

# A Framework of Pan-maps: facilitating a unification of Maps and Map-likes

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**Abstract:** Several new forms of maps and map-likes visualization have emerged owing to the advances in Information and Communication Technology (ICT). However, the current cartographic theories are insufficient to guide and support the applications of these new forms of maps and map-likes visualization. Specifically, these forms overstep the cartographic framework and challenge the cartographic theory. In this study, we term these new geovisualisation forms as Pan-maps, thereby proposing a framework to visualize Pan-maps based on time, space, attribute, and user variables. These variables can be divided into basic and compound variables, and a hierarchy among basic and compound variables using their interrelated composition relationships is established. Furthermore, we taken AR map as case study to verify the effectiveness of the proposed framework. The proposed framework is anticipated to provide theoretical and practical support for Pan-maps design and promote cartography development in the ICT era.

**Keywords:** Cartography, Pan-maps, Unified Cartographic Framework, Visualization

## 1. Introduction

Maps are regarded as a never-ending endeavour of presenting the world in an efficient, scientific and aesthetic way. Throughout the human history, map making went through several stages. For examples, the very first version of maps was found on the walls in caves, then on animal furs or paper-based materials. To date, all of them gradually become legacies since the invention of computers. It should be stressed that maps at a later stage are always more ubiquitous than those at an earlier stage. Today, with the rapid development of Information and Communication Technology (ICT) and the big data era, cartography meets its golden age too, as map makers and users are unprecedentedly broadened, leading to a diversification of map representations. To be specific, a large number of variations from traditional maps have emerged (map-likes), such as metaphorical maps, virtual reality (VR) maps, augmented reality (AR) map, and holographic maps (Guo and Ying, 2017; Peterson, 2007). The map-likes allows us extending representations and meanings of traditional map components (e.g., when, where, what, how); however, traditional cartographic theory do not well-adapt these extensions. In this paper, we attempted to propose a term “Pan-maps”, referring collectively to the maps and map-likes, aiming to clarify the basic mapping elements and their relationships in a newly-designed visualization framework, and further to update the cartographic theory in the ICT and big data era.

Map visualization framework originated from the visual variable system which proposed by French cartographer Bertin (1967,1983), who pointed out that shape, size, color, orientation, value, texture, location were the basic

elements that caused the difference of users' visual perception. Then, adapted from the development of ICT, the visualization form of Pan-maps ranges from 2D to 3D maps, form static to dynamic maps, from mapping the earth to other celestial bodies, from geographic to virtual spaces (cyberspace), from professional cartography to everyone cartography – moving towards a trend of being comprehensive and multi-dimensional. To satisfy the requirements of Pan-maps visualization, scholars have continuously enriched the visual variable system. Figure 1 shows the map visual variables proposed by the cartographic researchers over the last 50 years, including 2/3D visual variables, screen variables, and dynamic variables. Previous studies had put forward corresponding map visual variables from several research perspectives, which promoted the development of Pan-maps visualization research. However, to this day, some limitations need to be addressed. Firstly, the current cartography theories lack a discussion on the emerging map-likes forms, such as AR maps (Albouys-Perrois et al., 2018), chorematic maps (Reimer, 2010), kriskograms maps (Xiao and Chun, 2009), etc. Cartography is facing the challenge of new technologies and requirements. Secondly, most existing studies focus only on the visual description of one single characteristic, such as 2D, 3D, static, or dynamic. But these studies ignore the analysis of the visual characteristics of Pan-maps from a global perspective. Thirdly, the visual characteristics of Pan-maps objects are potentially interrelated and nested with each other, but the existing research framework failed to reflect the hierarchical relationship.

Map visualization variable	Variables	Bertin	Morrison	Caivano	Robinsonze	Wood	Dent	Tyner	Gao	Slocum	Rautenbach	MacEachren	Carpendale	DiBiase	MacEachre	Ai	Gar-on
2/3D Visual Variables	Shape	○	○		○		○	○	○	○	○	○	○				
	Size	○	○	○	○		○	○	○	○	○	○	○				
	Color(Hue+Saturation)	○									○		○				
	Orientation	○	○	○	○		○	○		○	○	○	○				
	Density			○													
	Color Value	○	○		○		○	○		○	○	○	○				
	Hue		○		○		○	○		○							
	Saturation		○				○	○		○							
	Arrangement		○				○	○		○		○					
	Texture	○	○				○	○	○		○	○	○				
	Spacing				○					○							
	Location	○			○		○	○		○	○	○	○				
	Sketchiness					○											
	Posture								○								
	Illumination								○								
	Shadow								○								
	Perspective									○							
	Height																
	LOD										○						
	Motion										○		○				
Screen Variables	Crispness								○			○					
	Transparency											○					
	Resolution											○					
Dynamic Variable	Duration													○	○	○	○
	Rate of Change													○	○	○	○
	Order													○	○	○	○
	Display Date														○	○	○
	Frequency														○	○	○
	Synchronization														○	○	○
	Rhythm															○	○

Figure 1. Visual Variables of Maps. These variables comprise 2D, 3D visual, screen, and dynamic variables. This figure shows the visual variables of maps proposed by various scholars over the past 50 years.

To address the aforementioned need for Pan-maps visualization in the ICT era, this study proposes a framework for Pan-maps visualization. Firstly, based on the Systematology and epistemology, this paper regards the map as a system formed by numerous dimensions, including both basic and compound variables. Basic variables are the essential elements of Pan-maps, and compound variables are the intricate elements combined by basic variables. The combination of basic and compound variables forms a visually visible map. Secondly, in this study, time (when), space (where), attribute (what) and user (who) dimensions are used to constitute a 4W representation framework of Pan-maps. Thirdly, we taken AR map as case study to verify the effectiveness of the proposed framework.

## 2. Proposed Framework

### 2.1 Strategy for Designing the Pan-maps Visualization Framework

Systematology holds that the system and elements are the fundamental modes of objects' existence (Backlund, 2000). The system is a unified whole comprising elements, and elements are interactive and interrelated parts of the system. From the epistemology perspective, Sokolowski (2000) proposed that any object can have multiple attributes, and the essence of an object is the combination of various interrelated attributes. The conjunction of various attributes constitutes an object (or a system), where each attribute is a variable. Elements are non-independent parts and cannot be separated from the system. When an

element detaches from the system, it loses the original function. In essence, there is a hierarchical dependency relationship between system and element.

This study introduces the theories of systematology and epistemology into the study of the framework of Pan-maps visualization. In essence, we can regard map as a system, and symbols as elements of map. In this study, the strategy for designing the Pan-maps visualization framework is presented, as shown in Figure 2. It could be considered that Pan-maps is a system formed by numerous variables, including both basic and compound variables. Basic variables are determined by "indivisibility" and "atomicity" as selection criteria. Compound variables are combined with basic variables to strengthen the graphic encoding of map objects and produce graphic symbols with more abundant information. For example, colour is built on hue, saturation, value, and transparency; thus, colour is a compound variable. There is multi-level dependency among basic and compound variables.

### 2.2 Framework Design

#### 2.2.1 Objects of Pan-Maps

The development of ICT has accelerated the integration of physical space and digital space. The digital space (also known as information space) such as cyberspace, virtual space and social media space have become the object space of map representation. With the intervention of the digital space, the geographical scene, human network, and social process, as well as all of the virtual and real objects that were mapped or built in the digital world all have become the representation objects of Pan-maps.

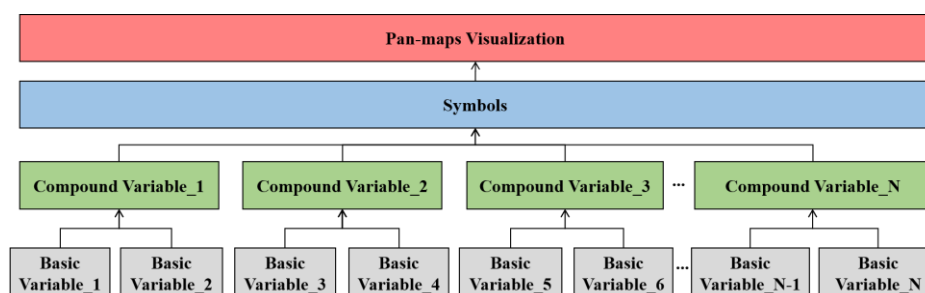


Figure 2. Theory of Systematology.

### 2.2.2 Framework

The representation of geographic objects in GIS (Geographic Information Science) primarily depends on three basic characteristics (Goodchild et al., 1992; Goodchild, 1992): (a) time (when), (b) space (where), (c) attribute (what). Time responds to the questions of when an object appears and how long it takes from the appearance to disappearance, representing the continuity and sequence of the object movement process. Space responds to where an object is and what kind of spatial relationship it has with other objects, representing the extent of objects' existence, including geographic location, spatial relationship, etc. Attribute responds to what an object is, representing the semantic information of objects. In addition, since user plays an essential role in information acquisition and dynamically adjusting visual information, we consider that user is a crucial variable in the framework of Pan-maps visualization.

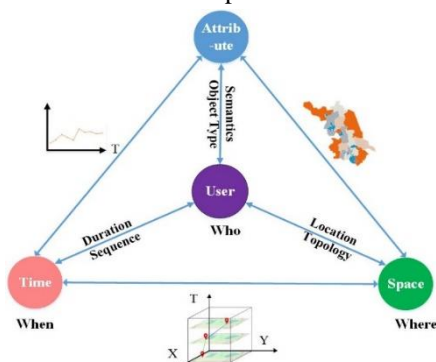


Figure 3. Framework of the Pan-maps Visualization. (modified from Kraak (2014))

In this study, the principle of the object representation in GIS is introduced into the study of Pan-maps visualization. Figure 3 delineate the structure and variables of the Pan-maps visualization framework.

## 3. Variables in the Framework

### 3.1. Basic Variables

Figure 4 shows the basic variables of the Pan-maps visualization framework. Time variables include occurrence time; space variables include location; attribute variables include hue, value, saturation, and transparency; and user variables include time scale, space scale, and attribute scale. Notably, there exists an open framework, which can be further optimized if necessary.

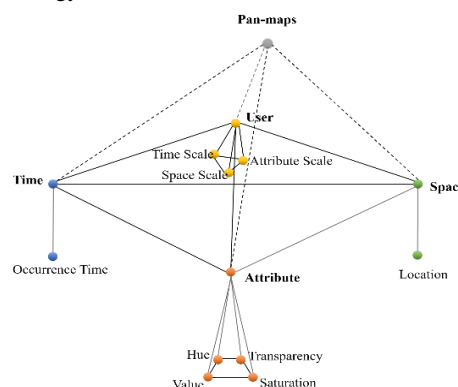


Figure 4. Basic Variables of the Pan-maps Visualization.

#### 3.1.1 Time Basic Variables

Because of the constraint of a physical carrier, traditional maps can merely express the static spatial objects. In the ICT era, map can express dynamic spatial objects and form continuous dynamic effects through position movement, flicker, environmental effects, etc.

Dynamic variables are vital elements in the dynamic representation of Pan-maps. Dynamic variables can help users obtain the temporal information of interest effectively when Pan-maps describes the temporal changes of space objects. The time change of objects has the characteristics of continuity, order, periodicity, rhythm, etc. By describing the occurrence time of dynamic objects, Pan-maps can give objects the ability of dynamic representation. Therefore, to represent the time characteristics of Pan-maps, we proposed that occurrence time is the basic variables of time process representation.

#### Occurrence Time

Occurrence time variable refers to the discrete points on the time axis, which corresponds to the frame concept in multimedia. In addition, it is primarily used to represent the discrete changes of object space or attribute characteristics in time series. Occurrence time variable can represent the time node when characteristics of map objects appear, disappear, or change. As the basic variable of time, the combination of occurrence time and other basic variables can form time compound variables, such as duration, order, change rate, etc.

#### 3.1.2 Space Basic Variables

Through space variables, objects can visually display their spatial location distribution and their spatial relationships

with other objects. Traditional map space implies the space formed by projection objects on the Earth's surface onto a plane through mathematical transformation algorithms. In Pan-maps, the representation of space extends from 2D to 2.5D, 3D, and even higher dimensions, which facilitates the users to (1) roam freely in the map space from the first-person perspective and (2) obtain different spatial experiences. The core of spatial representations can be summarized as the location feature. To represent the spatial characteristics in the Pan-maps visualization, this study proposed that location is the basic variable of space feature representation. Other space variables (e.g., shape, size) can be represented by location or a combination of location and other basic variables.

### Location

Location is the most essential variable of space. Through the topological connection between location points, object models, including line, area, and volume, can be formed and realize the spatial representation of various objects.

In traditional maps, location includes absolute coordinates, relative coordinates and addresses. Absolute coordinate refers to the value of all coordinates relative to the origin of the coordinate (0,0), such as geographic coordinate (20°17'E, 23°26'N). In contrast, relative coordinate denotes the coordinate value relative to a reference object, such as point A is located 30 degrees east of point B. Address is a complete description of a location formed by a string of words, letters, and numbers.

In Pan-maps, the concept of space is further expanded to non-geographic space, such as cyberspace, psycho-spatial, etc. The locations of these spaces can be represented by constructing a virtual spatial coordinate system. Xin (2017) used metaphorical map to express the distribution of file hierarchy data of computer.

#### 3.1.3 Attribute Basic Variables

Attribute variables are mainly used to represent the semantic characteristics of objects visually, that is, to respond to the question of what an object is. The representation of the space objects mainly depends on surface textures, including surface graphics and colour features. Therefore, this study proposed that the attribute basic variables included hue, value, saturation, transparency.

### Hue

Hue is recognized as the colour spectrum, namely red, green, blue, which is one of the basic variables of the attribute component. The application of the hue variable can enhance the information transmission effect of qualitative features of object categories and enrich the artistry of the Pan-maps visual representation, which makes the map more charming. For example, using the green colour to represent forestland and blue to represent water in map enables users to obtain the object category information efficiently.

In addition, according to people's psychological feelings, colours are divided into warm colours (red, orange), cool colours (blue, green), and neutral colours (black, grey, white), which mean that the hue variable can be applied on

the representation of qualitative differences of object attributes.

In terms of artistic representation, reasonable collocation of different colour can make the Pan-maps more attractive, and different colour symbols can stimulate users' sensory nerve visually, enhancing their reading interest.

### Value

Value is another attribute basic variables, which describes the amount of light reflected by symbols: the brightness or darkness.

Value is useful for describing the quantity or ordinal attribute of objects in map. When hue and saturation are fixed, the difference of the number or level of attributes among map objects can be represented by adjusting the value variable. For instance, the change of value can transform the red gradient from light red to dark red, which reflects the difference in disease transmission intensity across different regions.

In term of high fidelity effect expression, value can enhance the visual texture effect of 3D model or create realistic environmental effects. Through rendering different reflection effects on different sides of 3D models, such as bright, grey, and dark sides, value can make 3D models visually produce different lighting or shadow effects, thereby making map scenes more realistic.

### Saturation

Saturation describing the colour purity of symbols. In Pan-maps, the saturation can reflect the change of quantity level of symbols, highlighting the hierarchical difference of map object attributes.

### Transparency

Transparency describes the amount of graphic blending between symbols and background. The higher the transparency of symbols, the lower the visibility of map objects. Therefore, when highlighting the display effect of a specific symbol, the visibility of the symbol can be enhanced by increasing the transparency of the surrounding symbol with a low importance level. The transparency variable can enhance the visual effects of models (e.g., glass, water, etc.) in Pan-maps.

#### 3.1.4 User Basic Variables

User variables directly affect the representation of Pan-maps objects. Based on the difference of user influence content, user basic variables can be divided into time scale, space scale, and attribute scale.

### Time Scale

Time scale reflects the level of time resolution, which exhibits the temporal integration of spatial or attribute characteristics of map objects in time series, such as year, month, day, hour, minute, second, etc. Time scale can affect the change rate and rhythm of dynamic symbols, making the change of symbols characteristics in the same process exhibited differences.

Static maps have no room for time scale due to the immutability of time. But in dynamic maps, time scales can be divided into the fixed time scale and variable time scale. When the feature duration of map objects is constant,

the larger the time scale, the higher the temporal integration degree of features and the slower the rate of change, and vice versa.

### Space Scale

Space scale denotes the size of the smallest spatial representation unit of map objects. The larger the space scale, the lower the degree of refinement, and the rougher the geometric outline of map objects.

Space scales include fixed and variable space scales. The space scale of traditional maps is often fixed due to the constraints of physical carriers. But in Pan-maps, map can facilitate global or local object browsing through changing space scale.

### Attribute Scale

Attribute scale indicates the size of the smallest texture unit of map objects. Notably, the texture of map objects is mutable. Generally, texture of traditional map is unchanged owing to the fixed spatiotemporal scale.

However, in ICT era, with the change of the spatiotemporal scale (mainly space scale), the texture of Pan-maps objects changes correspondingly. When the space scale is large, the object representation often needs to be integrated, and the texture features of objects are expressed through rough and simple texture. Conversely, when the space scale is small, the object representation needs to be more refined, and attribute features of map objects should be expressed by the texture with rich details.

## 3.2 Compound Variables

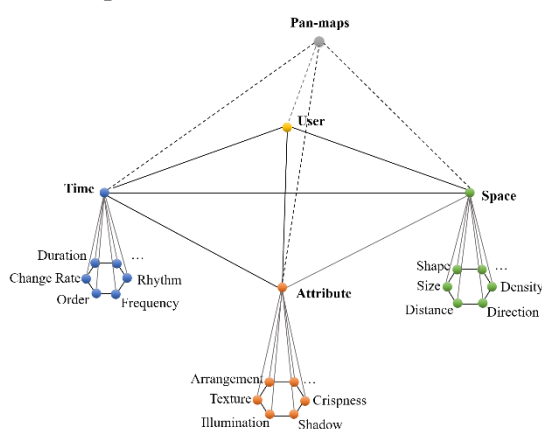


Figure 5. Compound Variables of 4 dimensions.

Figure 5 depicts some frequently used compound variables, which indicates that the conjunctions of basic variables could strengthen graphic encoding of map objects and generate redundant symbolization. Through the conjunctions of basic variables of time, space, attribute, and user, Pan-maps could realize the comprehensive representation of various characteristics of map objects. Among others, these include dynamic process, attribute content, appearance features, and structural features. In this section, we discuss the conjunctions and mapping relationships among basic variables of the Pan-maps visualization framework.

### 3.2.1 Time Compound Variables

#### Duration

Duration, also known as timespan, refers to the length of time between two occurrence time. The duration variable consists of occurrence time and its mathematical expression is as follows:

$$\text{Duration} = \text{Occurrence Time}(\text{Object State Change}) - \text{Occurrence Time}(\text{Object State Appear})$$

#### Change Rate

Change rate represents the speed of state change of map objects, which can be expressed by the duration and other variables. In essence, it describes the state change of the map object (such as size, shape, location, etc.). The structure of mathematical expression of change rate is:

$$\text{Change Rate} = \text{State Change of Map Object} / \text{Duration}.$$

#### Order

Order describes the sequence of the symbolic state change. The structure of mathematical expression of order is:

Occurrence Time (A) - Occurrence Time (B) < 0, State A appears before State B,

Occurrence Time (A) - Occurrence Time (B) > 0, State B appears before State A,

Occurrence Time (A) - Occurrence Time (B) = 0, State A and B appear at the same time.

#### Frequency

Frequency represents the number of periodic repetitions of Pan-maps object's characteristics within a specified duration, which can be expressed as a combination of duration and time scale variable. The mathematical expression of frequency as follows:

$$\text{Frequency} = \frac{\text{the Number of Periodic Repeats of State}}{(\text{Duration} * \text{Time Scale})}.$$

#### Rhythm

Rhythm is a special form of frequency, which represents the regular changes in the state of map objects. By grasping the rhythm of the visual state of map objects, the visual perception of the users can be improved.

### 3.2.2 Space Compound Variables

#### Shape

The essence of the shape variable is a location point or a collection of location coordinates. The shape variable can represent the external contour of map objects, identify the qualitative differences among different objects categories, and express the geometric morphology of objects through zero-dimension (point), one-dimension (line), two-dimension (e.g., circle, triangle, etc.), three-dimension (e.g., 3D model), and even higher-dimensional graphics.

#### Size

Size variable is generated based on the location variable, and the size of map objects can be inferred from the points that make up map objects. Size variable can represent the geometric size of objects in map space, as well as identify the quantitative difference among attributes of the same type of objects.

#### Distance

Distance refers to the length between the locations of spatial objects, and can be utilized to measure the proximity of objects in the map space intuitively. The mathematical expression of distance is as follows:

$$\text{Distance} = \sqrt{(ax - bx)^2 + (ay - by)^2 + (az - bz)^2}$$



Location(a) = (ax, ay, az); Location (b) = (bx, by, bz).

### Direction

Similar to the distance variable, the direction variable is generated based on the location variable. Direction can describe the orientation of objects in the map space. Generally, direction refers to four directions in traditional maps. However, in Pan-maps, direction can be two directions, four directions and even eight directions. The application of the direction variable can describe the trajectory, posture, and spatial order relationship of objects in the Pan-maps space. The mathematical expression of direction was as follows:

$$Direction(a, b) = \arctan\left(\frac{ay - by}{ax - bx}\right)$$

Location(a) = (ax, ay); Location (b) = (bx, by).

### Density

Based on the location, density can be expressed by the number of objects in a unit area, and its mathematical formula is as follows:

$$Density = \text{number (object)} / \text{area}.$$

Notably, when the area is fixed, the more symbolic location points representing objects, the greater the density, and vice versa.

### Arrangement

Arrangement is a kind of organizational form of the surface pattern of map objects. It forms a regular pattern through space variables shape, size and direction, combined with attribute variables hue, value, saturation, and transparency. Usually, arrangement variables are used to represent the surface features of objects with regular textures.

#### 3.2.3 Attribute Compound Variables

### Texture

The texture variable refers to the surface pattern of space objects. It simulated or abstracted the surface characteristics of map objects through the collocation of hue, value, saturation, and transparency to form a vivid color mixture. Texture is typically a 2D image, which is mapped to the surface of the 3D model through texture coordinates, also called UVs coordinates, like wallpaper on a wall.

### Illumination

The principle of illumination generation is similar to that of texture, which is to generate a lightmap (Sloan and Silvennoinen, 2018) for different positions of map objects through hue, value, saturation, and transparency variables, thus providing lighting effects to space objects. The illumination variable can strengthen the optical effects of 3D map scene.

### Shadow

The principle of shadow generation is similar to that of texture, which is to generate a shadowmap for different positions of space objects through hue, value, saturation, and transparency variables, thus providing shadow effects to space objects.

### Crispness

Crispness represents the clarity of spatial objects and is mainly affected by attribute variables hue, value, saturation, transparency, space variables distance, direction, and space scale variables. In the stereo scene, due to the perspective principle of the near-large and far-small, objects at different distances have a different degree of blur. The frequently used blur effect makes the long-distance model look more distant and blurred, whereas the foreground model can be clearly highlighted, making the 3D model produce a more realistic effect similar to the human vision, thereby improving the user's visual perception.

## 4. Verification of the Proposed Framework

In this study, we constructed a Pan-maps visualization framework based on time, space, attribute, and user variables. The conjunction of distinct basic variables in the framework can construct more complex compound variables and form various visual symbols, thereby realizing the object representation of maps. This section discusses the application process of the Pan-maps framework and take the AR map as examples to verify the effectiveness of the framework.

### 4.1 Application Process of the Proposed framework

Figure 6 illustrates the visualization process guided by the proposed framework, including mainly the following five steps: 1) selection of basic variables; 2) formation of compound variables; 3) selection of representation feature; 4) confirmation of map visualization forms; 5) output of Pan-maps result. Specifically, the basic variables layer is the atomic layer of map representation, which forms the basis of Pan-maps visualization, whereas compound variables are opted for more complex elements generated by the interrelationships of basic variables. In addition, the feature representation layer is the expression of temporal, spatial, attribute, and user features, as well as topological relationships of map objects through basic and compound variables. Map visualization forms layer refers to the construction of map (such as map symbols, map projection, etc.) from different visual dimensions, and the Pan-maps layer is the final output, being a unification of different representation forms of maps and map-likes.

### 4.2 AR map

We applied the designed framework on AR map as a case study to demonstrate how Pan-maps theory works for Pan-maps practices in ICT era. The application process can be decomposed into a five-layered structure, i.e., "basic variable layer - composite variable layer - feature representation layer - visualization form layer - Pan-maps result layer".

- 1) Nine basic variables in 4 dimensions were selected to build AR map;

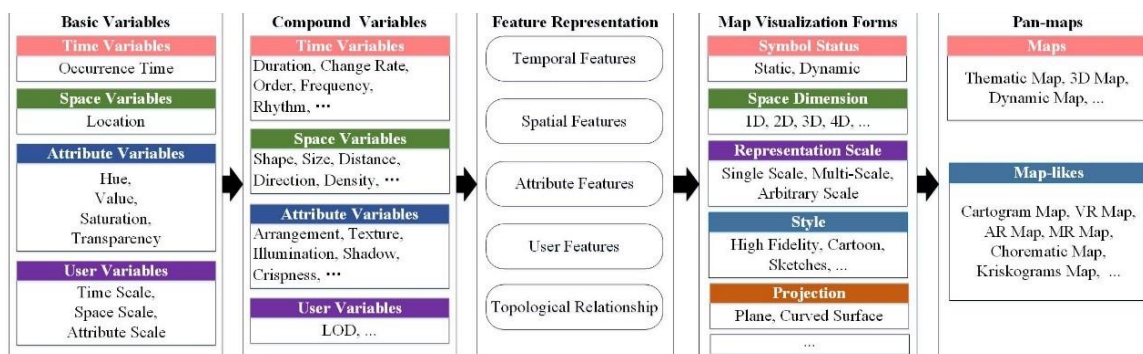


Figure 6. Application of the Pan-maps Visualization Framework.



Figure 7. The variables structure of AR map

- 2) Occurrence time, location, hue, value, saturation, transparency, time scale, space scale, and attribute scale were used to constitute the duration, order, change rate, and frequency variable which describing the dynamic effect of AR map objects in motion, the shape, size, distance and direction variables which describing the relative topological relationship among AR map objects in the virtual scene, and the colour, texture, illumination, shadow, crispness variables which describing AR map environment;
- 3) Furthermore, the spatiotemporal process of AR map objects can be expressed by change rate, order, frequency variables; shape, size, distance, direction, crispness, texture variables were the core factors that affecting the representation effect of morphological characteristics and the topological relationship of AR map objects; illumination and shadow were important variables to assist in rendering 3D scene effects.
- 4) Through the combination of the aforementioned basic variables and compound variables, the visual symbols of AR map further form dynamic, 3D, multi-scale and highly realistic effect representation;
- 5) Final AR map results are shown in Figure 7.

## 5. Discussion

Based on the characteristics of Pan-maps, the study proposes a 4W framework for the Pan-maps visualization from a global perspective, comprising four dimensions, namely, time, space, attribute, and user. Notably, these dimensions are independent but interrelated with each other. Through the collocation and combination of different variables, map representation across various styles could be further formulated. In addition, this study clarifies the hierarchy among basic and compound variables. Kraak (2020) and Wang (2020) reported that the time, space, and attribute were crucial components of maps representation, which is consistent with our study. Furthermore, we have added user variables to the proposed framework, which could help user focus on information acquisition and dynamically adjusts visual information (Goodwin et al., 2015; Oosterom and Meijers, 2014).

The introduction of basic variables in this study further deepens the connotation of map representation. From the overall perspective, we dug up the basic visual variables from time, space, attribute, and user aspects, thereby making the framework applicable to a wider range of fields, suitable for the Pan-maps visualization.

It is worth noting that this study clarified the hierarchy among basic and compound variables. Through the combination of different type of variables, the framework

further realized different styles of map visualization, which is consistent with the idea proposed by Sokolowski (2020). In addition, we built an application process based on the proposed framework and verified the values of this framework.

Undoubtedly, this study could be extended through additional fusions of the techniques and cognitions. The combination of different variables has different map visual effects (Robinson, 2019; Guo et al., 2018; Kraak, 2020; Sloan, 2018; Yim et al., 2016; Wood, 2012). Therefore, it is valuable for the study of Pan-maps representation to clarify the mapping relationship among variables, which remains the direction of our future efforts.

## 6. Conclusion

This study has two major strengths. Firstly, we take the unification of maps and map-likes as the research objects, and proposed the Pan-maps visualization framework that extends Kraak's "When-Where-What" frameworks to a "When-Where-What-Who" 4W framework and further specifies the representation variables of 4 dimension.

Secondly, we clarify the hierarchical relationship of variables and the role of each variable of Pan-maps. We categorized variables into basic variables and compound variables. For the purpose of visualization, basic variables are the essential variables of Pan-maps, which have atomicity and indivisibility. Through the combination of basic variables, compound variables with more complex functions can be formed and promote the development of Pan-maps visualization.

## 7. Acknowledgements

This work was supported by the National Natural Science Foundation of China (NSFC) under Grant [number 41930104 and number 42071366].

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