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Cyberlogic Paves the Way from Cyber Philosophy to Cyber Science

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***Abstract*—Cyberspace is a new basic space after the three traditional basic spaces – physical, social and thinking spaces (PST spaces). It is a trend that entities(objects) and PST spaces they are living in to be cyberized. On the one hand, the rapidly developing of cyberspace has the increasingly significant influences to PST spaces. One the other hand, the cyberization of objects in PST spaces have been continuously deepening and strengthening. Cyberization leads to the convergence of the four basic spaces, which also called Cyberspace and cyber-enabled Physical-Social-Thinking spaces (CPST spaces). In recent years, the philosophy research on CPST spaces and objects (short for Cyber Philosophy) has been developing rapidly while some researchers try to figure Cyber Science and its fundamental issues. Up to now, the bridge, fundament logic from Cyber Philosophy to Cyber Science, has not yet formed. This paper proposes a new concept of "cyberlogic" for establishing a bridge from cyber philosophy to cyber science. The etymology, concept, contents and methods of cyberlogic are presented, and the cyberlogic for the CPST spaces is shown. Moreover, main issues and methodologies for cyberlogic are discussed.**

***Index Terms*—Cyberlogic, cyberspace, cyber philosophy, cyber science, Cybermatics, Internet of Things, cyber physical system, cyberization.**

I. INTRODUCTION

THE morpheme "cyber" is derived from the Greek word *kubernan*, with the meanings of "steersman" and "to govern". In 1948, an American mathematician and philosopher Norbert Wiener first presented the word cybernetics, meaning the theoretical study of communication and control processes in biological, mechanical, electronic and computer systems, especially the comparison of these processes in neurophysiology and linguistics [1], [2]. Cyborg was formed by a blending of cybernetic and organism, referring to a human being with body organic and biomechatronic body parts aided or controlled by mechanical or electronic devices [3]. Recently, cyber has become a popular prefix to indicate objects that are associated with the Internet and computers, and typical concepts that have been raised include Cyberman [4], Cyberculture [5], [6], Cybercrime [7], Cybermatics [8], [9], Cyber philosophy [10], [11], and Cyber science [12], [13], [14].

Cyberspace is a new basic space after the three traditional basic spaces – physical, social and thinking spaces (PST spaces). It is a trend that objects and PST spaces they are living in to be cyberized. Cyberization leads to the convergence of the four basic spaces, which also called Cyberspace and cyber-enabled Physical-Social-Thinking spaces (CPST spaces). Cyberspace promotes the development of cyber philosophy and cyber science.

Cyber philosophy is an intersection of philosophy and computer science and is associated with new topics, models, methods, and issues revolving around five themes: minds, agency, reality, communication, and ethics [10], [11]. Philosophy of information (PI), as the logical theory of information considering the information content of logical signs and expressions, is an important subset of cyber philosophy focusing on "*conceptual issues arising at the intersection of computer science, information science, information technology, and philosophy*" [15]. PI provides philosophical approaches to drive, utilize and judge the essence and fundamentals of information [16].

Cyber science was first presented in the 1990s and developed to discuss applications and services for scientific purposes in information and communication technologies (ICTs) [12], [13]. Cyber science focuses on "*phenomena caused by CPST spaces*" and attempts to create a collection of knowledge about cyberspace, therein referring to cyber-related scientific and practical approaches [14], [17].

Both cyber philosophy and cyber science are defined towards these definitions based on informationization and networkization. With the development of cybernization, cyber philosophy and cyber science have newly definitions. Cyber philosophy consists of general and fundamental issues of cyber and cyber-enabled entities in CPST spaces of existence, knowledge, values, reason, mind, and so on; cyber science consists of the cyber and cyber-enabled entities' systematic knowledge in the form of testable explanations and predictions which are in CPST spaces. It is attractive for establishing interrelationships between cyber philosophy and cyber science.

As shown in Fig. 1. Cyberlogic acts as a bridge from cyber philosophy to cyber science. Cyberlogic covers the informal logic of natural language arguments and the formal logic of inference with purely formal content of cyber and cyber-enabled entities in CPST spaces. Cyberlogic is a scientific methodology providing foundational approaches for cyber science and cyber philosophy.

The remainder of this paper is organized as follows. Section II introduces the etymology, concept, contents and methods of cyberlogic. Section III presents cyberlogic for the cyber-enabled PST spaces. Section IV discusses the main issues and possibly available methodologies of cyberlogic, and challenges and conclusions are drawn in Section V.

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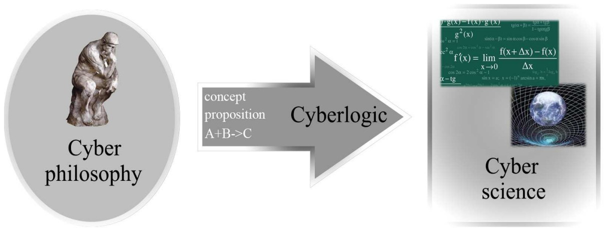

Fig. 1. The relationship between cyberlogic to cyber philosophy and cyber science.

II. Etymology, Concept, Contents and Methods of Cyberlogic

A. Etymology of Cyberlogic

The term cyber is derived from cybernetics and is used as a prefix to express concepts being related to cybernization [20]. In the 1970s, Control Data Corporation sold the "cyber" range of supercomputer, which established the word "cyber-" as being synonymous with computing [21]. In the 1980s, W. Gibson triggered a cyber- prefix flood in the novel "Neuromancer" [22], [23]. In the 1990s, "cybernization" was presented in the film "Ghost in the Shell: Stand Alone Complex" [24]. Accordingly, cyber is used to describe the influence in the cyberspace. In 1999, "cyberspace" was defined as a "notional environment in which communication over computer networks occurs", which can express emerging phenomena [25]. Cyberculture was presented in the 2000s as referring to "culture that has emerged from the use of computer networks for communication, entertainment, and business" [5], [6]. In 2013, cybermatics was proposed for describing an emerging interdisciplinary field in cyber-physical-social-thinking hyperspace [26], [27], [8], [28]. The development of cyber- is shown in Fig. 2.

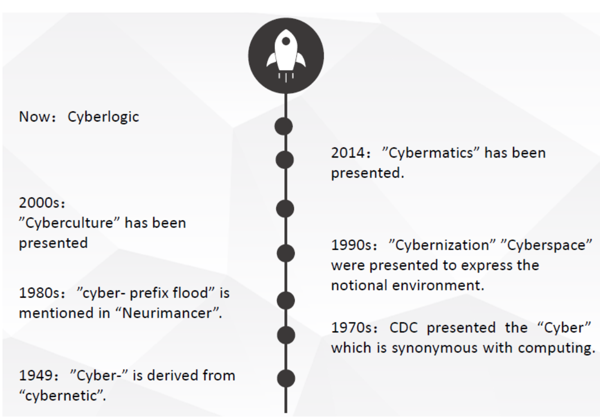

Fig. 2. The development of cyber-.

In Europe, during the High Middle Ages, philosophers attached close importance to logic. In the early 19th century, Aristotle presented the logic that became widely accepted in science and mathematics and remained in widespread use in the West. In the 1950s and 1960s, researchers expressed the knowledge in computers by logic with mathematical notation [29]. Logic is exerts tremendous influence on cyber science.

The etymology of cyberlogic is "cyber-" and "logic". This indicates that the logic exists in cyber-enabled PST spaces along with the influences of cybernization.

B. Concept of Cyberlogic

The concept of cyberlogic is inspired by traditional logic, in which there are specific logical relations support between assumptions of an argument and its conclusions. Logic originates from a concern with correctness of argumentation and ensures that those arguments arise from appropriately general forms of inference, described as follows [18].

- "Logic is defined as the essences and rules of entities. Entities exist in traditional PST spaces. "

Along with the development of cyberspace, the concept of cyberlogic can be defined as follows.

- Cyberlogic is the essences and rules of cyber and cyber-enabled entities in CPST spaces.

C. Main content

Cyberlogic mainly consists of the follow contents, more details are given in Section III:

- The essences and rules of cyber entities and cyber-enabled PST entities exist in cyber-enabled PST spaces, such as spatial-temporal logic in CeP Space and relationship between people in CeS space.
- The rules of single CPST space, the interactions among CeP, CeS and CeT spaces and the essences of CPST convergence space. The example of cyberlogic in spaces can be defined in follow:

$$CL \sim \{E(cyberspace), E(CeP), E(CeS), E(CeT), E(cyber\text{-}enabled\ PST)\}$$

In above equation, where CL is the cyberlogic, $E(cyberspace)$ is the essences and rules of cyberspace, $E(CeP)$ is the essences and rules of cyber-enabled physcial space, $E(CeS)$ is the essences and rules of cyber-enabled social space and $E(CeT)$ is the essences and rules of cyber-enabled thinking space; $E(cyber\text{-}enabled\ PST)$ is the essences and rules cyber-enabled PST spaces.

D. Methods for Cyberlogic

In contrast to logic, many new issues arises in the filed of cyberlogic, which require new methods to be developed. For example, the association among the CPST entities is a main issue of cyberlogic. The methods of associating entities in PST spaces with entities can be divided into two categories: knowledge-based and data-based. Knowledge-based methods refer to modeling PST entities in cyberspace according to our knowledge of them, while data-based methods establish a cyber entity for a PST entity by a set of its observed features. As to the methods of leveraging the ability of cyberspace to reveal the essences and rules in CPST spaces, some important forms include uncertainty-oriented methods, data-driven methods and cyber-augmented inference. Uncertainty-oriented methods focus on the uncertainty existing in the association between cyber and PST entities. Data-driven methods aims to complex essences and rules that are difficult for people to master. Moreover, with the cyberspace, the application scope of traditional inference methods can be extended. More details of these methods are given in Section IV.

III. Cyberlogic in cyber-enabled PST spaces

Cyberspace has a strong interaction with PST spaces. Cyber maps the entities in PST spaces to cyberspace, the entities in cyberspace are usually defined as cyber entities. Some of the entities in PST spaces establish the cyber-enabled entities in cyber-enabled PST spaces by cybernization. The relationship between entities in PST spaces, cyber entities and cyber-enabled entities is shown in Fig. 3. In the figure, the three kinds of entities (entities in PST spaces, cyber entities and cyber-enabled PST entities) and three kinds of spaces (PST spaces, cyberspace and cyber-enabled PST spaces) can be independent and also can interact and integrate with each other.

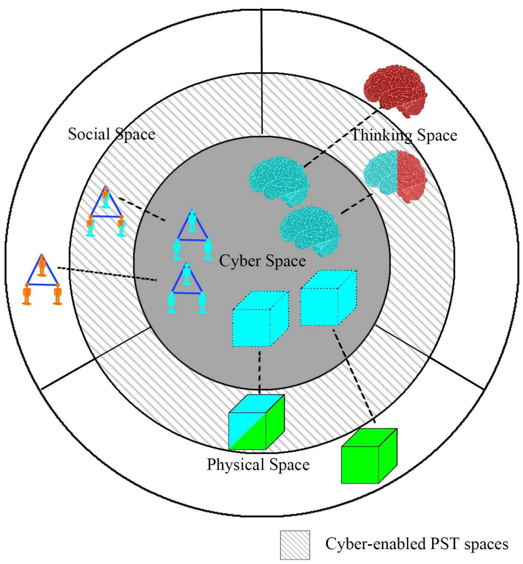

Fig. 3. PST spaces, cyberspace and cyber-enabled PST spaces.

A. Cyberlogic in Cyber-Enabled Physical (CeP) Space

Physical space refers to things that are provided by real environments and the physical universe. A physical object is an enduring object that exists through a particular trajectory of space and orientation over a particular duration. CeP spaces are composed of CeP objects and cyber entities that establish inter-mapping relationships, during which various sensors and actuators are applied over sensing and controlling one or more CeP objects on the terms of cyber entities.

In the CeP space, cyberlogic is reflected in the relationships between objects, for which the spatial temporal attribute is the basic aspect during their interactions. This part mainly focuses on three aspects of spatial-temporal attributes.

- *Unconfined Spatial Interactions*: CeP objects can overcome spatial attribute limitations in the CeP space. The transformation from CeP objects to cyber entities during cyber-physical mapping is the exemplification of cyber-logic. In the physical space, various interactions create relationship between physical objects, such as mechanical or electromagnetic methods, whereas cyberization is to establish interactions between cyber objects and CeP objects, and relationships between cyber objects have no relations with distance constraints.
- *Non-unidirectional Temporal Interactions*: Generally, in the physical space, physical objects are produced and develop irreversibly in a unidirectional state, and time always goes forward and passes uniformly in the same inertial system. In CeP space, time may be in the states of compression, expansion and reverse. For instance, cyber entities can be applied to simulate complicated or instantaneous physical experiments (e.g. atomic fission processes) in cyber space as simulated nuclear experiments, and these experiments break the constraints in the temporal dimension for changing the flow of time to a certain degree.
- *Spatial-Temporal Interactions*: In the macroscopic physical space, the physical objects must possess spatial and temporal consistency (we only discuss physical objects in classical physics here). However, in CeP space, a cyber object may be corresponded to several CeP objects, which means that this cyber object possesses more than one physical location at one time. In addition, for data in cyberspace, according to the big data storage mechanism, the actual data may be stored in multiple physical storage devices. Thus, in CeP space, cyberlogic is a useful way to solve problems.

B. Cyberlogic in Cyber-Enabled Social (CeS) Space

Social attributes have important implications for persons and groups referring to affiliation relationships, ownership management, and other aspects. They generally refer to the interaction of organisms with other organisms and to collective coexistence, irrespective of whether they are aware of it and irrespective of whether the interaction is voluntary [30].

In the CeS space, cyberlogic mainly reflects the mapping from a person into a cyber individual and presents the methods used to analyze human social activities in typical terms, including existence, relationship and lifestyle.

- *Homogeneous Social Existence*: A person can play different roles in a social situation. Generally, everyone plays one role in a social situation. In CeS space, a person can easily play homogeneous roles in one social situation. A person can map more than one cyber object (using different accounts), and different cyber objects play different social roles in CeS space. Thus, people in CeS space can play various roles following cyberlogic in one CeS situation simultaneously.
- *Social Relationships*: In the social space, social relationships have a strong association with living, working and hobby factors. On the other hand, in CeS space, such as online social networking, social relationships have no constraints with life, occupation and hobby factors.

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People attempt to map their social activities and emotions into cyber space by methods belonging to cyberlogic so that people can understand each other through cyber objects. It is easy to build close friendships with other people even if they have never talked face to face. In addition, CeS space allows people to build virtual families without relationships with our real families.

- *Social Lifestyle*: The CeS space has changed the social lifestyle, for which people establish models to formalize social activities using cyberlogic methods. For example, a person's interests can be identified by analyzing his social activities, and the analysis model provides an appropriate method for analyzing the probability of two strangers being able to form a relationship. A cyber object mapped by a person can exist forever even though they have died; in this way, the life cycle of a person can be prolonged.

C. Cyberlogic in Cyber-Enabled Thinking (CeT) Space

Thinking space mainly includes human thinking and thing thinking. The human mind is the faculty of a human being's reasoning and thoughts. It holds the abilities of imagination, recognition, and appreciation and is responsible for processing feelings and emotions, resulting in attitudes and actions. Thing thinking shall be formed by learning from biological organisms' behaviors.

In the CeT space, cyberlogic mainly reflects how to understand and analyze human thinking and how to build a machine with its own thinking capability revolving around the following aspects.

- *Cyber-Based Brain Research*: The human brain is a complicated object, and cyberization is a new way to study the human brain based on cyberlogic. First, heterogeneous sensors are adopted to collect human brain data for further brain situation analysis and predication. Second, the human brain can be simulated at the cellular or molecular levels for understanding human brain mechanisms and how various brain regions work together.
- *Brain Abstracted Cooperativity*: To obtain thinking information of human, emerging sensing technologies are applied to detect brain signals and human behaviors, thereby creating a complete human cognitive thinking model for human behavior predication using cyberlogic methods [19]. Intelligent interactions are achieved between a cyber individual and a real person in similar modes between two real persons. Brain abstracted cooperativity involves a heterogeneous network for achieving interconnections among different people and is expected to improve cooperation to achieve an aggregated functionality [9].
- *Self-learning Cyber Brain*: Machine learning progress promotes brain-oriented networks becoming a reality. An ideal "intelligent" machine is a flexible rational agent that perceives its environment and takes actions that maximize its chance of success in achieving goals. There are two types of cyber brains: one is a cyber brain with human-like thinking, and the other is a machine that has its own thinking ability. Both types of cyber brains are based on a self-learning cyber brain.

IV. Issues and Methods

In this section, the main issues and methods are discussed to identify the distinctiveness between cyberlogic and traditional logic.

A. Two Main Issues

1) Association between Cyber and PST Entities: The relationship between virtual and reality is the principal problem of cyber philosophy [31]. Consequently, the bidirectional association between cyber entities and PST entities is one of the fundamental issues of cyberlogic. On the one hand, many PST entities are mapped into the cyberspace by establishing corresponding models or cyber entities for them. Usually, these cyber entities only involve some aspects instead of every detail of the PST entities. These entities serve as the representatives of the PST entities in cyberspace. On the other hand, the resulting cyberlogic would be applied to the PST spaces in turn. Considering a scenario of smart home, first, human behaviors are mapped into cyberspace, and models are built for them. Then, once the human behavior has been recognized and analyzed in cyberspace, it would be helpful for people's daily life by applying the results in physical space.

2) Revealing Cyberlogic with the Cyberspace: Another fundamental issue is how to use the abilities of cyberspace to reveal cyberlogic in the CPST spaces. This issue focuses on how to acquire knowledge of the unknown from the known with the capabilities of cyberspace. The active subjects can be both humans and machines. In many IoT scenarios, humans can take advantage of numerous IoT sensors and actors with limited computation ability to analyze the cyberlogic in the CPST spaces. In contrast, with the development of Artificial Intelligence, it is likely for machines to achieve human-like intelligence, so that machines could assume more and more important roles in the practice of revealing cyberlogic, and even acquire knowledge by themselves. The solution of the first issue above has a large impact on this issue. For example, if the exact models of PST entities are not available, the respective errors and uncertainties should be taken into consideration in our computing and reasoning process to obtain the correct knowledge of the objective entities.

B. Association between Cyber and PST entities

The methods of building association between cyber entities and PST entities can be simply divided into that based on knowledge and that based on data. The first category is to establish the structure model for PST entities in a specific domain, according to the comprehension and abstraction of the domain experts. For the second category, a set of observed data about the features of the objective object composes its corresponding cyber entity.

1) Knowledge-Based Association Methods: According to the objectives of the specific tasks, we can build models for entities from different aspects such as identifications, features, and functions, according to our knowledge of the entities. For example, smart objects in IoT are physical objects that can compute, communicate, and even possess the intelligence

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in CeP spaces [32], and therefore when we model smart objects, abilities such as sense and action should taken into consideration. Agent technology is a potential solution to model smart objects [33], [34].

When modeling aims at only one particular application, it is comparatively easy and flexible. For example, we can model an object using tables of a database or using classes with an object-oriented programming language. However, if we want to share the models among different applications, extra mechanisms are required. There exist some model sharing mechanisms such as The ADO.NET Entity Framework [35] and hibernate [36], which enable us to share object modes among different applications. A recent trend to solve this problem, especially in IoT platforms and applications, is to manage the object models in a separated semantic layer [37], [38], [39], where entities are represented in commonly agreed ontological definitions. Applications abiding by these definitions can understand the entities from each other.

All the individual social behaviors and the group social behaviors belong to social entities in CeS space. It is more difficult to model social entities than physical entities because human behaviors are substantially more complicated and uncertain. In many cases, we need to simplify the social entities by reasonable assumptions and then build models for them. Human behaviors have cyber features in CeS space. For example, human behaviors will trigger sensors and actuators in a smart environment. In this situation, the social object can be modeled by the usage patterns of the sensors and actuators [40].

There also exist social features among smart objects in CeS space because the objects can communicate and cooperate actively and intelligently. Ning considered the social attributes of objects, including space time and ascription [41]. Atzori also mentioned the social relationships between objects [42]. For example, objects can establish co-location relationships and co-work relationships, as humans reflect when they share cohabitation or work experiences. He also anticipated a trend of socialized objects in cyberspace [43]. Therefore, social objects in cyberlogic must be a significant topic.

In traditional thinking space, modeling entities is performed in two ways. One way is abstracting the thinking and reasoning process of human beings. This way can be traced back to ancient Greece, where Aristotle expressed the reasoning thinking way via syllogism. This method continues to be developed. The other way is modeling the brain mechanism to obtain the general thinking model in cyberspace, as in the work in [44], which remains in its infant state.

The limitation of knowledge based on association methods is that it is difficult for human intelligence to comprehend and abstract exactly the essence and rules of the thinking of human beings. In particular, we cannot recognize the brain mechanism comprehensively and human activities exactly due to their complexity and variety. Moreover, even for some apparently simple physical attributes, for example, the spatial-temporal attribute, it is also difficult to achieve a consensual insight [45].

2) Data-Based Association Methods: The association methods based on data establish the entity in cyberspace by observing a set of object features. The method does not need the specific structure form to be given by domain experts and usually applies observed data to learn general models such as polynomial and multiple-layer perceptions. The experts need to establish the different models for the different object types for methods based on knowledge. However, for methods based on data, the process of modeling could be the same for different entities.

It is clear that methods based on data strongly depend on the data. The association depends on the amount and quality of data. When the amount of data is small, the association demands high quality. Instead, when the data quantity is sufficient, the data biases will be counteracting. One challenge of this association is to obtain sufficient data. However, our investigation ability is limited. Therefore, how we can obtain the object data selectively is the main topic in association methods based on data. Another challenge is how to choose the general models and the training algorithms.

A typical example of the association method based on data could be the combination of deep learning and big data. Deep learning allows computational models that are composed of multiple processing layers to learn representations of data with multiple levels of abstraction [46]. Deep learning has garnered great achievements in many domains such as image and speech recognition and games [47], [48]. Image recognition has long been the domain of the human brain. However, image recognition software can now recognize thousands of dog types, which is definitely a challenge to any human zoologist [48]. This demonstrates the advantage of association methods based on data. Speeches were once typically represented with hidden Markov models (HMMs), and Gaussian mixture models were used to evaluate how well the HMMs are. However, most advanced speech systems now employ deep learning to evaluate HMMs by learning from speech data [47]. With big data, program can even model very complex logic and strategies. A famous example is AlphaGo, a program of Go, which defeated one of best human player recently.

C. Methods for Cyberlogic

It is important to discuss how to use the ability of cyberspace to reveal cyberlogic. In this subsection, we discuss three categories of the emerging methods for cyberlogic.

1) Uncertainty-oriented Methods: Traditional logic method is characterized by certainty. Any relation and the true value of any proposition are assumed to be determinate. However, due to the uncertainty of the association between cyber entities and PST entities, uncertainty is a habitual problem for cyberlogic to confront. For example, for data based on cyber PST association, uncertainty in the data is common. Many factors result in data uncertainty: the observed data could be inaccurate and become outdated because of a change in the PST entities. The PST entities associated with data are sometimes uncertain because multiple PST entities could have the same observed values for common features. Moreover, for feature qualitative descriptions, it would be difficult to eliminate the uncertainty if there were to be no appropriate and globally agreed upon quantified approach. Therefore, new types of logic are desired for CPST spaces.

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The theory of probability is the mathematical foundation for quantifying uncertainty. In particular, Bayes' Rule provides an approach to the association of uncertainty from data to the corresponding PST entities, which also provides a foundation for numerous uncertain reasoning methods. Among these methods, the Bayesian Network is a extremely effective tool. Under the assumptions of independent probability and conditional relationships, a Bayesian Network excels at capturing the relationship and uncertainty of associations between data and entities and can yield accurate results in terms of probability. Nevertheless, the application scope of Bayesian Networks is limited. In many cases, the reasoning of a Bayesian Network is not operatable [49] or the independent assumptions is untenable. More methods for uncertainty reasoning are demanded for cyberlogic.

Fuzzy logic is a typical method for addressing the uncertainty of cyberlogic from qualitative descriptions. In traditional logic, the true value of any proposition, $\alpha \in C$, for example, is either 1 (true) or 0 (false). In fuzzy logic, the true value of any proposition ranges from 0 to 1. $C(\alpha) \in [0, 1]$ is used to represent the degree of truth of the proposition $\alpha \in C$. $C(\alpha)$ is also called the membership degree, based on which fuzzy logic defines the basic logic operators. Although many successful applications of fuzzy logic have been achieved, critics argue that the success should be attributed to the particular features of these applications [50]. Another drawback of fuzzy logic is that it does not clearly consider the correlations and anti-correlations among the component propositions [49]. Apparently, handling uncertainty will be a major challenge for cyberlogic in the future.

2) Data-Driven Methods: Traditional logic is driven by knowledge. Rules obtained from experiences is used to judge and infer according to the current situation. However, with new situations emerging constantly, experiences will be inadequate, and it is impossible for people to draw conclusions for every situation. Moreover, there are many situations that are too complex for people to comprehend. Therefore, in addition to knowledge-driven logic, we need logics of new forms. Although computers presently cannot reach the intelligence levels of human beings, with the powerful sensing and computing capabilities of cyberspace, they can collect a tremendous amount of data about new situations and are likely to find some inner essence and rules of such situations. These processes are called data-driven cyberlogic.

By combining with traditional logic, data-driven cyberlogic can be used to develop clear and comprehensible rules. Learning decision tree is such an exemplary approach. With the idea of choosing attributes with maximum entropy, a computer obtains a set of hierarchical judgment rules, which clearly show the chain of reasoning [49]. Unfortunately, a decision tree is not applicable to many problems, for example, the majority of functions wherein the result is true for more than half of the inputs.

There are also some forms of data-driven cyberlogic, although successful in many applications, that fail to generate clear or comprehensible rules, for example, artificial neural networks. Similar to the human brain, artificial neural networks are composed of a number of neurons that are interconnected by links. To optimize the output of the neural network, optimization algorithms learn from the data of the new situation and adapt the weights of the links iteratively. Although the resulting neural network can comprehend the rules of the new situation, these rules are difficult to interpret for human beings.

In big data, cyberspace is collecting huge amounts of data with varying sizes and diversity. Data-driven methods will play an increasingly more important role in the field of cyberlogic, and more effective methods are needed.

3) Cyber-Augmented Inference: Given powerful computing and storage capabilities, traditional logic inference is demonstrating new potential in CPST spaces. Problems of the past that could be described but too complex or time-consuming to analyze are now solvable with the aid of cyberspace. An interesting filed of cyber-augmented inference is automatic theorem proving. A typical approach is to build a solution space with arguments and rules first, and then searching the solution space using a computer. For example, the four color conjecture is a famously difficult problem that has attracted the attention of numerous top mathematicians. More than a hundred years after it was proposed, it was finally solved by a computer program designed by Kenneth and Wolfgang [51]. Another important filed is expert system [52]. Known logics of a specific domain are transformed into a expert system in cyberspace, and then real world problems are solved automatically. Recently, with the development of cyberspace, people have been building graph structured knowledge bases, named Knowledge Graph, in various domain, which will be important in automatically logic reasoning [53].

V. Challenges and Conclusions

Cyberlogic is a comprehensive and complex theme on which different people have different views. We defined it by a logic concept, which has multiple meanings. This means that the concept of cyberlogic must be controversial. With the development of objects and their CPST spaces, the essence of cyberlogic will continue changing and expanding. Therefore, we need to enrich the concept to realize the scientific expression. The correct view of cyber and cyber-enabled entities in CPST spaces can be achieved by cyberlogic. Cyberlogic will establish the new mechanisms in CPST spaces accurately.

Cyber philosophy, cyber science and cyberlogic all suffer from challenges in cyberspace. In the study of cyber, cyber philosophy has an important task of balancing virtual and real ranges. Cyber science mainly attempts to reveal CPST space phenomena via expression, modeling, processing, storage, communication and other approaches, whereas cyberlogic attempts to establish a bridge from cyber philosophy to cyber science. More specifically, the following challenges are found:

- Cyber philosophy: How does one address the gulf between cyberspace and physical space? Cyberspace is the mapping from PST spaces and even extended PST spaces. There is a gulf that is difficult to define. The gulf means the difference between cyberspace and PST spaces. If there is a one-to-one correspondence between cyberspace and PST spaces, we cannot utilize the cyberspace fully.

However, if the gulf is huge, the mapping and management in cyberspace become confused. Therefore, setting a suitable gulf is a challenge for CPST spaces.

- Cyber science: How does one establish the correct expression and reasoning in cyberspace? The main task for cyber science is to find the correct methods to establish a model in cyberspace. Inaccurate observation data and outdated data are the main challenge of expression. In addition, uncertain reasoning is also a significant challenge. The final results will be uncertain because of the challenges facing expression and reasoning in cyber science.
- Cyberlogic: How does one establish the rules in CPST spaces? Cyberlogic attempts to reveal the rules of cyber objects in CPST spaces. After establishing the model in cyberspace, based on cyber philosophy, we need to build up the logic from cyberspace to PST spaces. The challenge of cyberlogic is to find a method to reveal the rules from cyberspace to PST spaces. In this work, we need to understand the essence of the cyber objects and establish the logic between them.

This paper defined "cyberlogic" and mainly introduced "cyberlogic" from the following aspects: 1) The paper introduced the history of "cyber" and "cyber-" and then explained the etymology of "cyberlogic". 2) Based on the fundamental research of cyber, the objects and the spaces were the main aspects. Then, the paper discussed the logic of CPST objects in CPST spaces. 3) Next, according to the basic issues in cyberspace, it listed some specific methods of cyberlogic. 4) From a macroscopic point of view, the paper described the relationship between cyber philosophy, cyber science and cyberlogic and analyzed the challenges. Due to the research value of cyberlogic, substantial work must be performed, for example, on the specific logic in CeP, CeS and CeT spaces and the specific methods of cyberlogic.

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