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Article

Research on Basic Concept and Conceptual Model of Cyberspace Map

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Abstract: Cyberspace map, as one of the important tools to describe cyberspace, gives an image to the unpredictable and illusory cyberspace, and has become a research hotspot in the fields of cartography, cyberspace security. Clarifying the concept of cyberspace map and constructing the conceptual model of cyberspace map can promote people's unified cognition of cyberspace. Based on the view of cartography, this paper compares and analyzes some related concepts of cyberspace map, discusses the characteristics of cyberspace map, and gives its concept. After that, it analyzes people's cognition of cyberspace composition. On this basis, it caters to this cognition mode and proposes the conceptual model of cyberspace map. Then, the connotation of the model is elaborated from three aspects: element-space association dimension, element mapping dimension and the map representation dimension. Finally, the specific composition and symbolization of various elements are analyzed. The model provides the top-level framework and theoretical guidance for the research of cyberspace map. This paper aims to adapt to the development trend of Cartography in ternary space, clarify the basic concept of cyberspace map, promote the development of cyberspace mapping theory, and lay the foundation for subsequent research.

Keywords: cyberspace; cyberspace map; map characteristic; conceptual model; cyberspace elements; map representation

1. Introduction

With the rapid development of global informatization, the network has become an important foundation for the existence and development of national political, economic, military and other social systems, and cyberspace has become a new territory for competition and game among countries in the world. People interact with each other through the network all the time. The concept of meta universe has recently emerged, and cyberspace has become the second space for people's life.

With the rapid development of Internet, mobile communication network and sensor technology, map has also entered the era of information and communication technology(ICT) [1]. Just as map is a tool for people to understand geographical space, cyberspace map is an effective means to help us understand and recognize cyberspace. As the result of interdisciplinary integration of cartography and cyberspace security, cyberspace map is the representative of the extension of traditional cartography research from real space to virtual space. However, the current research on cyberspace map is not yet mature, and the understanding of cyberspace map is not unified. The conceptual model is "the mathematical/logical/verbal representation(mimic) of the problem entity developed for a particular study" [2]. The research on the basic concept and conceptual model of cyberspace map is one of the important contents of cyberspace map basic theory. Its research is conducive to unified cognition, but there is a lack of relevant research at present. Therefore, this paper starts with the basic concept of cyberspace map, and combines the composition of cyberspace, proposes the conceptual model of cyberspace map, which lays the foundation for the follow-up study of cyberspace map.

2. Basic Concepts of Cyberspace Map

2.1. Related Concepts of Cyberspace Map

As a member of the "pan-map" [iii], the research on the map of cyberspace started early and attracted the attention of scholars with the popularization of the internet, however, there is still a lack of unified understanding and clear definition of its concept. This paper gives an understanding of the concept of cyberspace map from the perspective of map objects by combing the related concepts of cyberspace map (as shown in Table 1).

Table 1. Related concepts.

Concept	Definition
Cyber/We b cartogra phy	<p>Cybercartography was formally defined as "the organization, presentation, analysis, and communication of spatially referenced information on a wide variety of topics of interest and use to society in an interactive, dynamic, multimedia, multisensory, and multidisciplinary format" [iv].</p> <p>Web cartography is the further development of digital cartography. In the network environment, government, enterprises and volunteers mapping coexist. It is an information flow or assembly line integrating multi-source mapping data acquisition, processing (production) and service. The overall efficiency is improved, and the main service mode is to provide network-based electronic map services [v].</p>
Extended reality map	<p>Based on computer science and relevant scientific technologies, virtual reality (VR) produces a digital environment in which visual perception, sense of hearing, and sense of touch are highly similar to those of actual environment within a certain range. With the help of necessary equipment to interact and interfere with objects in a digital environment, users may have feelings and experiences corresponding to those in the actual environment. VR is a scientific technology for understanding or simulating the nature[vi].</p> <p>The virtual environment and the real environment are matched and synthesized to achieve enhancement. The technology of overlaying 3D virtual objects to real world display is called augmented reality (AR) [vii]. Augmented reality map is a map based on video spatialization, which integrates virtual and reality for real-time geographic information visualization and intelligent geographic analysis through computer vision technology [viii].</p>
Game map	<p>Game map is the representative of the virtual space map. It's the digital expression of physics and society of the game world itself, including game base map and scene map. The game base map is often shown as eagle eye mode map or the environment map of the whole game. The game scene is the main activity place of the character, and the scene expression can be two-dimensional or three-dimensional [ix,x].</p>
Cyberspa ce/cyber map	<p>Cybermaps, as special maps for cyberspace, have been used as a tool for understanding various aspects of cyberspace. It can be simply defined as the map for visualizing numerous aspects of cyberspace, for instance, physical locations of cyberspace, traffic situation and so on[xi,xii].</p> <p>Cyberspace map is a visual expression of things, phenomena and processes in cyberspace. It is a form of mental map for cognition and navigation of virtual space [xiii,xiv].</p> <p>Cyberspace map is a kind of visualization expression technology of cyberspace and its elements based on cartography method and combined with visualization related theories and methods[xv].</p>

Pan-map	Pan-map is the extension and expansion of the traditional standard map. It is a comprehensive expression of the ternary space of geography, social humanities and information. It is a generalized map expression that analyzes the characteristics of the ternary space objects through map language, image thinking and spatial thinking, and realizes the functions of information acquisition, transmission and cognition between people, people and objects, and objects [3].
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The enumeration of related concepts reflects the evolution of the concept of cyberspace map. In the early stage, with the invention and popularization of the network, the proposal of cyber/web cartography was promoted [4, ^{xvi}]. The main goal of this period was to digitize the map and spread the map with the network as the carrier. The influence of the network on cartography was mainly in the production and use. With the development of extended reality (XR)[^{xvii}], including virtual reality (VR), augmented reality (AR), and augmented reality (MR), the map content extends step by step from real geospatial space to virtual space, but the object space is still dominated by real geospatial space or simulated real geospatial space. The purpose of augmented reality is to provide information for real geographical space. The game map as the representative, the virtual space as main expression subject attracts attention, but the simulation object is still mainly geographical space. Cyberspace map brings virtual cyberspace, which is completely different from geographical space, into the expression object, further breaking the barriers of traditional cartography. In recent years, with the integration of ternary space theory and cartography, the concept of pan-map has been put forward, cyberspace map and other non-traditional maps belong to it.

The above analysis shows that although different students have defined the concept of cyberspace map and its related concepts from different views, it is necessary to further discuss its concept, connotation and characteristics, so as to unify thinking and understanding, and lay the foundation for the subsequent construction of its conceptual model.

2.2. Characteristics of Cyberspace Map

It is generally believed that a map is a mapping of geographical space, and its essential characteristics can be summarized as follows: first, it has a rigorous mathematical basis for the positioning of space objects or phenomena; The second is to follow the cartographic generalization principle of abstract expression of the real world; The third is to use the abstract symbol system for formal expression. The characteristics of cyberspace map are analyzed as follows:

1. With the basic characteristics of the map

For the entity elements in cyberspace, the mathematical basis, cartographic generalization and symbol design are usually the same as those in geospatial expression; Virtual elements are obviously different from geospatial elements, but in order to realize the mapping from virtual space to map and provide support for cyberspace navigation and analysis, it still needs to be based on strict mathematical foundation, apply special cartographic generalization methods, and adopt reasonable expression methods. But these three basic characteristics have been expanded. In terms of mathematical basis, cyberspace map does not restricted mapping in Euclidean space. Existed cyberspace maps use hyperbolic space for mapping [^{xviii}]. Traditional maps focus on the correctness of spatial relationships, while cyberspace maps pay more attention to connectivity for describing the structure. However, it also needs quantifiable property, such as using the correlation degree in graph theory, the shortest path (expressed by the number of nodes passed rather than the mileage), and the degree of betweenness to carry out the measurement in the topological sense [13]. Taking the distance as an example, the virtual cyberspace has broken the traditional thinking mode and expanded from a single geographical distance to three categories: geographical distance, information distance and social distance [^{xix}]. In terms of symbols, virtual elements are invisible in the real world, and symbolization is freer. Cartographers can give full play to their imagination and use a variety of sensory channels for design. Therefore, a more comprehensive symbol design issue has been extended. In terms of cartographic generalization, the virtual elements of cyberspace map do not

have the problem of geographical accuracy, but considering the constraints of demand, scale and other expression factors, cartographic generalization must also be needed, and the standards and principles should be different from those of traditional maps.

We should broaden the definition of maps, expand the varieties and fields of maps, and not push out works that can be regarded as maps for the reason of maintaining the seriousness of cartography. Cyberspace map can be regarded as a reasonable extension of map concept in cyberspace [xx].

2. Taking cyberspace as the expression object

Cyberspace map takes cyberspace as the object of expression. Cyberspace is a combination of virtual and real space, including both tangible elements existing in physical space and intangible virtual elements. The spatial location and relationship of elements may be the location and spatial relationship in geographical space, or in virtual space. Therefore, the cyberspace map needs to create unified mapping among elements in different spaces. In addition, a standard system should be established to associate and integrate these elements. Finally, due to the strong data mobility and the fast changing connectivity in cyberspace, cyberspace maps need to express the high dynamic content changes in real time.

3. A collection of multiple expressions

Because cyberspace is a complex and highly dynamic space with the combination of virtual and real space, it is extremely difficult to express the virtual and real space with huge different characteristics and spatial-temporal resolution on the same map, and it is also difficult to meet the needs of different users and different application scenarios. Cyberspace map needs to design different expression forms and adopt different expression methods for different users and different application scenarios, so as to realize the effective expression of complex space oriented to complex application requirements. Therefore, cyberspace map is a collection of multiple expressions.

4. Unique information transmission

The text continues here. In the process of traditional map information transmission, cartographers select, classify and simplify their understanding of the objective world and process it through symbolization, which is transmitted to users through maps. Users identify symbols, and their understanding of the objective world is formed through the analysis and interpretation of maps. The analysis and interpretation of the map by the users is based on the original knowledge and experience of the objective world. Most of the elements expressed in the traditional map are objective phenomena that the users can directly observe, so the experience is direct and true. The users of cyberspace map recognize the virtual part of cyberspace by directly extracting map information. Similarly, the cartographers' understanding of cyberspace plays a more important role in map information transmission. Cartographers endow virtual and invisible subjects with real sensory images according to their own cognition. They also need to make choices in the flexible diverse mathematical basis and determine the mapping semantic information to build appropriate coordinate system of cyberspace.

To sum up, cyberspace map is a collection of expression forms that take the elements in cyberspace as the expression object, and the ternary space is intertwined with each other, with complex requirements. It has a more "direct" information transmission mode. According to the analysis of the three basic characteristics and individual characteristics of cyberspace map, this paper gives the concept of cyberspace map, and believes that cyberspace map is a tool for transmitting cyberspace information, which takes the elements of cyberspace as the expression object and uses a variety of expression methods to describe the structure, elements or entity attributes of cyberspace and their temporal and spatial relationships, as well as the phenomena and processes of cyberspace.

3. Conceptual Model of Cyberspace Map

3.1. Object Space of Cyberspace Mapping

Cyberspace map expresses the elements in cyberspace, and cyberspace is the object space of cyberspace mapping. People's understanding of cyberspace affects the abstraction and generalization

of the elements in cyberspace, that is, the mapping objects of cyberspace, and further affects the formation of the conceptual model of cyberspace map. Therefore, it is necessary to unify the understanding of cyberspace before constructing the conceptual model.

The understanding of cyberspace has generally gone through a process from narrow sense to broad sense [xxi]; in terms of width, cyberspace in the narrow sense[xxii] mainly refers to the virtual information space formed by relying on the Internet, while cyberspace in the broad sense covers all kinds of internet, including the Internet, radio and television networks, telecommunications networks, the Internet of things, various computer systems, and various embedded processors and controllers in various industrial systems; in terms of level, cyberspace in the narrow sense mainly refers to virtual cyberspace, that is, cyberspace within information space, while cyberspace in the broad sense involves real geographical space, virtual information space and social space, that is, multi-space[xxiii,xxiv]. All kinds of data and information contained in cyberspace belong to information space. As the material basis, the communication infrastructure exists in geographical space. As the participants, the attributes and relationships of people and various organizations belong to social space, and the actual people exist in geographical space. Therefore, the mapping object space of cyberspace map has expanded from the traditional binary space of geography and social to a hybrid of geographical, social, and information spaces, namely ternary space [xxv], and the form of elements has expanded to the coexistence of entity and virtual.

The cyberspace described in this paper refers to the generalized cyberspace both in level and width. According to the literature^{xxvi}, cyberspace is composed of four basic elements: facilities (carrier, i.e. infrastructure), data (object, load), persona (subject, i.e. user), and operation (activity behavior). Its connotations are as follows:

1. Persona is the subject in cyberspace, which may be an individual or an organization or a group. It has subjective initiative and carries out purposeful activities in cyberspace through the operation of physical devices. The relationship between personae and facilities, data and operations are subject-object relationship.
2. Operation is a specific activity carried out by a persona in cyberspace and its impact on politics, economy, culture, society, military and other aspects. The activities in cyberspace are the expansion of human activities from social and geographical space to information space. From the macro scale, these activities include the operation and maintenance of cyberspace, service provision, supervision, attack defense, etc. from the micro scale, they are the specific operation processes of data creation, storage, replication, deletion, extraction, replacement, etc. Operation is the means and method of a persona's activities in cyberspace, which is related to the purpose and needs of the persona. Realize the impact of the persona 's activities in cyberspace on multiple spaces through operation: for physical facilities in real physical space, such as the destruction of facilities by virus; For virtual elements in the information space, for example, hackers' attacks on government websites made them unable to operate normally, , so as to reduce the credibility of the government; For humanities and social space, for example, the spread of false information and , the creation of public opinion influence, etc. Through operation, roles form activities in various spaces, and the ultimate goal is to have an impact on things in real space.
3. Data exists in virtual space and can be understood as assets in cyberspace. It cannot exist independently, relying on the existence of devices in the real geographical space, through device storage, transmission, etc. Data is dependent on facilities.
4. Facilities exist in the real geographical space, which belongs to the physical part of cyberspace and is the material basis of cyberspace. The most important function is the carrier of data and also carries the activities of roles. Facilities are the direct objects and tools for the role to operate, and the role can only carry out activities in cyberspace through the operation of facilities.

In addition, the idea of " cyberspace can be viewed as three layers made up of five components " proposed by the U.S. military[xxvii] has been widely recognized, and the Defence Research and Development Canada's report has adjusted but continued the framework [xxviii]. Literature ^{xxix} also uses a hierarchical approach to divide cyberspace into geographical layer, physical network layer, logical network layer, cyber-persona layer and entity persona layer. Literature 19 also believes that cyberspace is a hierarchical space involving people, machines and objects, and covers real physical

space, virtual information space and knowledge space. It can be seen that the hierarchical cognition of cyberspace has become a mainstream and habitual way, but they have ignored the importance of "data" and "operation", and failed to fully cover the elements of cyberspace.

By analogizing the elements of cyberspace and traffic, the literature ^{xxx} solves the problem of difficulty in understanding the composition caused by the ethereal cyberspace. This paper continues the above research, combines hierarchical cognition and improves element types, abstracts cyberspace objects into geographical elements, physical elements, logical elements, cyber-persona elements, entity persona elements, data elements and activity elements, and explains the space of the elements and the relationship between them, As shown in Figure 1.

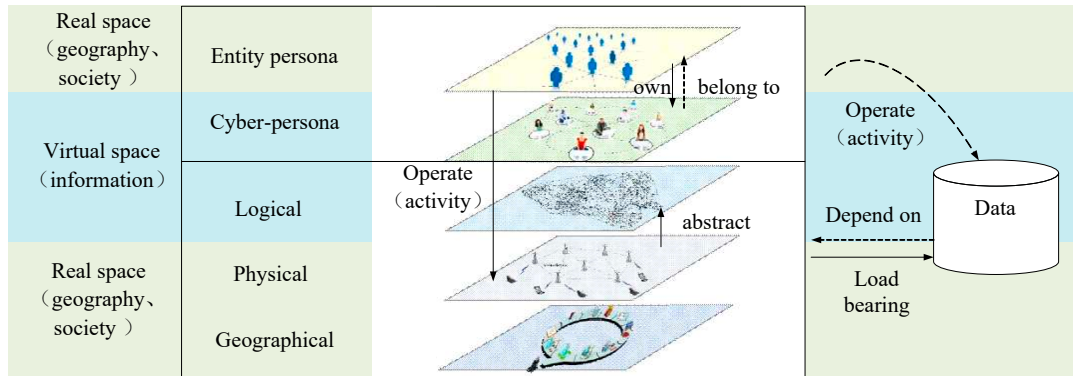


Figure 1. Composition of cyberspace.

3.2. Conceptual Model of Cyberspace Map

The object in cyberspace is the content expressed by the cyberspace map. Based on the above analysis of the composition of cyberspace, this paper proposes a conceptual model of cyberspace map, which divides the map content elements into seven categories: geographical elements, physical elements, logical elements, data elements, activity elements, cyber-persona elements and entity persona elements. Geographical elements, physical elements and logical elements are the basic elements to describe the cyberspace environment, and they are the basic elements of the cyberspace map; cyber-persona elements and entity persona elements can be collectively referred to as persona elements; Activity elements and data elements are separated into one category, as shown in Figure 2.

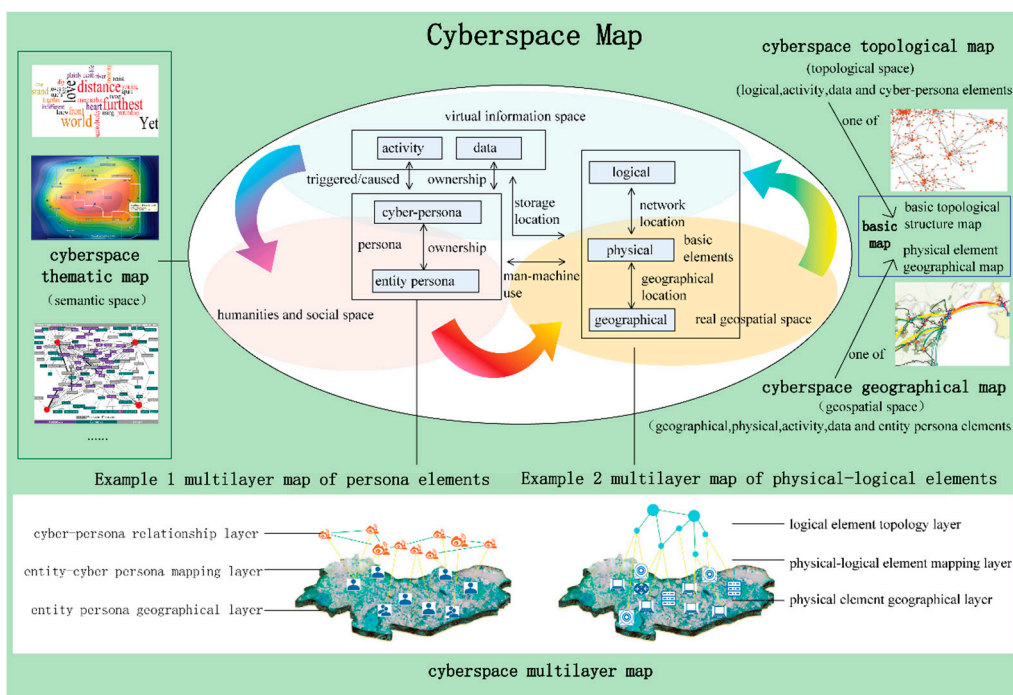


Figure 2. Conceptual model of cyberspace map.

Compared with the traditional map, cyberspace maps are more complex in describing spaces and requirements, and have more flexible and diverse forms. Next, the connotation of the model is described from the dimensions of element-space association, element mapping and map expression.

3.2.1. Element-space association dimension

As a multi-dimensional space woven by geography, society and information, the cyberspace elements have different degrees of correlation with different spaces. The movement and change of anything and phenomenon, including human activities, occur in a certain space and time^[xxxii]. Therefore, in a broad sense, all elements can be considered to be related to geographical space. Even virtual data elements, the physical devices stored in them also have geographical coordinates. But on the one hand, we pay different attention to different elements, such as virtual data elements, which mainly focus on the characteristics embodied in the information space, so it is more relevant to the information space. On the other hand, the ternary space is not completely separated from each other, but constantly integrated, so we can not think that a certain category of elements belongs to a certain space, but only that such elements mainly reflect the characteristics of a certain space, that is, they are strongly related to a certain space and weakly related to other spaces. Therefore, this paper believes that geographical elements and physical elements are strongly related with geographical space, logical elements, data elements, activity elements and virtual role elements are strongly related with information space, and entity persona elements are strongly related with humanities and social space. They are also related with other spaces, but the degree of relation is weak. As shown by the arrow in Figure 2, red represents the degree of relation with humanities and social space, yellow represents the degree of relation with real geographical space, and blue represents the degree of relation with virtual information space.

3.2.2. Element mapping dimension

The concept of location exists in both the real and virtual environment, which refers to the space occupied by a specific target. There are real geographical location and virtual network location in the cyberspace map, and the network location includes IP address, URL, user login or information release location and so on ^[xxxiii]. In terms of basic elements, we collect data through cyberspace surveying and mapping, and obtain the attribute of elements including geographical location, network location, topology connectivity through network resource detection, topology analysis, entity positioning and other technologies, so as to deeply perceive and associate multiple types of locations, so as to establish a mapping relationship between the virtual world location and real world location. Realize the mutual mapping between geographical elements and physical elements through geographical location. Realize the mutual mapping between physical elements and logical elements through network location.

Other elements need to use social network, social engineering and other methods to obtain the ownership information of persona and other elements, and obtain the network activity information through network detection and other technologies. The mapping between persona elements and basic elements is established through the man-machine use relationship. The mapping between persona elements and data elements is established through the ownership relationship. The mapping between persona elements and activity elements is established through triggered / caused. Virtual-persona and entity persona are mapped to each other through the ownership relationship. As shown in Figure 2.

3.2.3. Map representation dimension

According to the location-based pan-information map [32], the elements of cyberspace map are aggregated in generalized "location", including geographical location aggregation, network location aggregation and semantic location aggregation. Corresponding to different aggregate locations, the

basic forms of cyberspace map are geographical map, topological map and thematic map^[xxxiii] (as shown in Figure 2).

Geographical map is similar to traditional map, which describes cyberspace from the outside according to the material basis of cyberspace construction in geographical space. By superimposing the elements on the basic geographical information, the geographical distribution of various elements and their attribute information is displayed. It mainly includes geographical map of various elements such as geographical, physical, activity, data and entity persona elements, etc.

According to the connectivity of network nodes, the topological map describes the cyberspace from the inside, and shows the logical connectivity and node attributes by superimposing elements on the basic connectivity structure of the network. It mainly includes the topological map of various elements such as logical, activity, data and cyber-persona elements, etc. According to the high dynamic characteristics of cyberspace, topological map depicts the changing connectivity and data flow. For example, usually, the external physical connection between devices does not change, but due to the change of virtual ports, the connectivity between devices changes. This phenomenon cannot be expressed in geographical maps, but can be shown in topological maps.

Thematic maps also describe cyberspace internally, mainly including thematic maps of data and entity persona elements, etc. It pays attention to the expression of the internal semantic features of the elements, and the forms are more flexible and diverse. It selects the semantics to construct the coordinate system according to the needs, and constructs the spatial relationship in the thinking by means of virtualization. Spatial relationship is the key feature that distinguishes maps from information graphics. Cyberspace thematic map, according to the needs of the map, extracts the semantic information of the elements, and converts it into spatial relationships, including adjacency, association, inclusion, connectivity and so on^[xxxiv].

Various elements can be mapped separately as required, or multiple elements can be expressed in one map at the same time. The basic topological structure map and physical element geographical map composed of nodes and links in logical elements describe the objective environment of cyberspace and are the basic map of cyberspace. Other elements need to be superimposed on the basic map to form the geographical map or topological map of one category or multiple categories of elements. The three basic forms of cyberspace maps achieve transformation by extracting topology information and semantic information. They gradually depict cyberspace from external description, internal description to internal characteristics. The logical composition of cyberspace map is shown in Figure 3^[33, xxxv-xxxvii].

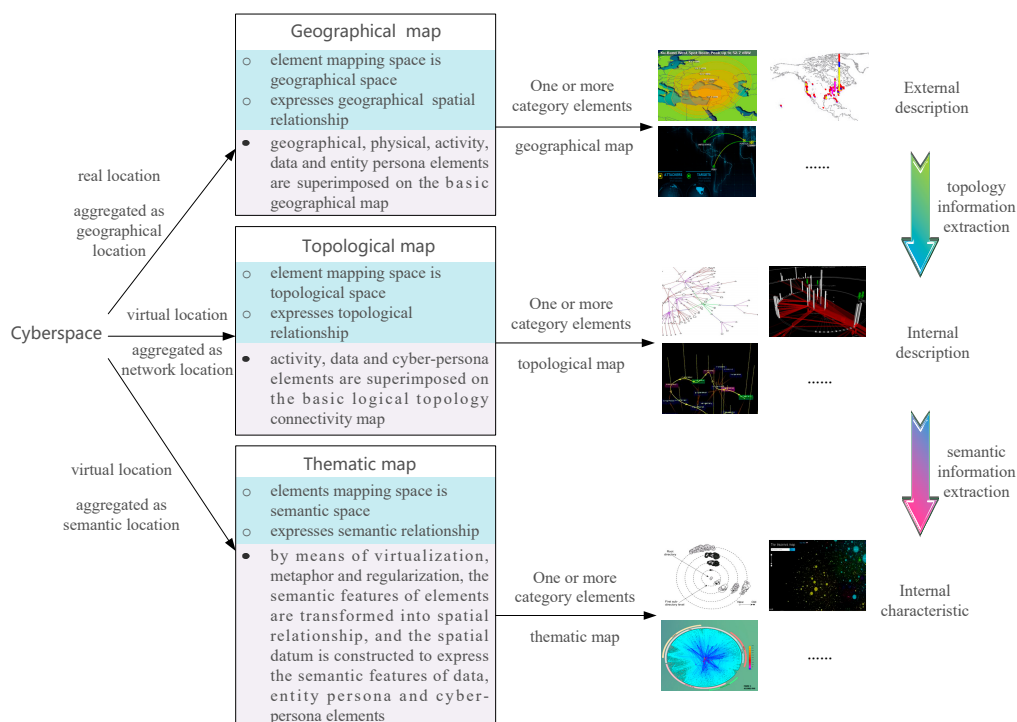


Figure 3. Logical composition of basic form cyberspace maps.

In order to describe cyberspace as comprehensively as possible, the above basic form maps can be selected as needed and combined into multilayer maps. The following two examples are persona elements multilayer map and physical -logical elements multilayer map (Figure 2 multilayer map example 1 and example 2). The persona elements multilayer map is divided into three levels. The first layer is the entity persona geographical layer, which draws the entity persona according to the geographical location; The second layer is the entity-cyber persona mapping layer, which is located above the entity persona geographical layer and is composed of the mapping relationship network between entity persona and cyber-persona. The third layer is the cyber-persona relationship layer, which is located at the top level and depicts the semantic relationship between cyber-persona. Similarly, the physical-logical elements multilayer map consists of three layers from bottom to top, namely, the physical elements geographic layer, the physical-logical elements mapping layer, and the logical elements topology layer. Multilayer map spans different types of space and depicts cyberspace as comprehensively as possible.

These two groups of virtual and real relations reflect the extension of real geographical space and humanities and social space in cyberspace, and the blend of ternary space. Entity persona is the existence of people or organizations as physical entities in the real geographical world. Cyber-persona is the "spokesperson" of entity persona in the virtual part of cyberspace. Similarly, physical elements exist in the real geographical world as physical entities, carrying virtual elements of cyberspace. Logical elements can be seen as the "spokesperson" of physical elements in the virtual part of cyberspace. Physical elements and logical elements are more important because they carry the basic environment of cyberspace. Like books as spiritual products, the text content is attached to the paper, and the virtual spiritual space and the real physical space are unified in books^[xxxviii]. Physical elements are the "unity" of cyberspace virtual and reality, the link between the two worlds, and the most important. This is also the internal reason why people naturally start from drawing physical devices when studying cyberspace maps. At the same time, the achievements in this field are also the most prominent.

Secondly, when using cyberspace maps, as mentioned above, a single map is difficult to meet the requirements. Three basic forms of maps and combined multilayer maps can be used together in a multi-view format as needed, that is, two or more basic form maps or multi-layer maps can be used simultaneously to express the same object or theme. A single basic form map only describes a certain space, while a multi-layer map extends to a multi-space, and a multi-view describes a multi-space from multiple perspectives (as shown in Figure 4).

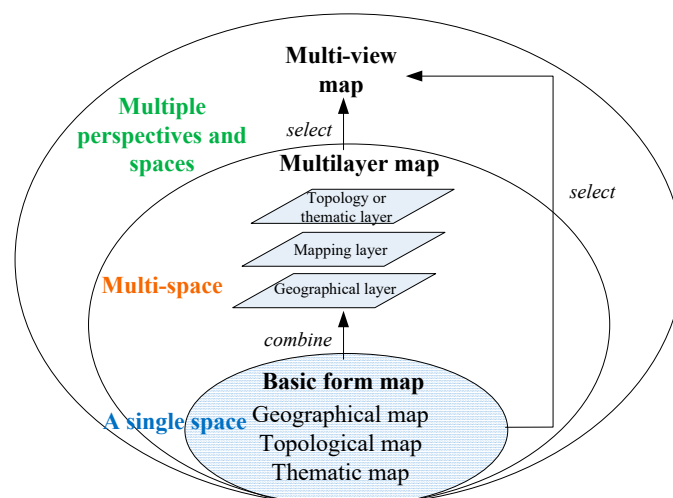


Figure 4. Cyberspace maps using mode.

Finally, in terms of representation design, the strength of elements and different spatial relation degree affects the expression of maps. For example, literature 15 classifies the representation methods

coaxial cable, twisted pair cable, optical fiber, radio wave, etc. According to transmission medium, which are represented by linear symbols, and media types are distinguished by color or shape. In addition, it usually displays the bandwidth and link load, and generally uses size and color for hierarchical representation, as shown in Figure 6c^[xliii].

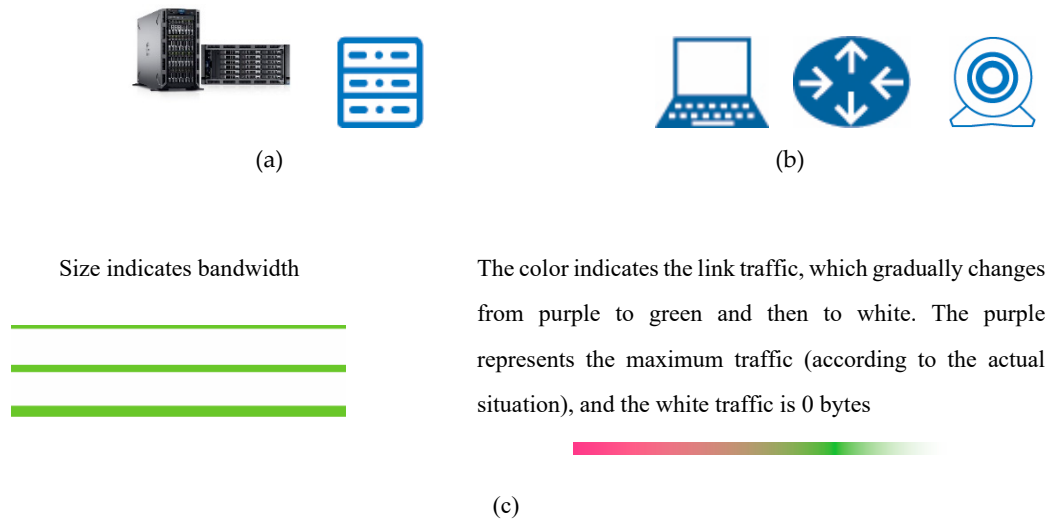


Figure 6. Example of symbolization of physical elements: (a) server entity image and symbol; (b) dot symbol example (notebook, router, camera); (c) examples of linear symbols.

Logical elements are the abstractions of physical elements, which are nodes and links. The logical connection between elements and the functional attributes of loaded systems, services and programs are obtained. It is the description of basic states such as network links and performance. Compared with physical elements, logical elements symbol design should be more concise.

Nodes are abstracted as dot symbols, and shape variables are usually used to distinguish different types of nodes. As shown in Figure 7a, a rectangle is used to represent the client and a circle is used to represent the server ^[xliii]. Links symbols are the same as transmission lines, but the focus of the expression is the connectivity between nodes. Specific attributes such as media and bandwidth can no longer be distinguished in detail.

The system, service and program represent the status and functions of the network, and are abstracted as dot symbols, in which words are often used, such as representing the specific service content, adding "Web", "email", "DNS" and so on (Figure 7b^[38]), or symbols and numbers / text notes. When only describing their composition and functions, they are expressed in the form of charts or graphs.

Some codes (such as viruses) can also carry out activities in cyberspace, similar to persona elements. However, their activities lack subjective initiative and are subject to the setting of the subject, so they are not considered as persona elements, because they are malware in nature and are classified into logical elements. They are considered as special elements because they have the ability to copy, delete, tamper with data or device configuration. Malware usually uses dot symbol and is designed as destructive and horrible graphic such as virus, demon or skull in practice. When representing a specific malware, words or specific graphic combinations can be added according to its own characteristics, such as Trojan virus and Ladybug virus (Figure 7C).

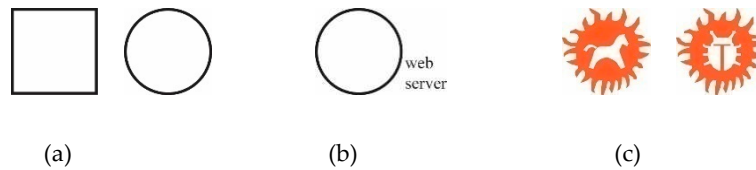


Figure 7. Example of logical elements symbolization: (a) client and server; (b) web service; (c) Trojan virus and Ladybug virus.

2. Data elements

Data elements describes the distribution of cyberspace data assets. It mainly includes business data (divided into industrial data, telecommunication data, financial data, etc. according to industry), system data (machine data, log data, application data, statistical data, etc.), which "circulate" in cyberspace, form virtual, and are "assets" in cyberspace. When symbolizing, they can be abstracted as dot symbols, and different shapes are used to represent different categories, as shown in Figure 8, which respectively shows the symbols of safety data, statistical data and financial data. The expression of statistical information of data elements is one of the key contents of symbolization. Usually, fixed-point symbol method is used, combined with histogram, pie chart, etc., to represent the data volume and proportion of various types of data in traffic.



Figure 8. Example of data elements symbolization.

3. Persona elements

Persona elements are the main body of activities in cyberspace and mainly reflect the sociality. Entity persona elements refer to the subjects existing in the real environment, including user, management and construction entity, etc. Entity persona elements are active in cyberspace through cyber-persona elements. cyber-persona elements refer to the main body existing in the virtual environment, and are also elements of virtual form, including websites, accounts, etc.

Persona elements are abstracted as point shaped symbols and visualized graphics can be used, but in most cases, they can be abstracted as geometric shapes. Websites usually use their own logo or name as text symbols. When expressing the account number of a specific application, the symbols can be designed in combination with the icon of the application. As shown in Figure 9, the personal accounts of individual and group organizations, hackers and popular customers, apple payment and microblog [36] are respectively represented.



Figure 9. This is a figure. Schemes follow the same formatting.

The relationship between personae and other elements is the key to expression, and the semantic relationship is represented by linear symbols. The relationship includes the subordinate relationship and cooperation relationship, as well as the ownership relationship with other elements such as cyber-persona element. The relationship is diverse and depends on needs. Usually, size and color variables are used to indicate the strength of the relationship and distinguish the relationship types.

4. Activity elements

Activity elements describe the phenomenon, process and influence of cyberspace. It's specific operation, means and methods of persona in cyberspace, mainly including normal activities and network attack and defense.

Normal activities can be divided into information behavior and technical behavior [^{xliv}]: information behavior takes information as the object, such as visiting and browsing web information, downloading and uploading information, creating, storing, changing and transmitting data, etc.; Technical behaviors mainly include network technology development, maintenance and program upgrading. They are represented by dot symbols, as shown in Figure10a, which are data download, development and upgrade.

Network attack and defense include harmful program intrusion, network attack, information destruction, etc. Generally, the moving line method is used to represent the network attack, and the starting point is the attacker and the target. Specific behavior activities in attack and defense can be designed with reference to military symbols, as shown in Figure 9b10b, which are credential based access and scan detection [43].



Figure 10. Symbolic example of activity elements: (a) Regular activities; (b) offensive and defensive activities.

Activities do not have specific physical forms, but they are different from data elements that are also virtual forms. It is the behavior and influence of the role as the main body in the process of transforming and understanding data and equipment. It occurs not only in the virtual information space, but also in the real geographical space. In the real geographical space, disasters affecting the physical security of hardware equipment, electronic interference, countermeasures, electromagnetic radiation, etc. [45^{xlv}], acts of man-made destruction or normal damage affecting the operation of the network also belong to activities. These activities in the real geographical space are easy to understand and can be represented by the event map in the traditional map. Therefore, the focus of attention in the cyberspace map is the activities in the virtual information space.

The expression object of cyberspace map is the elements of cyberspace. Combining the design principles of map symbols, utilizing basic map symbols and thematic symbols, a series of products of cyberspace maps are ultimately formed.

4. Conclusions

In order to make better use of cyberspace map to recognize cyberspace, it is necessary to study the basic concepts of cyberspace map in order to reach a consensus. This paper first analyzes the related concepts and characteristics of cyberspace map, and gives the definition of cyberspace map. Then, according to the cognitive mode of the hierarchy of cyberspace and based on the composition of cyberspace, the conceptual model of cyberspace map is proposed, which describes the form and content of cyberspace map and the symbolization of elements. In the research of conceptual model, the connotation of the model is elaborated from three dimensions: element-space association, elements mapping and map representation. Particularly, a method based on generalized location aggregation of elements information was proposed to solve the problem of inability to uniformly map cyberspace map elements involving multiple space; on the basis of summarizing existing achievements, three basic forms and multilayer of cyberspace maps, as well as the use of multi-view, are proposed. The construction of the model not only referred to the current research results of cyberspace map, but also absorbed the technical ideas and experience of location-based pan-information map, pan-map, visualization and so on, so as to ensure the advancement and feasibility of the model.

As a multidisciplinary integration field, the follow-up research is mainly carried out from two perspectives. First, starting from the research of cyberspace, deepen the understanding of cyberspace, and promote the understanding of the connotation and architecture of cyberspace map with practical needs. The purpose of map use can be further clarified from the actual needs of cyberspace security,

cyberspace operations, cyberspace navigation and so on. Second, starting from cartography research, we should not only make good use of the deep foundation of traditional cartography research, but also break the thinking imprisonment of traditional cartography. According to the characteristics of cyberspace, we should carry out the research on cartography technology such as representation method and symbol design, so as to promote the experimental verification of the model and form the products system of cyberspace map.

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