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# A new geographical language:
## A perspective of GIS

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**Abstract:** Language plays a vital role in the communication, sharing and transmission of information among human beings. Geographical languages are essential for understanding, investigating, representing and propagating geo-spatial information. Geographical languages have developed and evolved gradually with improvements in science, technology and cognitive levels. Concerning the theoretical progress from geographical information ontology, epistemology and linguistic theory, this paper firstly puts forward the concept of a GIS language and discusses its basic characteristics according to changes in the structures, functions and characteristics of geographical languages. This GIS language can be regarded as a system of synthetic digital symbols. It is a comprehensive representation of geographical objects, phenomena and their spatial distributions and dynamic processes. This representation helps us generate a universal perception of geographical space using geographical scenarios or symbols with geometry, statuses, processes, spatio-temporal relationships, semantics and attributes. Furthermore, this paper states that the GIS language represents a new generation of geographical language due to its intrinsic characteristics, structures, functions and systematic content. Based on the aforementioned theoretical foundation, this paper illustrates the pivotal status and contributions of the GIS language from the perspective of geographical researchers. The language of GIS is a new geographical language designed for the current era, with features including spatio-temporal multi-dimension representation, interactive visualization, virtual geographical scenarios, multi-sensor perception and expedient broadcasting via the web.

The GIS language is the highest-level geographical language developed to date, integrating semantic definitions, feature extraction, geographical dynamic representation and spatio-temporal factors and unifying the computation of geographical phenomena and objects. The GIS language possesses five important characteristics: abstraction, systematicness, strictness, precision and hierarchy. In summary, the GIS language provides a new means for

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people to recognize, understand and simulate entire geo-environments. Therefore, exploration of the GIS language's functions in contemporary geographical developments is becoming increasingly important. Similarly, construction of the conceptual model and scientific systems of the GIS language will promote the development of the disciplines of geography and geographical information sciences. Therefore, this paper investigates the prospects of the GIS language from the perspectives of digital technology, geographical norms, geographical modeling and the disciplinary development of geography.

**Keywords: GIS; language; conceptual model; ontology**

## 1 Introduction

Language is a carrier of information. People can exchange, share and propagate information using language (Yang, 1999). Humans need language to record the various objects that exist objectively in geographical environments. Languages consist of a large number of definitions, and their logic systems can be used to describe geographical phenomena, observed processes or regularities from practices. In the domain of science and technology, each discipline has formed its own special methodology of representation and systematic framework. A disciplinary language needs its own discipline to support the development of itself. To some extent, a disciplinary language can affect and accelerate the progress of the discipline as well.

Geography originates from the processes by which people explore or understand the geographical environments where they live. Humans also need rules for these processes to exchange or disseminate geographical knowledge (Lin *et al.*, 2003). This need for rules has promoted the formation and development of a geographical language, the most important tool for understanding, representing and transmitting geographical information. To some extent, it is clear that the evolution and development of a geographical language have mainly concentrated on functional extensions and changes of form, which are impacted by humans' observational methods and levels of understanding (Lin *et al.*, 2003, 2005, 2009; Huang *et al.*, 1999; Lu, 2011; Gong Jianhua, 2010). From ancient cliff paintings, such as Shanhai Jing[1], and a map of Mawangdui[2] to modern maps with strict mathematical foundations and even virtual geo-environmental representations, the forms and content of geographical languages have changed tremendously over the years (Lin *et al.*, 2003, 2005, 2009; Huang *et al.*, 1999; Lu, 2011; Gong Jianhua, 2010). As a basic tool for the representation or transmission of geographical information, maps can precisely describe geographical space and objects (Qi *et al.*, 2011; Su *et al.*, 2009). Furthermore, they gradually boost the forming processes of the cartographical language, which is employed primarily in geography. With improvements in understanding, TUPU[3] (Chen 2007; Xu Jun *et al.*, 2010), which integrates Geographic Information Systems (GIS) and visual graphic, abstract mathematical and rigorous logical thinking, extends the functions of the cartographical language and enhances the forms and content of geographical language by means of expression as "shape-mathematics-mechanism".

[1]The Classics of Mountains and Rivers, a famous ancient book of China
[2]Ma Wang Dui Map, a famous ancient map of China
[3]A new type of atlas that is presented by Chen Shupeng of China

GIS employs digital technology to depict or represent the geographical world and facilitates the reformation of geographical theories and methods. As the communicative media of geographical information have been transformed from paper maps into digital codes, man's capacity for description, analysis and representation of the geographical world has been qualitatively upgraded. Radically speaking, GIS, which came into being in the 1960s, actually played a key role in the development and reformation of the geographical language. In a way, the GIS language thoroughly changes our methods of and capacity for spatial thinking and understanding through the organization of geographical information, the discrimination of spatial structures and spatial distribution patterns and the simulation or redisplay of geographical processes and spatial scenes. Therefore, to people, the GIS language is a new type of abstract or generalization, a new paradigm and platform for understanding the objective geographical world. In other words, the GIS language provides people with a linguistic tool for understanding, studying and simulating the geographical world. For this reason and to further explore and think about the GIS language from the perspective of scientific linguistics, the language is not only a basic requirement for constructing a scientific system of geographical information science but is also an important topic in itself for geographers to explore.

In the past decades, many scientists have thought about or analyzed the significant role GIS plays in the development of a comprehensive geography with different viewpoints (Lin *et al*., 2003, 2005, 2009; Huang *et al*., 1999; Lu, 2011; Gong Jianhua, 2010; Qi *et al*., 2010, 2011; Su *et al*., 2009; Chen, 2007; Xu *et al*., 2010; Guo *et al*., 2011; Cai *et al*., 2009; Li *et al*., 2010; Cai, 2010; Li, 2007; Yu *et al*., 2007; GoodChild *et al*., 2007; Coucleis, 2010; Li *et al*., 2009; Sun *et al*., 2004; Xu *et al*., 2005; Kuhn, 2001; Hallisey, 2005; Qi *et al*., 2010; Wang, 2000; Du *et al*., 2000; Su *et al*., 2007; Hu *et al*., 2008; Zhang, 2003; Du *et al*., 2006; Wang, 2006; Smith *et al*., 2009; Kong, 2010; Dangermond, 2010; Han *et al*., 2011; Wu *et al*., 2006). However, in general, these researchers do not survey the real role of GIS in the development of geography from a linguistic perspective. We can find many instances of theoretical support for the GIS language from the methodological disciplines of GIS (Qi *et al*., 2010), such as spatial information ontology (Li, 2007; Yu *et al*., 2007; GoodChild *et al*., 2007; Coucleis, 2010; Li *et al*., 20; Sun *et al*., 2004; Xu *et al*., 2005; Kuhn, 2001) and spatial information epistemology (Hallisey, 2005). Other disciplines, such as those involving the study of the evolution of the geographical language (Lin *et al*., 2003, 2005, 2009; Huang *et al*., 1999; Lu, 2011; Gong Jianhua, 2010), the cartographical language (Wang, 2000; Du *et al*., 2000; Su *et al*., 2007; Hu *et al*., 2008) and computational linguistics (Yu, 2003), also acknowledge the GIS language. Obviously, it is necessary that we perceive GIS as a new generation of geographical language with attentive thinking, especially with regard to innovating scientific thinking, methods and tools of geography (Cai, 2010).

This paper first reviews the latest progress of geographical languages and proposes that the language of GIS represents a new generation of geographical language. Then, section 2 defines the conception of the GIS language and characterizes its functions from the perspective of language. With the aforementioned theoretical foundation, section 3 sketches out the scientific attributes of the GIS language. The last section summarizes the findings and significance of this research and indicates directions for future research.

# 2 Conception of the GIS language and its functions

## 2.1 Geography needs a new generation of scientific language

The formation and development of languages play very significant roles in the survival processes of human history (Shen, 2010; Wang *et al*., 2005). Humans use languages to convey emotions or exchange knowledge, employ natural scientific languages such as math to depict objective rules of nature and make digital computational languages to digitize the physical world. For a long time, the geographical discipline did not generate its own unified scientific language (Ding *et al*., 2005; Pan *et al*., 2004). However, to some degree, some factors have created a linguistic framework for traditional geography and promoted its development, such as a text language with special rules, a cartographical language with standardized legends and mathematical models (Yuan *et al*., 2010; 2011) with better distraction and induction.

Nonetheless, we notice that there are still some deficits in geographical language in methods to describe or represent geographical objectives. It is well known that informatization and digitization are the main characteristics of science and technology at present. Therefore, geography really needs a new disciplinary language with the following characteristics: First, it must effectively integrate traditional geographical languages into a single descriptive system with a unified platform, such as a natural text language, a cartographical language and mathematical models. Second, it must be able to precisely interpret spatial morphological characters, attribute characters and the relationships of geographical objects. Third, it must effectively describe and visually reveal geographical phenomena and their evolutionary mechanisms or processes.

With respect to the improvement of geographical language (Lin *et al*., 2003, 2005, 2009; Huang *et al*., 1999; Lu, 2011; Gong Jianhua, 2010) and the current driving factors of the development of GIS, it is difficult to construct a standardized GIS disciplinary paradigm. However, researchers can still find some ways to delineate the basic framework of the GIS language from the development of the scientific connotations of geography, the progress of the cartographical language (Wang, 2000; Du *et al*., 2000; Su *et al*., 2007; Hu *et al*., 2008), redefinitions of man-earth relationships in GIS (Zhang, 2003), etc.

In 1966, Beguin and Thisse had already created an outline of a geographical representation framework – a Geographical Measurement Framework (Miller *et al*., 2003). Goodchild also created a type of representation paradigm for GIS according to the semantic atom of geographical information (Goodchild *et al*., 2007). Generally speaking, through Table 1, people usually construct geographical linguistic representation paradigms by thinking about the multiple dimensions of geometrical features, spatio-temporal attributes, geographical semantics and spatial computation. In other words, the aforementioned elements commonly establish the foundation of a highly precise geographical representation of GIS.

## 2.2 Definition of GIS language

From a linguistic point of view, to be a social language, GIS must be social and allow the exchange and transmission of information (Wang *et al*., 2005). For the following reasons, we can treat GIS as a scientific language of geography: 1) the public can obtain the spatial information that they need using different types of GIS because GIS possesses the social functions of acquiring and propagating spatial information; 2) GIS has been the primary medium and tool of spatial information for exchanging information and providing service; 3) GIS is also the main analysis and storage medium of spatial information; 4) GIS has common symbolic systems that are followed by society and are broadly mandatory, which is the premise of the geographical semantic representation of the GIS language.

**Table 1** The representation of GIS for spatial characteristics of geographical objects

| | | Spatial mode of description | Spatial mode of representation | Spatial mode of analysis |
|---|---|---|---|---|
| Spatial analysis | Geometrical relationships | Position, distance, adjacency, direction, network, etc. | Determination & randomness | Temporal sequence analysis |
| | Correlation relationships | Similarity, homogeneousness, sample, heterogeneousness, interpolation, etc. | Static state & dynamic state | Spatial relationship analysis |
| | Statistical relationships | Probability, density, reasoning, uncertainty, etc. | Scatter & consecution | Attribution analysis |
| Geometrical space | Planar space | | Euclidean space | Geometrical features analysis |
| | Sphere space | | Non-euclidean space | Scale features analysis |

In conclusion, the GIS language is a comprehensive digital symbolic system that can help people express the spatial distributional patterns or changing processes of geographical objects and phenomena and aid people in achieving general recognition of geographical space. The map symbols and geographical scenes of GIS, with prominent characteristics such as geometry, statuses, processes, spatio-temporal relationships, semantics, and attributes, help achieve this task. According to the above definition, it is clear that the GIS language represents a new generation of geographical languages because it can express spatio-temporal features with multiple dimensions, present inter-dynamic visualizations, virtually represent geographical scenes, perceive with multiple sensor, be conveniently distributed via web, etc.

The GIS language is a type of general symbolic information express system with multi-sensor perception (Lin *et al*., 2005). The GIS language can code, save, represent and convey spatial information to depict the interior mechanisms or evolutionary characters of geographical spatio-temporal processes. Therefore, the GIS language is also a basic linguistic tool for decision-making support (Figure 1). Actually, the GIS language helps us completely understand the spatial processes underlying geographical entities and phenomena, conceptual entities, and the application of GIS entities.

### 2.3 The functions of the GIS language for geographical languages

Early geographical languages used natural languages to describe engendering or subsistent geographical events (Figure 2) with replicative symbols or simple graphics that are generalizations or extractions of the objective world. Therefore, the language of geography mainly helps people to transfer their mode of thinking for geographical spaces. Maps originate from the need to objectively represent the main features of geographical space. Maps can transfer geographical information to people via expressional methods of special symbolic systems and models of graphical description. By combining the accuracy of mathematical language and the visualization of graphic language, maps have generally developed as a type of descriptive model with their own symbolic systems of geographical spaces. Therefore, the cartographical language represents the second generation of geographical languages (Lin *et al*., 2003; Ding *et al*., 2005). Revolutions in computation and measurement have emerged in traditional geography domains since the mid-20th century. In the 1990s, another tide has risen in geographical computation. In this century, with the forthcoming developments of Web 2.0, some factors have substantially impacted the language of geography, including Grid, Parallel and Cloud Computing. GIS is an inevitable result due to its ability to quickly and accurately process spatial information with computers. GIS is a new developmental phase of geography because it completely inherits the cartographic description paradigm and integrates many other disciplines or new technology into a single entity. The GIS language is the best pattern of development of the geographical language. As shown in Table 2, the developmental history of the language of geography has three main phases: the natural language, the cartographical language and the GIS language. Among them, there are relationships of inheritance and development.

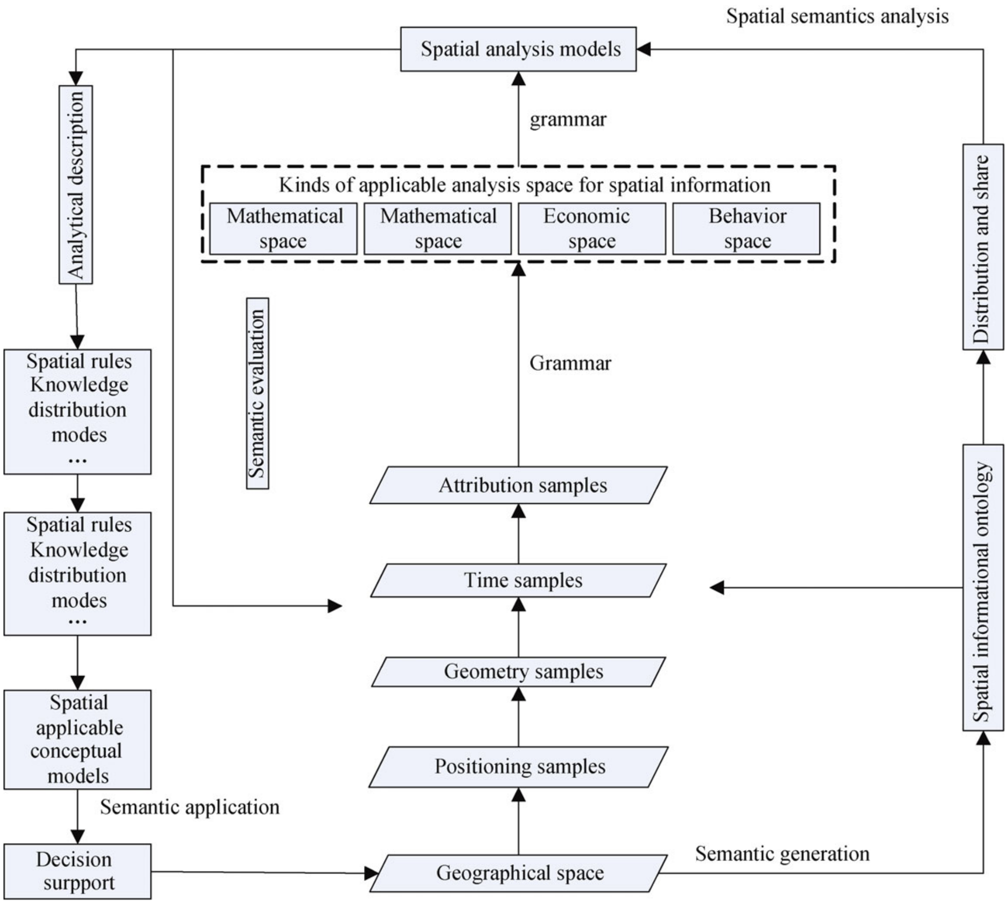


**Figure 1** Conception of the GIS language

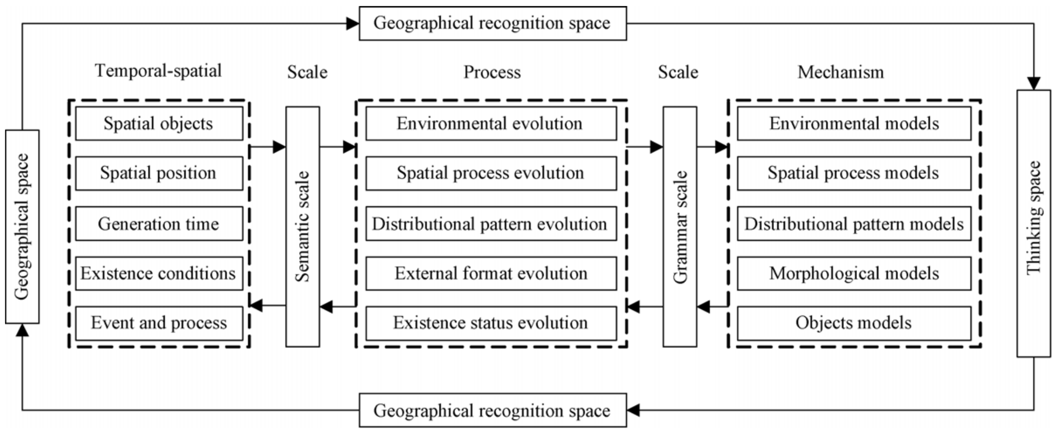


**Figure 2** Processes, scales and mechanisms of geographical language

**Table 2** A comparison of different geographical languages

| Features | Text language | Cartographical language | GIS language |
|---|---|---|---|
| Spatial semantics | Simple geographical conceptions | Perfect semantic framework | More perfect semantic framework and coding system |
| Spatial geometry | Using text to describe the rough shapes | Completed 2d-shape expressional methods | Multi-dimensional expressional methods |
| Spatial relationships | Simple description and representation | Geometrical graphics in planar | 2d- or 3d-spatial relationships expression |
| Spatial attribution | Almost do not care about the attribution | Completed spatial attributions | Definitive spatio-temporal attribution |
| Spatial mechanisms | No mechanism | Limited mechanism expression | Whole spatio-temporal mechanism expression |
| Spatial processes | Simple description | Partly describe processes | Spatial process modeling and expressing |
| Spatial representation | Mainly by simple text and graphics | Perfect graphical symbolic systems | Multi-dimension spatio-temporal complicated representation |
| Spatial scales | Scale definition is obscure | Perfect scale definition | Multiple-scale representation |
| Linguistic features | Using natural languages for expression | Beautiful graphics and symbols | It can express spatial information well |

# 3 The structures and functions of GIS language

## 3.1 Structure framework of GIS language

A language usually has three structural components: semantic, grammar and pragmatics, respectively. Semantics are a unique convention on the definition of some particular objects or events. The semantics of a peculiar word will change themselves with different conditions. The semantics of the GIS language are mainly generalizations of the attributes or characteristics of geographical objects, geographical phenomena, geographical events, etc. The semantics of GIS are the true foundation of descriptions of objective geographical rules, displaying geographical knowledge and implementing geographical representations. Grammar is the method of expression of language. The grammar of GIS language is mainly concerned with the theories and methods of spatial analysis, such as spatial relationships (Zhang, 2003), spatial data mining and spatial data visualization. However, the theoretical structures of spatial analysis are very sophisticated; thus, the theoretical frameworks of spatial analysis (Wang, 2006; Smith *et al*., 2009) still need to be further improved. In fact, pragmatics are arrangements of semantic components. The pragmatics of the GIS language cover both narrow and broad aspects. Hereinto, the narrow pragmatics are mainly concerned with the internal applications of GIS semantics, for example, spatial analysis and scaling up or down using spatial data. By contrast, the broad pragmatics are all the real applicable domains of GIS, such as communication, public security and national defense. GIS pragmatics can provide decision-making support for spatial data analysis results or the prediction of spatial developing tendencies. In actuality, in the GIS language, semantics, grammar and pragmatics are very closely related, commonly constituting the logical structures of GIS language (Figure 3).

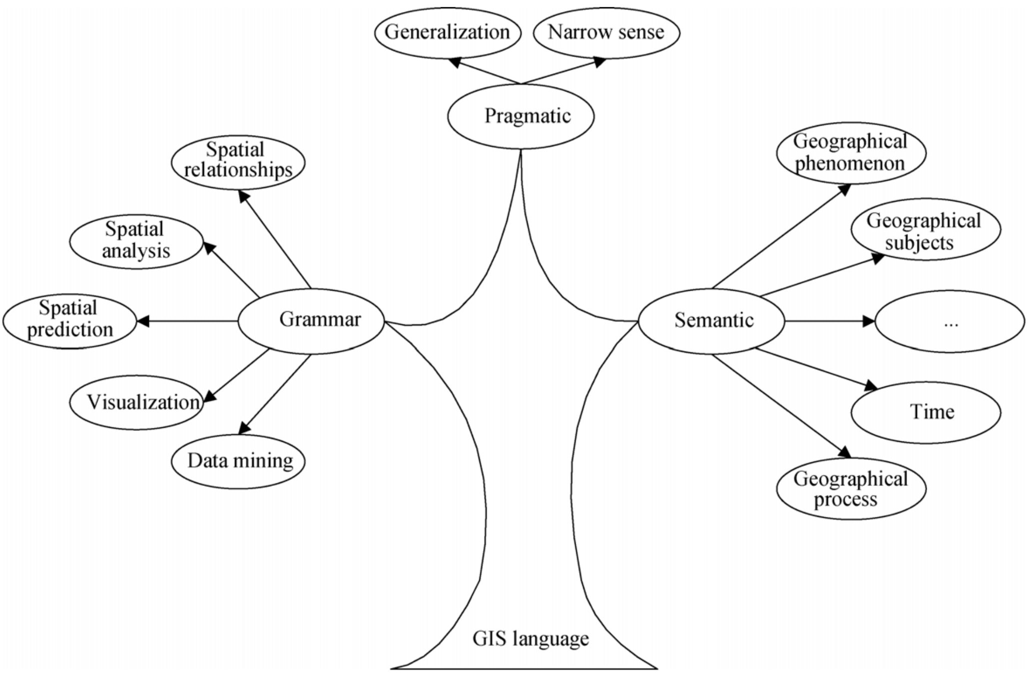


**Figure 3** Logical structure of GIS language

## 3.2 Functions of GIS language

### 3.2.1 Transmitting geographical information

The propagation of geographical information is one of the most crucial roles of GIS language functions. From the visual variables of cartographical symbols to the formation of a virtual geographical environmental system (Lu, 2011; Gong Jianhua *et al*., 2010), researchers have explored the theoretical rules of informational transmission of the geographical language. In particular, with some relationships, characteristics and rules are difficult to understand or directly express because they are concealed. In 1966, Balchin and Coleman

(Rescorla, 2009) proposed the term "graphicacy" to highlight the understanding or effective transmission of spatial information.

It is clear that the modes of transmission of geographical information are constantly changing considering the evolutionary processes of the geographical language. Although maps increase the transmission rates of geographical information, there are still some errors or lags in their print or distribution processes, especially with faster propagation needs. However, the GIS language offers many advantages in terms of the transmission of geographical information, such as shorter updating cycles, faster acquirements, more massive delivery, higher public attention and cheaper costs. The GIS language further improves the socialization of geographical information services. Moreover, an abundance of web-based public geographical service platforms have acquired broad common conformations, including Google Maps and GeoGlobe (Gong Jianya *et al*., 2010).

**3.2.2** Exchanging geographical information

GIS has changed and affected the methods of exchanging geographical information. In particular, it has accelerated rates of exchange. By integrating Web and mobile communication technology and providing access to the public, the GIS language improves informational exchange and broadens the application domains. In addition, the GIS language also forms so many new methods of informational exchange, such as spatial blogs, inter-annotation maps, mobile cell navigations and positioning systems. Moreover, by employing other methods of informational exchange, such as multi-scale expressions and immersive virtual geographical environments, the GIS language has significantly enhanced information delivery and exchange.

**3.2.3** Geographical representation

Geographical representation does actually mean that people use the language of vision or mathematics (Smith *et al*., 2009) to express spatial knowledge and rules about the earth's surface. Virtually, geographical representation is an interactive process of spatial understanding, information transformation and exchange (Han *et al*., 2011). The GIS language can extend the ranges of application of spatial data (Han *et al*., 2011) and strengthen their availability by creating virtual geographic environments, geographical enhancements of reality, geographical super-media, video-GIS, etc. The expressional content of the GIS language covers geographical entities and their spatial relationships, uncertainties (Jiang *et al*., 2009; Yang Xiaoyun *et al*., 2009; Liao *et al*., 2009), geographical dynamics and ontology, differences in understanding the geographical world (Goodchild *et al*., 2007), etc.

Visualization is one of the most significant and effective methods of expression of spatial information because of some exciting scientific discoveries, according to O'Sullivan and Unwin (Goodchild *et al*., 2007), that usually exist in visualization processes. When people represent the geographical world through GIS, they perhaps ignore some laws or distributional patterns that can only be observed on unique scales due to expressional scales or methods of symbolization. In addition, people should notice that each geographical model has its own appropriate scale and effective spatio-temporal range. If people neglect this consideration, they will obtain errors in their results. Therefore, with regard to the characters of geographical representation, we can construct a standard representation paradigm (Goodchild *et al*., 2007; Miller *et al*., 2003) of the GIS language to help people master the objective geographical rules according to the expressional mechanisms of the natural language.

#### **3.2.4** Spatial understanding

It is clear that the recognition function is one of the most important aspects of languages (Wang *et al*., 2005). The GIS language can assist people in fully understanding geographical space. Firstly, the GIS language has the same spatial understanding ability as the cartographical language. Some functions that come from the cartographical language, such as symbol variables, color theories and psychological rules of cognition, can also directly help people achieve their spatial recognition process. Secondly, the GIS language improves the expressional abilities of the cartographical language with many new functions, such as super-media structures (Du, 2000) and geographical videos (Kong *et al*., 2010), because digital media have better spatial cognition effects compared to paper maps. Thirdly, the GIS language develops spatial similarities and predictability, which can further promote understanding of the rules that exist in geographical space (Al-Ahmadi *et al*., 2009; Wang *et al*., 2010a, 2010b, 2010c; Du *et al*., 2010; Jones *et al*., 2008; Zhu *et al*., 2010). In summary, GIS can aid people in completing spatial understanding processes, for example, coding, expressing or decoding geographical entities (Yang Zuqiao, 2009).

### **3.3 Content of the GIS language**

In this paper, we mainly define linguistic mechanisms as content frameworks of the GIS language. Our research references theories from cartography, ontology, epistemology, etc. (Figure 4). Languages have broad constraints that are complied by an entire society. Languages also have stationary symbolic systems with peculiar pronunciation, forms and semantics (Shen *et al*., 2005; Wang *et al*., 2005). The foundation of a language is its own philosophical ontologies, which are actual objectively existing objects. The interior of geographical information is the semantic generalization of the objective attributions of geographical objects. We can conclude that real geographical information is the foundation of the GIS language. According to the theories of geographical information ontology (Li, 2007;

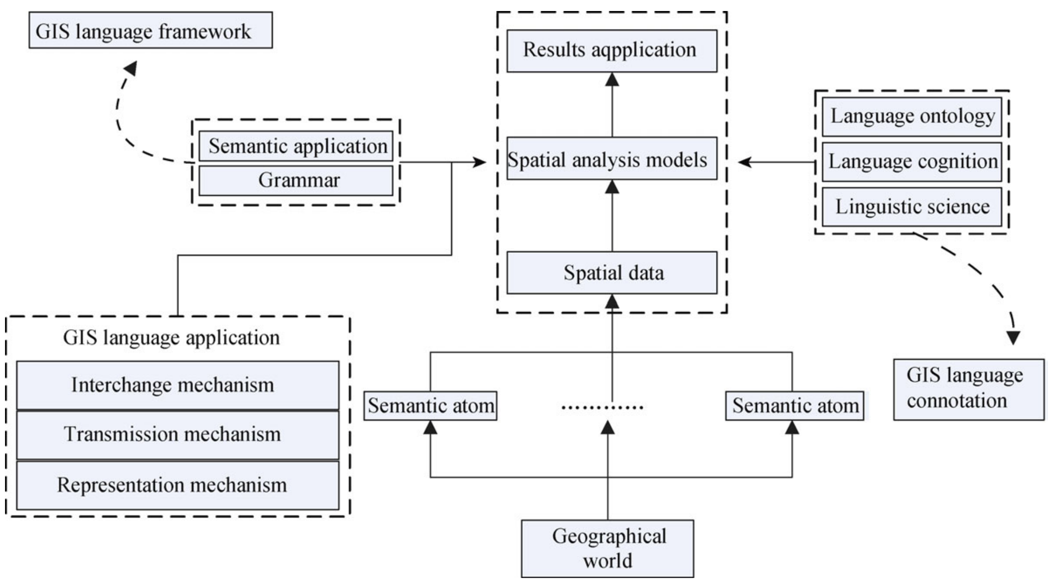


**Figure 4** Content framework of GIS language

Yu *et al*., 2007; Goodchild *et al*., 2007; Coucleis, 2010; Li *et al*., 2009; Sun *et al*., 2004; Xu *et al*., 2005; Kuhn, 2001), the cartographical language (Wang, 2000; Du *et al*., 2000; Su *et al*., 2007; Hu *et al*., 2008) and linguistic theories, understanding the intrinsic characters of the GIS language can help us construct its content framework.

Therefore, the mechanisms of the GIS language are both internal and external. The internal mechanism is mainly concerned with the basic modes of GIS semantic transformations (Figure 5), such as descriptive or representative paradigms of spatial objects (Goodchild *et al*., 2007; Coucleis *et al*., 2010; Miller *et al*., 2003), semantics and pragmatics, etc. The external mechanism is mainly concerned with the exchange and transfer of spatial information with different regional conditions, scales and time. We need to keep in mind the following three points: 1) data are the braces of the GIS language; 2) spatial analysis is the soul of the GIS language; 3) recognition is an important exterior trait of the GIS language. Therefore, to some extent, people can treat the GIS language as a perfect unity of the spatial modeling language and geographical computational language, employing the relationships among data, spatial analysis and recognition.

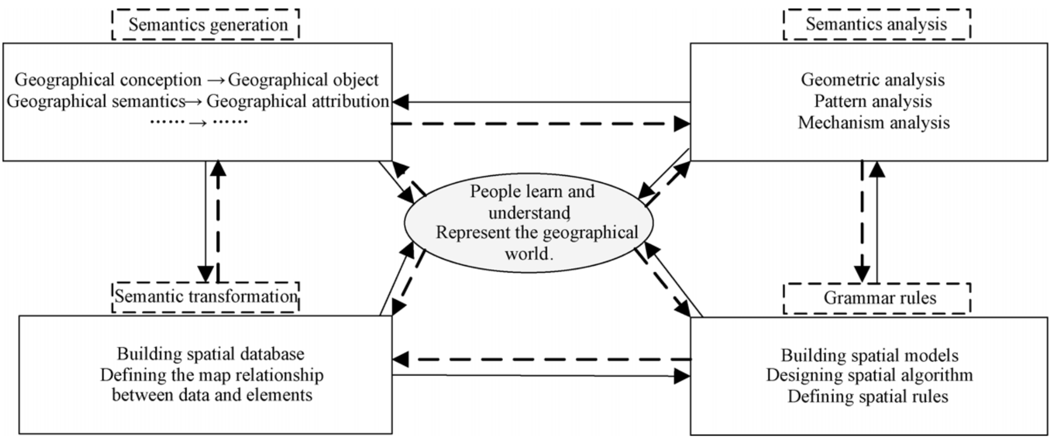


**Figure 5** Internal mechanism of GIS language

## 4 Features of GIS language

This research considers five features of the GIS language: abstraction, systematicness, strictness, precision and hierarchy. It is clear that the GIS language perfectly combines the semantics of geographical objects, feature abstraction, behavioral descriptions and spatio-temporal computational processes. That is to say, the GIS language can help people further understand an entire geographical space by employing spatial distribution patterns, geographical conception models, spatial relationships, human activities, etc. (Coucleis, 2010).

### 4.1 Abstraction

Abstraction implies that the GIS language can extract intrinsic characteristics from geographical space. From a philosophical perspective, spatial information is the result of the thinking and abstraction of human brains concerning the objective geographical world.

Therefore, the GIS language is actually a functional extension of the human brain with which we can save or address spatial information. From this viewpoint, geographical conceptions, models, cartographic models and spatial images are all semantic abstractions of geographical environments and their attributions within a particular observational scale. Abstraction of the GIS language is definitely reflected in geographical space and semantics. With regard to the former, people can obtain a spatial coordinate reference framework and build a spatial foundation for a geographical representation of the GIS language. Geographical semantics concern time, attributions, morphologic and spatial relationships through phenomena, objects, processes and the events of the geographical world. People can obtain geographical data, which incorporates all of geographical semantics. According to abstraction, the GIS language keeps key information necessary for humans to understand geographical processes. Abstraction of the GIS language provides a linkage between the objective world and the subjects of understanding the processes of spatial information cognition.

### 4.2 Systematicness

The GIS language has specific symbolic systems, its own data visual methods and spatial analysis methodology, which actually form a unified system. The GIS language is a comprehensive expressional system with special symbols, including 2-D or 3-D graphical symbols, multimedia symbols with voice, animation or video, interactive texts and dynamic annotations. In addition, with the application of new technology, virtual geographical scenes, geographical videos and augmented realities have all gradually become important components of the symbolic system of the GIS language. The GIS language employs peculiar symbolic systems to visualize geographical information according to geographical visual theories and methods. Actually, the GIS language has become a scientific linguistic tool for understanding geographical space and mining the geographical knowledge of the real world by integrating specific spatial analysis models (Fang *et al*., 2010). It is clear that the GIS language is systematic due to its rigor and logical unity.

### 4.3 Strictness

As a scientific language of representation of the objective world, the GIS language can clearly be distinguished from other languages in terms of strictness, as evidenced by its rigorous mathematical foundation and scales. Regional and spatial positions are characteristics of geographical semantics. The GIS language finds its own semantic expressions in the precise reference framework of geographical space. With the constraints of a coordinating system and scale, the GIS language can precisely describe the spatial position of geographical semantics. Scale is also an important attribute of geographical semantics. Therefore, scale is an important index for measuring the details of geographical semantics. Table 3 shows the three main scales of the GIS language, which are cognition, representation and analysis. The cognition scale is the extent of the measurement of the semantic details of geographical objects. The representation scale is the extent of recognition for the expressional details of spatial information. The analysis scale is the extent of understanding the rules hidden in spatial information.

**Table 3** The scalable characteristics of the GIS language

| Content | Definition | Features | Examples |
|---|---|---|---|
| Cognition scale | Recognizing the details of semantics for spatial objects | Recognition space | Classification norm, coding system, such as levels of settlements |
| Expression scale | Visualizing or expressing the details of spatial information | Representation space | Cartographic models, visual methods, such as spatial data symbolizing |
| Analysis scale | Understanding spatial rules or laws | Analysis space | Spatial analysis models, such as road buffering analysis |

### 4.4 Precision

There is an abundance of contradictions between certainty and uncertainty in the objective geographic world. We can easily enumerate many examples of the uncertainty of geographical information. For example, there are always some error between the geographical information that people acquire and the objective geographical world due to the limitations of observational methods or technology. People also often generate different recognitions of the same geographical objects because of different perspectives or applicable purposes (Goodchild *et al*., 2007). However, given its rigorous mathematical foundation and measurements, the GIS language can effectively remove the influence of spatial information uncertainty and precisely state geographical semantics by strictly and accurately elaborating them with different scales. Therefore, the GIS language can provide accurate geographic semantic supports to people in their geographical cognition processes or spatial decision making. For example, the GIS language can give us accurate answers for spatial direction service requests, geographical semantics or relationships inquire (Du *et al*., 2010). It is clear that GIS is a language of geographic informational representation that possesses the feature of precision.

### 4.5 Hierarchy

By extracting features of time, the attributes, morphology, positions, statuses and spatial relationships of geographical objects and phenomena, the GIS language can gather abundance elements with different semantics and construct all types of conceptual models for the geographical world. Furthermore, the GIS language can use geographical data with many different semantics and further implement their spatial representation.

Let $T$ be a geographical time, $R$ be a geographical attribute, $G$ be a geometric morphology, $P$ be a spatial coordination, $Q$ be a spatial relationship and $i$, $j$, $k$, $l$, $m$ and $n$ be natural numbers if and only if they are within the condition $1 \leqslant i, j, k, l, m, n \leqslant N$. We can construct a multi-component conceptual model for geographical elements, which we call a Feature. A Feature can be expressed as follows:

$$Feature = F\left\langle T_i, R_j, G_k, P_l, S_m, Q_n \right\rangle \qquad (1)$$

Obviously, we can obtain many Features by integrating different values with different status conditions:

$$T_i, R_j, G_k, P_l, S_m, Q_n$$

Therefore, we can use different values of Features to express different geographical conceptual models. With the former assumption, layers of GIS can be clarified as sets of geographical element data that share the same or similar geographical semantics. Therefore, a layer is a very important grammatical structure of the GIS language. Layers are a very convenient way to organize and manage data, perform spatial analysis or find statistics, for example, spatial hierarchical sampling statistics (Wang *et al*., 2010c) or assessment of area attribute values (Wang *et al*., 2010a). Actually, a layer is a special sentence structure of the GIS language. The GIS language itself represents geographical semantics with the following paradigm: geographical element → geographical word → geographical conception → geographical conceptual mode→layer. It is clear that the GIS language has obvious hierarchical characteristics.

Beyond this paper, there are still some features that need to be implemented to address some issues of the GIS discipline (Wang Jiayao, 2010). Such issues include the uncertainty of spatial information, similarity or prediction of geographical processes (Liu *et al*., 2002; Li *et al*., 2011), intervention for geographical scene perception and quickly changing development.

## 5 Conclusions

GIS has affected and changed our methods of understanding the geographical world and the exchange of spatial information since it came into being in the 1960s. In addition, GIS is one of the best basic tools available to us for exchanging and transmitting spatial information. It is full of referential meanings created by employing perspectives of language to improve the disciplinary frameworks of GIS, promote the technological design patterns of GIS software, resolve the current issues of GIS development, etc.

In the history of the discipline of geography, the GIS language represents a new geographical language because it implements unified and formalized descriptions of the spatial relationships of the earth's surface, geometric features, geographical semantics and spatio-temporal attributes. This paper demonstrates that the GIS language also merges spatio-temporal representations of the geographical world and computational processes. Abstraction, systematicness, strictness, precision and hierarchy are all of the dominant features of the GIS language.

In actuality, improvements in the GIS language are deeply affected by technology and other disciplines. There are still many topics worthy of future exploration to improve the GIS language, including the following: 1) how does digital technology affect the functional extension and attribute changes of the GIS language; 2) how can the GIS language respond to shifts in the geography paradigm; 3) how does the disciplinary methodology of GIS promote the formation of GIS language systems; 4) how does the enhancement of the expressional ability of geographic language improve the functional structures of the GIS language.

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