmetic, geometry, music, astronomy), law, medicine and theology in the 13th century. After hundreds of years of changes, the exploration in the domain of basic disciplines has become increasingly perfect, and that in the domain of applied disciplines has blossomed everywhere. This has led to the continuous division and refinement of modern disciplines and the emergence of a large number of new disciplines. On the other hand, with the continuous development of science, the knowledge and information confined to a single domain are often insufficient to support the in-depth research of some specific problems. At this time, interdisciplines come into being. For example, mathematical logic is an interdiscipline of mathematics and logic, and computational physics, biochemistry, neuropsychology and so on are also interdisciplines.

Generally speaking, the information or knowledge within the domain of an interdiscipline will also belong to the single disciplines associated with it. Even if some are not interdisciplines, the knowledge or information involved is not necessarily unique to them. Just like that paleontology is a branch of life science, but due to the characteristics of the discipline, it will inevitably involve a lot of knowledge of archaeology, geography, history and other disciplines.

If classifying information by domain can be regarded as dividing information horizontally into groups, classifying information by hierarchy relation is to divide the information vertically. Taking "article" as the benchmark unit, it can be divided downward into paragraphs, sentences, words or letters and other levels, and can upward derive the form of publications composed of a number of articles, such as monographs, books, magazines, periodicals, newspapers, etc., or electronic publications such as e-blog and network new media.

Dividing hierarchy relation is an effective supplementary means to divide domains, and the two complement each other. Because it is not difficult to find that there are still a lot of content in a single domain. It is obviously not enough to use only domains as the condition for classifying information. Moreover, domain itself is also a relatively abstract concept. Everyone may not have the same understanding of domains, and may have ambiguity about the affiliation of the information within domains. The hierarchy relation looks more intuitive and makes it easier to formulate rules for implementation.

6.3 Act

In essence, logical information network is an information system that can collect all information and knowledge, and the content objects of these information and knowledge (namely information elements) are all generated by the user roles in the system.

User has use cases that correspond to the role, known as the user's "acts". In logical information network, both logical and information functions are actually based on these acts. The expanding and collapsing of argument chain are kinds of acts, so are domain dividing, and hierarchy dividing and classifying of information. In addition, the aforementioned assembling and disassembling, fusing and separating, serializing and deserializing, and the correlating that establishes relations between information elements are the basic acts provided in logical information network.

Besides these ones, we can also set some other acts for logical information network that are consistent with general information systems, such as:

i). Hiding and unhiding of information elements.

After a user in the system creates any content, the relation linking owner and owned object is generated between the user and content. It can be determined through this relation that the owned object is the owner's private object, but it can also be unhided to other users by the owner. Or it can be considered that the owned object can only be private and cannot be unhided, or the owned object can only be public and cannot be hided. The choice about these different natures of the relation depends on the will of the actual builders of the logical information network.

If its objects can only be set private, it is a personal information management tool. If its objects can only be set public, it is a public information repository or information market. If its users can choose to set their information private or public, it is not only a combination of personal information management tool and public information repository, but also a comprehensive information platform with social attributes. That means the degree of information disclosure that users can choose (e.g.: completely unhide / unhide to all users / upload copies to public repository, conditionally unhide / unhide to part of users / unhide to friends, completely hide / unhide only to self, etc.), determines the characteristics and development trend of this comprehensive information platform.

ii). Merging and splitting of synonymous and near-synonymous information elements.

In public information markets, there may be a situation that two users upload two pieces of information respectively. The text expressions of the two pieces of information content are similar, so are the meanings. Or it can be regarded that they are equivalent expressions of each other, which are synonymous or near-synonymous information elements.

For example:

User A: "Nikola Tesla is a famous electromagnetic physicist";

User B: "Tesla is a scientist who has made outstanding contributions to the domain of electromagnetism".

In logical information network, it can be regarded that there is a synonymy relation, near-synonymy relation, or equivalence relation between the two.

Public information or knowledge may lead to comments and debate, and the presence of multiple pieces of similar information will distract the focus of attention. Thus, in this case, merging synonymous or near-synonymous information elements together into a common combination would be an appropriate operation for response.

Of course, this should not be an operation act available to all users, but only to the users with system administrator role. Moreover, this process is not achieved overnight. Presumably there should be a certain application review process to deal with the wide impact that such an operation may have on the open platform.

If the merged information elements are later determined not to meet the criteria of synonymy or near-synonymy, it is available to split the group of information elements through the reverse operation of merging to restore them to independent elements. This may not be common, but it cannot be dismissed as non-existent.

iii). Version control of information elements.

Variability is one of the characteristics of the objects in information systems. Users can modify the content of the objects by reasonably using the operations provided by the systems. When the information element object changes, a change record is generated. The change record is the most important basis for tracking the change process of object content. Just like in software engineering project management, tools of version control system (such as Git, SVN, etc.) are basically used to manage programming codes, so as to achieve a whole life cycle understanding of code content. The information elements in the logical information network also have a life cycle from creation to modification, remodification, continuous modification and finally deletion. The record of the whole process is helpful to keep track of the changes of various information and knowledge.

If private information elements are versioned, users can easily trace back to past information. If public information elements are versioned, it is better for displaying the whole process of a piece of certain knowledge, from being proposed to being declared, argued, corrected and finalized by different users.

7. Logical Information Network: Significance

The significance of logical information network lies not only in providing many functions of logic and information, i.e. a tool for presenting object formalization for all arguments and a container that can hold all logical information. Moreover, it has many applicable scenarios, which can provide a new boost power for the development of the fields such as **scientific research**, **knowledge popularization**, **reading mode**, **cognition and memory**, and **artificial intelligence**.

7.1 Scientific Research & Popularization

7.1.1 Scientific modeling

Scientific research is a process of constant pursuit of truth, and modeling is one of the very important scientific research methods.

Scientific model is a simplified description of the research object, which may be in the form of text, or may include different types of manifestations such as images, sound, video, physical objects, and data streams and so on. The reason for this kind of description may be that the shape, characteristics, essence or development laws of the studied object are not fully understood, and can only rely on the known part. Or in order to deeply analyze some internal essence of the studied object, it is necessary to select specific characteristics to describe. Or setting some specific external conditions for the studied object as the basis, so as to observe and analyze the symptoms of the studied object such as the performance or behaviors.

As a result, a model is often an idealized state that is close to, but probably not identical to, something in reality. It may correspond to a theory with a certain practical basis, or be derived from a bold speculative hypothesis. In the process of scientific research, it is usually to list some internal and external conditions and construct a model framework first, and then study some practical problems based on this model. Obtain some data on the basis of the model through some methods of research and proof. Whether they are the empirical methods of observation, experiment and questionnaire survey, or the analysis methods of qualitative, quantitative, probability and statistics, or the argumentation methods of deduction, induction, reduction to absurdity, or the research methods of documents, cases, classification and comparison. And then infer one or a series of conclusions from that, or verify the correctness of one or more views. After that, revise and adjust the model based on the conclusion to make it continuous improvement, in order to approach the essence of objective things as much as possible.

During this period, it is necessary to observe and analyze various characteristics of the studied object and set various assumptions or restrictive conditions, and there is always a strong logical relationship between these characteristics and conditions. In addition, from establishing an idealized model to obtaining data from experimental observation, and then drawing a conclusion based on the data, the whole process also cannot go on without logical analysis and reasonable derivation and argumentation.

Therefore, information such as characteristics and conditions is the basis of a model, while logical means such as analysis and induction are the guidance to construct an ideal model. It is just like that a perfect building can be produced only when combining a pile of qualified building materials with a high-quality design drawing. Only by following sound logic, it is probable to gradually integrate all kinds of information together, make it concrete, and progressively construct a complex and complete model.

In this series of process, the logical information network built with the help of information means can provide it with fast, flexible and powerful auxiliary tools. Static information is used to describe the characteristics and conditions of model, while dynamic information is used to describe the research methods of model. It will form a complete description of the model by combining the two.

In addition, the logicality of a description made up of information elements can also be fully and clearly displayed. Whenever argumentation or derivation is concerned, information elements such as "proposition" and "argument" can be applied. When it comes to description on something, information elements such as "concept", "narration statement" or "information relation" need to be used. Such stereoscopic presentation makes it easy to analyze whether every detail in a scientific model is reasonable, whether there are still defects and loopholes, etc. Moreover, it has flexible structure, more convenient adjustment and stronger overall readability.

Constructing a scientific model in an information container with logicality, and making it concrete, is conducive to gradually forming a more complex scientific system. In addition, each person can easily establish his own independent model of some actual phenomena or problems in such an open container, no matter whether the model seems to conform to the current theory recognized by others, no matter how absurd and shocking it looks. Of course, the proposer also needs to bring enough evidences for the model and its conclusions to support that the model is credible, so that it can gain more recognition from others in the comparisons with different models in same domain.

Establishing independent models in the name of individuals is also conducive to weakening the deterrence of existing authorities in the industry to latecomers. Since the absolutely rigorous deductive argument or complete inductive argument only exists in some specific partial paragraphs of argument or some ideal states, there are always some imperfections in the argumentation and derivation of scientific models. In other words, it is still hard to get a perfect and universally applicable model today. The road of science is long and obstructed. Every milestone on the road is important, but the ideal truth can be got closer only by continuous exploration without stopping. Although classical theories have contributed a lot to later generations, it is also imperative to transcend the classics, get rid of the inherent thinking, push through the old and bring forth the new, and constantly emerge improved models compared with the traditional ones. The more different models, theories and hypotheses, the more likely it is to promote healthy competition in the academic circles, and form a situation of contention among hundreds of schools of thought, which is very helpful for the research in domains where it is difficult for human beings to find out the rules.

The 2017 Nobel Prize in Physiology or Medicine was awarded to three scientists who had contributed to important theoretical models in the study of the molecular mechanisms of circadian clock. The model described in detail the significant role of clock-gene expression proteins in regulating the circadian cycle. In the same domain of chronobiology, since the 1950s and 1960s, researchers have put forward various theoretical models: melatonin regulates the sleep-wake rhythm, and the compound time giver composed of environmental signals such as light, temperature and eating regulates the phase of biological circadian rhythm, etc. These different models represent the proposers' respective research findings and understandings in the domain of circadian clock.

In the more obscure frontier domain of physics, there are more independent models. In the early 20th century, the establishment of the two theoretical systems of general relativity and quantum mechanics promoted the development of the standard models of particle physics and cosmology, but it still failed to solve all the mysteries of the material world. Models such as "dark matter" and "dark energy" have been proposed to explain the absence of mass and energy in astronomical observations that are inconsistent with previous theoretical calculations. However, these potential particles and energy have never been captured in physical experiments. In addition, the existing mechanical models for the interpretation of the four fundamental forces *[34] are not perfect, and cannot perfectly interpret celestial phenomena such as black hole and cosmic inflation theory. In the face of various puzzles, scientists have successively put forward many different cutting-edge theoretical models, such as modified gravity, supersymmetry, a fifth force, parallel universes, string theory and so on. Although these theories also need to be verified by practical observation and experiment, more theoretical models also provide more perspectives, ways of thinking and experimental methods, which all indicate that human beings have one more understanding of science and a further step towards truth.

[34] The four fundamental forces: weak nuclear force, strong nuclear force, electromagnetic force and gravity.

7.1.2 Interdisciplinary Research

By the end of the last century, human exploration in major basic disciplines has been nearly perfect, and the scientific research force in a single domain has already shifted from scientific theory to scientific application. In the new century, the general direction of scientific research should gradually turn towards the goal of cross-domain and interdisciplinary research, and constantly create new interdisciplines.

Different from single-domain research, interdisciplinary research has higher requirements on the breadth of knowledge and information. It may not only involve any knowledge in each relevant single domain, but also needs information independent of every single-domain and closely related to multiple single-domains. The wider coverage of information means that it may become more difficult and less efficient to collect information on relevant domains, which may lead to higher research difficulty and more difficult to determine where to start in case of complicated problems.

Improving the efficiency of scientific information collection is a very important and meaningful thing. This is just like when we do data retrieval in databases, we usually need to do some work to improve the retrieval efficiency in advance. One of the most commonly used global means is to divide the massive data into different tables, partitions or even into databases.

Similarly, in logical information network, we can also finely divide all information and knowledge by domain. The hierarchy dividing and classifying of domain information mentioned above is only a method of fine logical division, and the physical division of domain information needs to be carried out at the level of database or other storage devices. It is a simple and reasonable way to divide into tables by domain, but it must be adjusted according to actual data volumes and peak reading and writing traffic. In addition, how to divide the information data of cross-domains? Divide into separate tables, or leave redundant data in all tables of related domain? This is worthy of careful consideration in practical operation.

Moreover, due to the large number at present, domains of different nature can also be managed separately based on actual business needs. Such as dividing the domains of natural sciences with strong logicality, and the domains of social sciences and humanities with less logicality into different databases, or dividing databases referring to the domestic mainstream classification methods (in China) of more than ten disciplines such as "philosophy, literature, science, engineering, law and medicine", and so on.

Dividing multifarious information by domain facilitates classification management. However, for those who only master the knowledge of their own domain but need to carry out cross-domain cooperation, their communication may encounter barriers due to the gap between domains.

There are always some unique knowledge concepts in every domain that are not well known to people outside the domain. In addition, some information involved multiple domains has no different connotation but different terminology expression, just because different domains may have their own specific academic norms. Or perhaps, the same term has different meanings in different domains. All of these are possible causes of the gap between domains.

So, how to eliminate the gap and ambiguity of knowledge between different domains and reduce communication barriers? Perhaps mapping multiple different descriptions for the same domain knowledge or information in a specific domain simultaneously would be a practical solution that logical information network can provide. These types of descriptions can be directed to people outside the domain, junior people in the domain and professionals in the domain respectively. The first type of description is to use common, unambiguous, generally acceptable words and sentences outside the domain to ensure that people outside the field can roughly understand. The second type of description, based on the first type of description, associates a small amount of introductory domain knowledge, and simplifies part of the lengthy narrative content added to meet the first type of description, so as to ensure that junior people in the domain and people with high cognitive ability outside the domain can basically understand. The third type of description, on the basis of the second type of description, further relates a large amount of professional domain knowledge or concepts, and collapses a part of the derivation process or narrative words and sentences that can be regarded as common sense in the domain. The description content can be more concise and suitable for professionals who have a high grasp of most of the knowledge in the domain.

In this way, the "Multiple Information Description Scheme" (MIDS), described at levels of "no-threshold - advanced - professional", will undoubtedly produce a huge number of seemingly redundant information, but the rich data will also enrich the details related to knowledge. And meanwhile, the clear hierarchy will also enable more people to understand and recognize its true meaning, so as to reduce ambiguity and communication barriers.

7.1.3 Science Popularization

There may not only be a gap between professionals in different fields in the academic circle, but also a wide gap between inside and outside the academic circle.

For a long time, the cause of science has been seen as hidden away in the ivory towers, and the results of scientific research are far from the general public. Regularly researchers only follow academic ethics, and the main goal is to publish their research results in journals or conference reports. From journal papers to the general public, there is still a lack of positive promotion power. As laymen, most of the public will not directly read scientific research papers. Even after reading these articles, the extent of comprehension and digestion is quite limited.

Moreover, nowadays people have more and more ways to access information and knowledge, and various kinds of mass media play a part in bridging the role between academia and the public. However, the general public mostly lacks sufficient identification ability for these sources of information. And the mass media are intermingled, which cannot ensure proper scientific literacy. What's more, for unknown purposes, someone deliberately misinterprets scientific research achievements, resulting in rumors. It not only misleads the public, but also makes the public germinate or aggravate their distrust of science.

Therefore, it is necessary for the scientists in academia to shoulder greater responsibility in order to popularize their research achievements to wider audiences. Just like what is emphasized in the academic report entitled *the Public Understanding of Science*, published by *the Royal*

Society in 1985, is the importance of communicating science to the society. If going to bridge the alienation between the scientific community and the public, it is essential to improve the public understanding and participation of science.

To improve the understanding of science, it is necessary to provide more understandable scientific materials. The "Multiple Information Description Scheme" provided in logical information network for cross-domain cooperation and communication is also applicable here. Because the general public outside the academic circle are also the people outside the professional domain. Compared with other people in the academic circle, the general public is further away from the academic circle, and more ignorant of the academic norms and professional terminology in the domain. This requires scientists to actively transform their academic achievements in the third type of description into the first or second type of description.

As scientific knowledge transitions gradually from the third type of description to the first type of description, it is necessary to convey research information truthfully without exaggeration or distortion, and use scientific terminology carefully. This is bound to be a long process with constant adjustment. It is likely to cost a lot of manpower to build up these scientific information content in logical information network in a planned way. The time and effort spent in this is also a significant expense compared to the direct cost of doing research. Thus, in this regard, the scientific community should engage in a more active and responsible manner, otherwise it will be difficult to achieve real results.

On the other hand, in order for science to be more widely understood and gain higher participation, it is necessary to consciously cultivate the scientific literacy of the public. Only by putting scientific knowledge and scientific consciousness into people's lives can help them to understand science better. From the basic education of young children to the ubiquitous mass media such as television, radio, advertising, Internet information and social applications, if they can be seamlessly integrated with the third type of description and interact deeply, so as to give full play to the advantage of direct access to the forefront of science, it will undoubtedly be very beneficial to mend the gap between the scientific community and the nonscientific community.

Moreover, it should be particularly pointed out that the information and knowledge constructed in logical information network have strong logicality in nature. However, at present, there is no special logic course in primary and secondary schools domestically (in China). Only in mathematics which is closely related to logic, some superficial knowledge of logic is involved. And in college, logic is basically just an independent discipline of domain, studied by a small number of professionals, and has not been widely promoted. In terms of knowledge in the domain of logic, this level of acquaintance is not sufficient to support a complete understanding of scientific information by the public, nor to meet the knowledge reserve required by scientists to popularize the scientific achievements in the third type of description. Lack of knowledge of logic means that the basic identification skill is not solid, which is one of the main causes of the rapid spread of rumors in many cases. Therefore, it is of great significance for the popularization of all scientific knowledge both to offer logic courses in schools and to publicize the basic concepts of logic among the public.

The ultimate goal of scientific research is to bring benefits to the general society. If it is ensured that the public can touch the real research results and clearly understand how the results affect individual lives and benefit the public, it will in turn bring unprecedented understanding and support to the scientific community inevitably. Meanwhile, it will also provide enough clear instructions of requirements for the development direction of many applied scientific research domains. That will be a great driving force for the cause of science.

7.2 Cognition

Cognition is the core content of cognitive psychology research, and it is the process of human understanding external things and information. To sum up, it is basically the two aspects of "recognition" and "knowledge", i.e. individuals acquire and distinguish the information input from the outside, as well as the analysis, processing, memory storage and feedback output of information.

7.2.1 Reading

At present, the main way for us to obtain useful information and knowledge from the outside world is through reading. As the main object of reading and the carrier of human cultural knowledge inheritance, text has existed and evolved for thousands of years. Although, text can be used to record and transmit information, which has always been regarded as the important foundation of information technology. Some people even regard the birth of text as the first revolution of information technology. But strictly speaking, text is only a kind of concrete expression of abstract information, and the text itself also needs corresponding carrying media, such as paper. Since the invention of papermaking technology, paper has played a perfect role in long-term text recording and knowledge inheritance for thousands of years, which makes great contributions to the progress of human society.

However, from another point of view, the text on paper also has obvious shortcomings, because it has always been plain. What is plain text? If we read an article or a piece of text according to its display order, we can see only one kind of order in which the text contents are arranged. That is to say, the core content of the information it conveys is a single and unchanging entity, without diverse information combinations, and it cannot be presented to the world in a stereoscopic and multifaceted form.

Even so, generally in fact, different people reading the same plain article may still get different information. Even if the same person reads the same article many times, they may have different feelings. This needs to be viewed from the perspective of cognitive science. Human cognition of external information is a complex process. First of all in this process, the sensory organs need to receive the input stimulation of information from the outside world. Secondly, the information is processed through the cognitive system, and then it enters the brain for long-term storage.

Reading is a form of receiving information from the outside world. Different people may have different ways of reading. Some read from the first word to the last word step by step; Others read the final conclusion first and then go back to the previous text to find relevant content; Others read in leaps and bounds, only capturing some important points in paragraphs. In this way, the information received by each person reading the same text is bound to be different.

The level of information processing varies from person to person, depending on the unique personal reservoir of knowledge and information, which is the context used to analyze and understand information. If unthinking like swallowing dates, naturally there would be no special understanding, and what comes into mind is still a whole paragraph of text. If being good at retrieving information to find the key points in the outline, or being good at questioning systematically to find out doubtful points and difficulties, or finding some details to solve some doubts in the heart. In these ways, everyone will also have different contents of the received information processed after cognitive understanding and absorption. It may be information as a whole, or it may be information only in one aspect. What is made by organically combining everyone's understanding, is a stereoscopic and multifaceted form of information mapped by a piece of plain text.

This form of information is very similar to the form of information carrier provided by logical information network. A whole article in a logical information network can be regarded as an information section, and the information after understood can be a pile of fragmented information elements. Linking these information elements together can fuse into a same information section as this article, or form some other forms of information combination. Such a variable form is much more informative than a single plain text. Because it contains not only the same amount of information elements as plain text, but also the logical relations between various information elements.

One person can only harvest one-sided information through a plain reading form, so if improving a stereoscopic and multifaceted reading form, will it bring richer information and better reading effect?

Limited by the development of media technology, paper has occupied an important position in information media for a long time. However, since the middle of the 20th century, computer has emerged on the historical stage, and human beings have entered the era of information explosion. Information is gradually moved into the storage devices of computers, transmitted through network cables, and displayed on the output devices, such as monitors, and screens of mobile phone. The functions of information, such as storage, transmission and display, are no longer completed by a single medium, but are modularized and distributed into various component equipment. At the same time, the stereoscopic presentation of information has become possible with the continuous development of information technology.

At present, books and journals in mainstream media, as well as the widely digitized new media news, internet blogs and so on, are still in the form of flat long text, which can be separated in logical information network. Such separating operation may be done by the author of the long article, or by readers after reading it. The author can refine the main points of the article and provide definitions for important or unfamiliar concepts. Readers can add targeted reading notes, comments, question about some contents and so on. These will exist as fragments of information elements in the logical information network. The separated fragmentary elements from different articles may be related to each other due to various relations such as causality, defining, near-synonymy, mapping, affiliation, etc., and together become domain knowledge in a certain domain. With a large number of domain knowledge connected, it is bound to be easy to touch a series of surrounding fragmentary elements through a single fragmentary element. It can also take any fragmentary element as entry point to quickly reach relevant information from outside to inside the domain, and form a flexible way of knowledge access and acquisition.

7.2.2 Memory

So far, human understanding of the mechanism of brain cognition and memorization is still very limited. Currently, the memory models recognized by cognitive psychologists are mainly the Atkinson-Shiffrin's multi-store model of memory and the information processing theory of memory, which were proposed in the early stage of cognitive psychology in the 1960s and 1970s. It should be said that the birth and rapid development of cognitive psychology at that time were greatly influenced by the theory of information science. A-S memory model and the information processing theory also borrowed many concepts in information science and computer science to varying degrees.

A-S memory model is mainly composed of three memory systems: sensory memory, short-term memory and long-term memory. These three different memory carriers can be thought of as respective corresponding to the registers of input devices, runtime storage devices and persistent storage devices in computer hardware.

In terms of functions and characteristics, they also correspond to each other. The "input – processing - output" model, the core of information processing theory in cognitive psychology, also benefits from the working mode of computer. After the signals of computer's input devices, also including all kinds of sensors, are received by registers, they will only stay for a very short time before being transmitted to memory. Correspondingly, after the sensory memory of human brain receives the stimulation from sensory organs such as visual, auditory, taste, smell and tactile senses, if attended, the corresponding sensory information will enter short-term memory; otherwise it may disappear rapidly within a few seconds. As a temporary storage when computer is running, its runtime memory does not have the function of storing information for a long time. Usually, only after performing relevant operations, result data will be saved to persistent storage devices. On the other side, when the attended information enters the short-term memory of human brain, it needs to go through the processing such as encoding or rehearsal before it is moved to long-term memory for persistent storage, otherwise it will be forgotten in a short time.

It can be seen that in the cognitive process, the input and processing of information is for the storage of information. Before storage, it needs to continuously go through the steps of stimulation, attention and rehearsal; otherwise there will be a risk that the information may be forgotten in advance. When retrieving and outputting, memory is generally based on some retrieval requirements as conditions, and then scan along certain paths in long-term memory until an appropriate information node is found, or give up after a long time. Although the limit of long-term memory capacity has not been measured off at present, which is generally considered to be an infinite and large enough information storage space, the forgetting behavior that cannot retrieve the required information is not uncommon.

As for forgetting, some say that it is because the traces left by memorization are gradually fading, while others think that the memorization traces interfere or inhibit each other, resulting in the loss of access to it. As early as the late 19th century, German psychologist Hermann Ebbinghaus studied and drew the famous forgetting curve to illustrate the rule that the memory content changes with time. That is, the forgetting process begins after memorization, goes rapidly at first, and gradually slows down later. On the premise of this rule, scholars studying memory have continually put forward a variety of methods to strengthen memorization, such as reviewing many times after one memorization, which consolidate and strengthen long-term memory, and the review interval should be short first and then long. Or, when processing, actively adopt a variety of different encoding methods for information at the same time, such as auditory encoding, visual encoding, image encoding, semantic encoding, etc., so as to increase the clues of memory and improve the efficiency of memory storage and retrieval. Some researchers have also summarized an "encoding specificity principle", which holds that the effect of recall is the best when the encoding episode matches the retrieval episode.

To sum up, obviously human brain has many weaknesses and restraints in the process of input and output information, which restrict the efficiency of information retrieval. Meanwhile, the cost of maintaining vast amounts of information in memory all the time is also extremely great, which itself is not in line with the current human cognitive talents. In addition to constantly trying to develop and optimize the brain utilization and better memorization means, in fact, it is also a very worthwhile method to store some information with the help of external auxiliary devices.

Compared with human brain, computer has the advantages that it almost never forgets and its capacity can be continuously expanded. Combined with today's fast and ubiquitous network environment, supplemented by smart phones, and smart watches, smart wristbands, smart glasses and other portable or wearable devices, and even permanent implantable devices and brain-computer chips that may appear in the future, these are not unreachable in terms of hardware technology.

In terms of software, logical information network, which can provide stereoscopic and multifaceted information form, is undoubtedly the most appropriate auxiliary mode of extra-brain storage. On the level of logic, the information model of logical information network is similar to the information form after understood and processed by human brain. The fragmentized, hierarchicalized and networked logical information network can store and manage a large amount of stereoscopic and changeable information. The characteristics of the model, such as the information element mapping, symbolization and key-value system of concept, facilitate quick retrieval in the information container. Various information elements and information relations strengthen the connection between information and enrich the practicability of logical information network. The object types such as proposition, concept, condition and attribute based on the foundation of logic also make logical information network more robust in logical representation.

Different from the previous auxiliary devices for memory mostly aimed at enhancing memory ability, the auxiliary devices based on logical information network can focus on helping users hold the information content that is not very important but occupies a mass of storage space. Theoretically, there is the possibility of unlimited expansion of extra-brain storage. On the one hand, it can help human brain release more working memory space and save the input and output cost of long-term memory, so that it can process more important information, which make the role of brain focus more on acting as a "central processing unit" (CPU) rather than a pure "storage" (memory). On the other hand, it can also leave room for imagination to enhance brain-computer interaction in the future. After all, for now, "1 (human brain) + 1 (computer) >> 2" is still a considerable possibility. Even without such long-term consideration, logical information network can also provide more auxiliary functions with the support of existing mature information technology, which will be more practical in the short term than those pure tools such as e-memos and GTD applications *[35].

7.2.3 Artificial Intelligence

i.

Cognitive science studies the cognitive mechanism of human beings, which is the core of the "software" part of human intelligence. In addition, the research on the "hardware" part of human intelligence mainly focuses on the domain of brain science or neuroscience. The combination of the two results in roughly all the components of human intelligence.

Human beings not only yearn for the causes of their own intelligence, but also hope to open up a new field of artificial intelligence research, that is, through studying and understanding of themselves, to simulate and artificially create intelligent machines similar to human wisdom.

It should be said that the research of artificial intelligence is closely related to cognitive science. Currently, it is generally accepted that artificial intelligence is an interdisciplinary subject between cognitive science and computer science. The research of artificial intelligence is to take the achievements of cognitive science as the criterion and goal, and try to realize it with computer technology.

The domains associated with artificial intelligence and cognitive science mostly overlap with each other. As an emerging discipline in the 20th century, cognitive science was born by some American scholars integrating part of the research content from six different disciplines, including philosophy, linguistics, psychology, anthropology, computer science and neuroscience. Although artificial intelligence existed only as a branch of computer science at the beginning, its research scope covers a wide range, including "natural language processing" related to linguistics, and "robotics" simulating human thoughts and behaviors and involving logic and praxeology. There is also the "ethics of artificial intelligence," which is related to various disciplines such as philosophy, psychology, moral philosophy and anthropology.

Moreover, although these two research domains have maintained a high degree of attention, and both academia and industry have invested a lot of research efforts, they are still far from revealing the core question, "**how does wisdom come from**".

[35] GTD (Getting Things Done), time management applications, including To-Do List, Schedule and other functions.

ii.

Furthermore, there are many research schools of artificial intelligence, each of which has its own research methods, which depend on their different cognitive ideas. Over the past decades, these several schools have been advancing one after another, and the tide waves are constantly changing. Symbolism and connectionism have successively served as the weather vane for the development of the field. In recent years, with the media effect brought by the success of AlphaGo, artificial neural network and deep learning, as representatives of connectionism, have been widely praised and become the mainstream research direction in the domain of artificial intelligence.

The research method of connectionism is mainly to imitate the structure and working mode of human brain. Its proponents believe that the basic element of cognition is brain neurons, and the cognitive process is that huge number of neurons connect and interact with each other, which results in intelligent thinkings or behaviors. Therefore, understanding the structure of brain and the working mechanism of neurons is expected to understand the process of information processing in brain, and even reveal the mystery of human wisdom.

However, human's understanding of brain is still very limited. The current situation of brain science research is similar to that of physics in the early 20th century, where some achievements have been made but there has been no major understanding or breakthrough. The reason is that the current research methods of human brain are not efficient. As Paul Allen, who was a former cofounder of Microsoft and later strongly funded brain science research, argued that, "the way we explore human brain now is much like a being a medieval blacksmith trying to reverse engineer a jet plane."

Reverse engineering means that adopting the experimental test means such as shape observation, debugging and disassembly analysis, for an object of "black box" without any understanding of its internal structure and nature, to speculate its origin or structure, function and characteristics. At present, human brain is such a "black box" for us, and the more cutting-edge research method is mainly to freeze and slice up the brain, image it under a high-resolution microscope, collect the genetic information in each slice and make a map of the brain structure.

Imagine if a modern computer had suddenly appeared a hundred years ago, before computers were invented, how researchers would analyze or even imitate it at that time. It is obviously very difficult to disassemble a computer in reverse without a complete understanding of its working mode and principle, and without such rich tools as today. More importantly, dismantling a computer can only reverse its tangible hardware equipment at most, and its internal intangible software content can hardly be decrypted in this way, as anyone who works in information technology knows.

Compared with the chips and integrated circuits in computers, the hardware of human brain is considered by researchers to be at least 8 - 10 orders of magnitude more complex. No wonder some domestic brain science experts believe that not only in this century, but also likely in the next century, brain science will still be in the forefront of science, with many unsolved mysteries.

The slow progress of brain science research, for those medical diagnosis and intervention of critical brain diseases entirely based on this, may be a reality which has to be accepted. But for the goal of taking this to develop "brain-like intelligence", it seems that such a path may not be the best choice at present.

One false step will make a great difference. The function of brain microstructure is still unclear, and there are still variables for the research in this direction. If there are subversive discoveries in the future, will the "brain-like intelligence" developed on the basis of previous brain science research collapse? Is it necessary to overturn and start again?

Therefore, even though the current development of machine learning has been able to accomplish some things that were once impossible, such as defeating or even annihilating the human world champion of Go, it is still very likely to be far from the ideal real intelligence.

iii.

What is the difference between the current "brain-like intelligence" and real intelligence? The "brain-like intelligence" focuses on the imitation of the "hardware" form of human intelligence, while ignoring the effect of "software". Among them, the capability of logic is the most important foundation of the "software" part of human intelligence.

As we all know, the biggest problem in the domain of machine learning is that those complex algorithms, models and systems generally lack transparency of decision-making and interpretability of results. Meanwhile, they are not capable of logical derivation, unable to identify or infer causality. In fact, there is a certain connection between these two points.

The so-called interpretability means that it is basically possible to understand its complete process of decision-making from the perspective of human beings. However, most models of machine learning are "black-box" models, in which there are generally only massive numbers, matrices, neurons, hidden layers, parameters and so on, as well as large-scale reuse of few simple abstract formulas, activation functions and algorithms. The interpretability of these elements is relatively weak, and as the "black-box" systems built on such model elements become more and more complex, their internal mechanism becomes extremely difficult to express in a way understood by human beings, and the interpretability is not guaranteed at all.

On the other hand, most machine learning models to date are based on statistics. The results obtained by statistics can only show that there is certain interdependency between things or information, namely the correlation between each other, but cannot directly reflect whether there is a causal relationship, so it is impossible to provide complete and powerful support for summarizing experience or predicting the future. This often makes the results and interpretations of model predictions deviate significantly from the actual situation, which in turn leads to further deterioration of their interpretability.

The internal lack of necessary logical connection and external lack of appropriate expression form are the core reasons for the current dilemma of interpretability in the domain of machine learning. Therefore, more than one pioneer in the field of machine learning have proposed that such kind of problems can be improved from the aspects of causal reasoning models, cognitive theories and models. Judea Pearl (2011 Turing Award winner) and Yoshua Bengio (2018 Turing Award winner) have put forward their own researches on causality models and published relevant research papers or works. *[36] However, it can be seen that their researches focus on combining causality with machine learning in the hope of improving the shortcomings in algorithms. The specific approach is roughly to try to determine the possible causal relationship in correlations under some specific graph structures and probability distributions, and further judge which the object on either side of the relationship comes first, which one is the cause and which one is the effect.

It is believed in private that even though it lacks the ability of logical reasoning, such partial optimization of algorithm is not useful to improve the limitations of machine learning itself.

In essence, machine learning is just an algorithm that uses massive sophisticated mathematical means, especially statistics, to simulate decision-making. It can provide a prediction scheme to deal with a single problem or achieve a single type of goal to a certain extent, but it is not the result of deductive "causality", nor the intelligent behavior we imagine that can think independently and respond to different types of events. For the time being, let's call it an *Advanced Semi-Adaptive Algorithm* (ASAA).

In order to meet the requirements of thinking and responding to different types of events, a flexible algorithm mechanism that can be self-adaptive and self-expansible is necessary. Self-adaptive means that for different events in the same type, the variable parameters in response algorithm need to be adjusted according to reality. At present, machine learning frequently requires manual intervention in parameter adjustment and optimization, so it is called "semi-adaptive". Self-expansible means that the response algorithms can automatically generate countermeasures for different types of events, which machine learning does not have now.

iv.

As we all know, algorithms, data and computing capacity are generally regarded as the three elements of the development of artificial intelligence technology today. In addition to algorithms, data is also an important factor affecting the decision-making effect at the level of "software", because the self-adaptive algorithms depend on the support of massive data and constantly improving data set models.

In recent years, the data set models based on graph structure have attracted more and more attention, among which the most concerned representative is Knowledge Graph. Knowledge Graph is an upgrade of ordinary graph structure, and entities and relations are its most basic elements. Entities include concepts, attributes and other types. Concepts represent different objects and their categories, and the attributes of concepts correspond to attribute values one by one. As the nodes in graph structure, entities are connected with each other through relations to form a network knowledge structure. In this sense, part of the structure in logical information model is very similar to it.

To continuously expand and improve a knowledge repository based on Knowledge Graph model, it is necessary to study knowledge retrieval, knowledge representation, knowledge fusion, knowledge reasoning and other technologies. So, in order to meet its operation, it is also needed to

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[36] In his 2019 work *The Book of Why: The New Science of Cause and Effect*, Judea Pearl proposed three levels of "association", "intervention" and "counterfactual" to explain the relationship between causation and correlation.
Yoshua Bengio and his laboratory colleagues published a research paper *A Meta-Transfer Objective for Learning to Disentangle Causal Mechanisms* in 2019, outlining a deep learning model that can identify simple causality. The algorithm in the paper essentially forms assumptions about which variables have causality, and then tests the variations on different variables.

build a special work engine for Knowledge Graph. In contrast, the structure of logical information model itself contains elements of reasoning type, mainly proposition and argument, and reasoning algorithm can be a part of logical information network as dynamic information, which makes it possible for logical information network to include knowledge both data and reasoning algorithm concurrently.

Knowledge reasoning is considered to be the only way to strong artificial intelligence. Reasoning is a kind of intelligent behavior combining knowledge and methods. Originally, knowledge and methods, corresponding to static information and dynamic information respectively, are both forms of information, but just we have artificially classified them in understanding.

The cognitive level of human beings is not fixed from birth, but continues to improve with acquiring information from the outside, then transforming into the cognition of knowledge and methods of doing things, and continuously integrating and updating in the process of growing up. Currently, no experiment shows that knowledge and methods are divided into different regions in brain to remember for human intelligence, that is, the processing, storage, integration and update of all knowledge and methods can be treated as in a unified form of information.

For artificial intelligence, combining knowledge and methods into the same form and keeping them stored in the same entity make it possible to reduce the overhead of information communication in the process of retrieval and storage, enhance the consistency and security of information, and make the process of information processing more flexible. This is conducive to not only reasoning new knowledge, but also improving working methods or algorithms. These are the basis of an entity with complete "self-adaption" and independent "thinking", as well as the basic capabilities required for stronger artificial intelligence.

From this perspective, logical information network can be regarded as the upgrading and expansion of knowledge graph to a certain extent.

v.

Algorithm and data are the main part of the "software" of artificial intelligence, while computing capacity is the "hardware" part. Unlike "software", which can be improved through acquired cognition, "hardware" is usually congenital and is not directly determined by cognitive behaviors even if it is changed postnatally.

Here we might as well call those "hardware" or other abilities, which are associated with intelligent behaviors and are not acquired through cognitive ability, "**talent**". Such as that the computing capacity of artificial intelligence reflected in nothing more than the number and frequency of computer chip cores, the efficiency of instruction set, the capacity of runtime memory, the bandwidth of transmission bus and other data indicators. It is roughly equivalent to the combination of brain storage capacity and mental agility of human intelligence, which is a "talent" other than cognitive ability. Various signal sensors and information input sources, equivalent to human sensory organs, are also part of "talents". The function of these "talents" is to support the input of information and the processing of intelligence.

If assuming that human intelligence and artificial intelligence process information in a similar way, their main difference lies in the innate differences between individuals. In addition to human beings, other animals may also have a certain amount of intelligence, especially gorillas, dolphins and other few species are considered to be closest to human intelligence. Biological anatomy experiments show that the gap between them and human beings in intelligence is mainly reflected in the difference in brain capacity and brain structure. This is a cognitive talent difference between species.

In addition to the input and processing of information, the "talent" also supports those abilities that depend on the output of information. This category mainly refers to the ability to manipulate the body, which can be divided into physical action, facial expression, and voice (or language) expression and so on. Different species, or different intelligent entities, may also have some unique talents, which are not determined by intelligence. Such as that the streamline shape of dolphins makes them good at swimming, the slender body of cheetahs is suitable for sprinting, bats have wings for flight and can emit ultrasonic waves for echolocation, etc.

For artificial intelligence, there are also various robots for different purposes, which specialize in different actions, are good at operating different external mechanical and electronic equipment, or are able to listen and answer. In addition, as one of the important development directions in the cross-domain of brain science and cognitive science in the future, the research on brain-computer interface and brain-computer fusion is also expected to provide more diverse talents and abilities for human beings and artificial intelligence.

On the whole, the talent essentially refers to the subjective characteristics of intelligent entities, which are closely related to the input, processing and output of information in the domain of cognition. Logical information model can play a central role in such a system. (Figure 50)

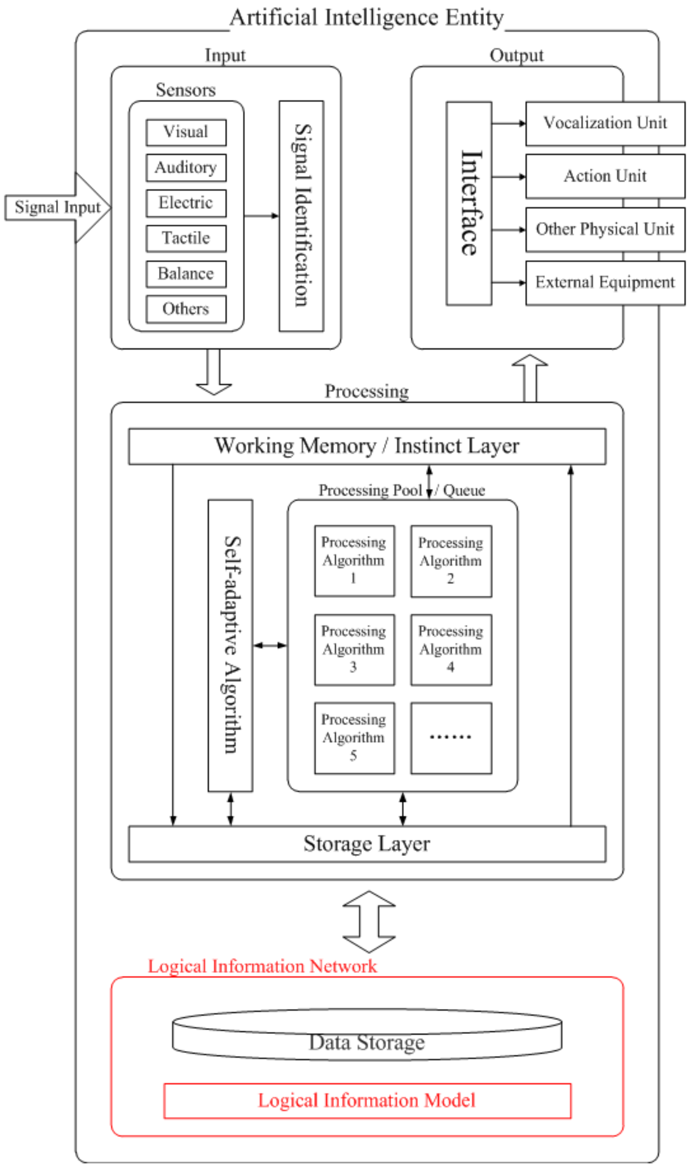


Figure 50: Structural diagram of artificial intelligence understanding.

vi.

In a nutshell, the growth of human intelligence begins with observation. Observation is to perceive all kinds of information around through sensory organs, including self-understanding. Observation is followed by imitation, a major manifestation of low-order intelligence, which is the beginning of acquiring and memorizing knowledge. As learning and imitating, along with constant doubting and gradually thinking. Learning and imitating come with constant doubting and gradually thinking. What comes with learning and imitating is constant doubting and gradual thinking. From a large number of individual phenomena observed, to infer the general laws of things, to summarize behaviors, methods or paradigms, then to re-observe and revise, gradually to improve, and to form their own logical ability. In the process of thinking, after accumulating enough self-awareness, it is possible to distinguish oneself from other entities, understand and tolerate others' behaviors and views, or breed senses of identity to other entities.

Correspondingly, the real evolution of artificial intelligence should also start from obtaining information. Firstly, sensors pick up external signals and process them into interpretable information. Then, to use the initial self-adaptive algorithm to select the appropriate processing algorithm, to combine with the previously stored information and knowledge for self-processing. Finally, to form new static information and knowledge or the behavior algorithm of controlling itself and the surrounding hardware; Or to directly trigger action instructions to drive and operate various equipment; Or even to improve and update the self-adaptive algorithm.

8. Logical Information Network: Unsolved Problems

Logical information network is suitable for managing information, especially the information clusters which have internal logical relationship with each other, so it has a wide and valuable application prospect. However, due to the characteristics of fragmentization, it is possible to make the amount of information in logical information network be several times greater than its information source. This brings some difficulties to its collection and management of information elements, and makes it probable to produce some thorny problems to be solved in practical application.

The possible difficulties mainly focus on the following points:

i). How to collect massive information in logical information network?

Solution: In the short term, it can rely on manual collection and web crawler technology. In the medium to long term, it is suitable to use vision based character and image recognition, auditory based speech recognition, sensor recognition based on other sensory abilities and so on.

ii). How to fragmentize the large sections of collected information?

Solution: In the short term, manual operation can be used. In the medium to long term, it is suitable to use specific optimized technologies of semantic analysis or other customized algorithms.

iii). How to ensure the efficiency of the storage and retrieval of massive information elements after collection?

Solution: In the short term, the storage and access functions provided by graph database can be used. In the medium to long term, it is suitable to use other targeted customized algorithms of new type self-developed data storage media.

iv). How to identify and merge similar information elements?

Solution: In the short term, it can be judged manually. In the medium to long term, it is necessary to customize relevant algorithms.

v). How to solve the problem that the usage of physical storage space increases exponentially after activating the version control of information elements?

The amount of data contained in a rich logical information network is likely to be astronomical in itself. If coupled with the version control function of information elements, the actual required storage space will be further increased, and the growth law and change cycle will be even more difficult to control. At present, it is difficult to have a perfect solution once and for all. There is no other way but to monitor it in actual application scenarios, and to adopt the intervention of "manual & customized algorithm", so as to prevent the situation from exceeding expectations or getting out of control.

vi). How to deal with excessive information?

For massive information, whether in logical storage or physical storage, there must be a threshold, whether it is a preset fixed value or a variable changing with the system's development. This threshold is the watershed for the system to adopt different strategies for the received information.

The possible strategic measures will be roughly as follows:

Conservative monitoring: In the process of collecting data and importing into the system, only to monitor the growth of data volume, but not to optimize the data content;

Optimizing step by step: On the premise of not affecting the operation performance of the system, to optimize the data imported into the system to a certain extent in stages and from time to time, so as to restrain the growth rate of data volume;

Expanding the storage: To transfer some newly imported data or extremely inactive old data to standby storage or external storage devices;

Strategic discarding: After identifying and processing some newly imported data, to only retain the processed data, and discard other original data directly.

Of course, these strategies are only a prediction about the operation of ideal logical information network. Specifically, how to set the threshold (or multi-thresholds), how to set different strategies for different thresholds, and how to implement the specific strategies, these require to customize relevant algorithms.

vii). How to deal with non-literal information?

The logical information model and logical information network introduced in this article are completely constructed on the basis of literal form at present. However, in terms of information form, literalness is only one of them. Sound, image, video, abstract spatial geometry, even smell, tactility, etc. are all different forms of information. Can such non-literal information be incorporated into logical information networks, and how? This is an important problem to be considered in the follow-up research and practice.

viii). How to represent the connotation of concepts and other information elements composed of concepts in logical information model?

This is a problem worthy of long-term thinking and discussion.

9. Summary

i.

The closer get to logic, the closer get to knowledge, the closer get to wisdom.

It is not that only what learned in logic textbooks is logic. Everyone (or every intelligent being) is able to have its own unique logic, as long as it conforms to the basic elements of logic. All logical contents exist in the form of information, and some of them are accepted and recognized by the public, and then become knowledge. The collection of knowledge eventually forms higher wisdom.

ii.

Logical information model, which combines the concepts of logic and informatics, is a new data model based on graph structure, and the underlying data structure of logical information network.

Everything in the world is information. The information that can be recorded is able to become a part of logical information network in the form of logical information model.

Logical information network is an effective and flexible way to reorganize and manage information. All the information contained in it is allowed to be associated with each other by some logical relation. The spatial structure of this logical relation can be presented quickly and intuitively by using the method of graph visualization.

Logical information network has a wide range of application scenarios, which can provide a great boost to the cause of scientific research and scientific popularization, the development of related domains of cognitive science, and even the development of artificial intelligence.

iii.

In the 1940s, the theories of human basic disciplines represented by quantum mechanics and relativity made major breakthroughs, which brought the explosive prosperity of applied science and technology after the Second World War. However, in the 21st century, the research of basic disciplines has been stagnant for several decades, and the fundamental theories have been unable to make another breakthrough, remaining in the era of Einstein in the last century. In recent years, almost all scientific and technological achievements are the development of applied science and technology, and the development of applied science and technology seems to be gradually reaching its limit.

Similarly, there have been few major breakthroughs in the research on relevant fundamental theories of artificial intelligence in the past few decades. Most of the achievements in recent years are the improvement of hardware computing power and software algorithms, and the continuous exploration and mining in application scenarios.

Fundamental theories are often far from practical applications, which make it boring and not easy to create benefits, so few researchers are willing to devote themselves to them. In addition, the process of research and argumentation is complicated and abstract, difficult to understand, and involves many concepts. So researchers usually have to rely on their personal brain power to sort out the whole research process, including huge number of data processing and corresponding argumentation analysis.

In this case, the value of logical information network will be more obvious. The role it plays for scientific modeling can help to reduce researchers' consumption of brain power in memorizing and recalling the abstract processes of argumentation and modeling, and put more energy into the creative thinking of how to construct ideal models. Moreover, it can also be regarded as a new cognitive model, which provides a new direction for the development of artificial intelligence.

Although it is still a long way from building a logical information network to realizing real "artificial intelligence", this does not prevent us from doing something that can bring value and play a positive role for it in the process. Such as information network visualization tools for assisting scientific modeling, stereoscopic information processing tools for assisting reading, time management and information management tools for assisting memorizing, new knowledge repository similar to "Knowledge Graph" but containing more logical information, adjustment of self-adaptive algorithm of artificial intelligence, etc. These are the embodiment of important values of logical information model and logical information network.

To provide a new methodology and a new tool for the cause of science is one of the fundamental and original intentions of the author in writing this article.

iv.

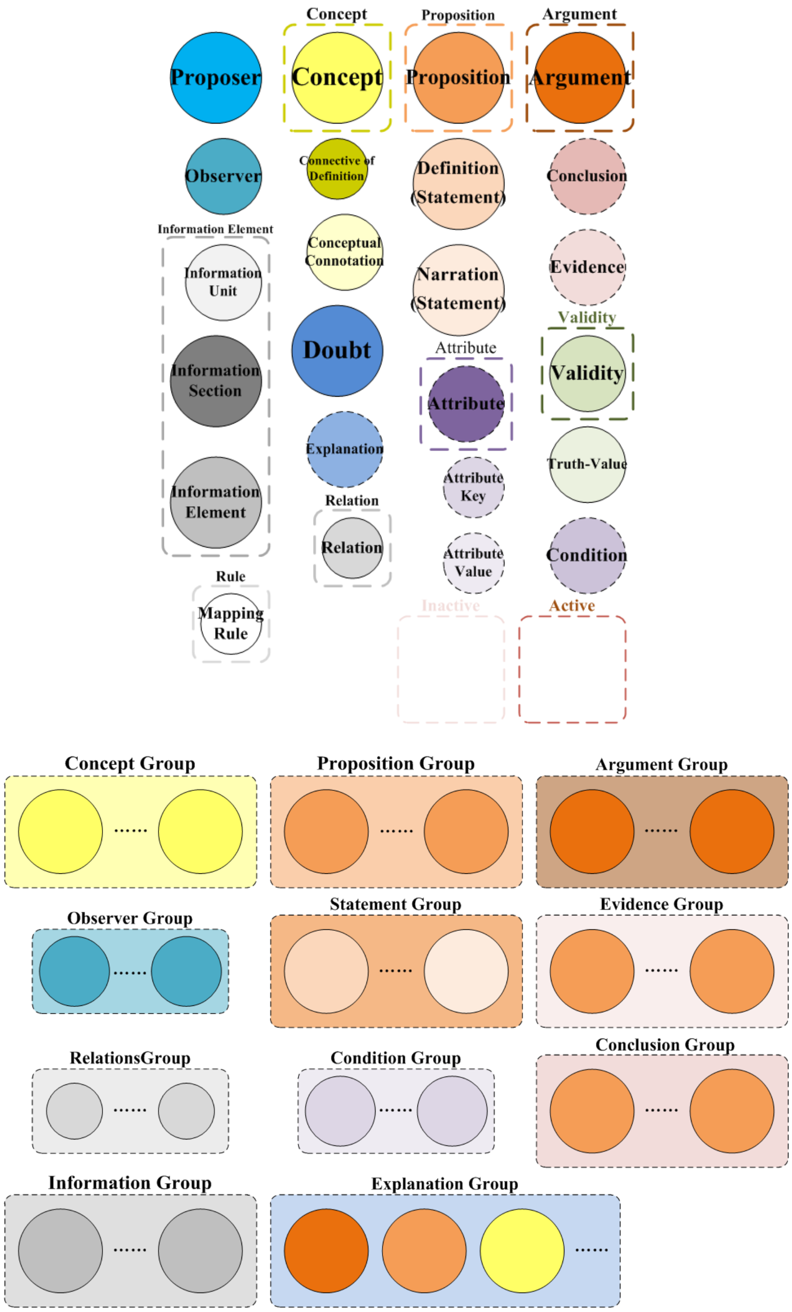
This article only focuses on describing the composition of logical information model and some possible features and functions of logical information network. It does not involve the algorithms or rules that may be applied in the content of logical information network. If necessary, it will be explained in another article in the future.

10. Acknowledgments

In this article, I would like to pay tribute to the masters and giants who have dedicated their lives to the noble cause of science and the development of science and technology of mankind in the history of scientific development.

Thank myself for my persistence and during the low tide of my personal career and the major epidemic.

Appendix A. The view design scheme of logical information model



Appendix B. A simple example of the conversion between text description and code description: Algorithm of binary search

Binary search, also known as half-division search, is a common, simple and efficient search algorithm. Its purpose is to find the element matching the keyword in the sorted queue. The whole process can be described in an easy-to-understand form as follows (Paragraph ①):

"First of all, there is a keyword as the search criteria, and a group of sorted elements as the search base queue. Find the element in the middle of the queue and compare it with the keyword. If the comparison result matches the search criteria, return the result and it means that the search is successful. If the comparison result does not match the search criteria, treat the elements before and after this position in the queue as two sub-queues. If the comparison element precedes the keyword, treat the back queue as the new base queue; otherwise, treat the front queue as the new base queue. Then repeat the previous steps until an element matching the search criteria is found, then return the successful result; Or if all elements do not match the search criteria, return a failure result."

If this description is disassembled into easy-to-operate steps, it can be as follows (Paragraph ②):

0. Prerequisites: a keyword as the search criteria, and a group of sorted elements as the search base queue;

1. Find the middle position of the base queue through the positions of the head and tail elements, and its corresponding element;

2. Compare the middle element with the keyword;

3. If the comparison result matches the search criteria, it means that the search is successful and return the search result (i.e. the position of the comparison element in the base queue);

4. If the comparison result does not match the search criteria, (treat the elements before and after this position in the queue as two sub-queues)

4-1. If the comparison element precedes the keyword, treat the back queue as the new base queue;

4-2. otherwise (i.e. if the comparison element succedes the keyword), treat the front queue as the new base queue;

5. Repeat steps from 1 to 4 (then there will be fewer and fewer elements in the base queue);

6. (before there is no element in the final base queue,) until an element matching the search criteria is found, then return the successful result;

7. Or (after there is no element in the final base queue,) if all elements do not match the search criteria, return a failure result (-1).

Since the number of elements in the base queue changes when the previous steps are repeated in Step 5, the head and tail elements of the base queue will also change, so the position of the head element of the base queue in the initial queue and the position of the tail element in the initial queue need to be taken as part of the prerequisites. The steps after readjustment are as follows (Paragraph ③):

0. Prerequisites: a keyword as the search criteria, a group of sorted elements as the search base queue, the position of the head element of the base queue and the position of the tail element of the base queue;

1. Find the middle position of the base queue through the positions of the head and tail elements, and its corresponding element;

2. Compare the middle element with the keyword;

3. If the comparison result matches the search criteria, it means that the search is successful and return the search result (i.e. the position of the comparison element in the base queue);

4. If the comparison result does not match the search criteria, (treat the elements before and after this position in the queue as two sub-queues)

4-1. If the comparison element precedes the keyword, treat the back queue as the new base queue (that is, update the position of the head element of the base queue);

4-2. otherwise (that is, if the comparison element succedes the keyword), treat the front queue as the new base queue (that is, update the position of the tail element of the base queue);

5. Repeat steps from 1 to 4 (then there will be fewer and fewer elements in the base queue);

6. (before there is no element in the final base queue, that is, the position of the head element in the base queue has not exceeded the position of the tail element,) until an element matching the search criteria is found, then return the successful result;

7. Or (after there is no more element in the final base queue, that is, the position of the head element in the base queue has exceeded the position of the tail element,) if all elements do not match the search criteria, return a failure result (-1).

Then, the steps can be converted into corresponding pseudo codes one by one as follows (Paragraph ④):

```
0. (int) key, (int[]) array, (int) head, (int) tail;
1. int mid = (head + tail - head) / 2; int midElement = array[mid];
2. bool comparisonResult = (key == midElement);
3. if (comparisonResult) { return mid; }

4. else {
4-1.        if (midElement < key) { head = mid + 1；   }
4-2.        else { tail = mid -1; }
   }

5. repeat { step(1 - 4); };
6. if (head <= tail) { return result of step5; }
7. if (head > tail) { return -1; }
```

According to the real code styles, Step 5 and 6 can be combined into a loop, and Steps 1 to 4 can be included in this loop body, while initial values should be given to the positions of the head and tail elements of the base queue. The improved executable code is as follows (Paragraph ⑤):

```
0.      (int) key, (int[]) array;
        int head = 0, int tail = array.length - 1;
5~6.    while (head <= tail) {
1.          int mid = (head + tail - head) / 2; int midElement = array[mid];
2.          bool comparisonResult = (key == midElement);
3.          if (comparisonResult) { return mid; }
4.          else {
4-1.                if (midElement < key) { head = mid + 1；  }
4-2.                else { tail = mid -1; }
            }
7.          if (head > tail) { return -1; }
        }
```

Although the code has room for improvement in terms of execution efficiency and readability, it is already a piece of code that can actually run and meet the basic requirements of the algorithm.

It can be seen that from the easy-to-understand text description Paragraph ①, to the easy-to-execute code description Paragraph ⑤, there is an operable relationship of mutual mapping and conversion between every two adjacent paragraphs. Although the conversion process in the example is simplistic and idealistic, and it may also become quite further complicated when in the face of other complex or composite algorithms, this also makes it possible, within the framework of logical information networks, to automatically convert ordinary text descriptions into functions that can be performed by computers. This possibility will be a very important part in developing from logical information model to logical information network, then to achieve fully autonomous artificial general intelligence without additional programming.

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