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A Model and Algorithm of Dynamic Map Expression and its Application

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Abstract

On the basis of summarizing the research results of visual variables, we define six dynamic visual variables of the map symbol in this paper. We analyze the related attributes of dynamic symbols, and then construct a dynamic map expression model based on symbols. A key technology to realize dynamic expression, the key frame transform algorithm is present in the paper. The cartography process of the urban population proportion dynamic change map of the cities in Shandong province are taken as an example to demonstrate the methods and process of dynamic mapping based on the above map dynamic expression theories and models, which includes base map digitization, sorting and processing of attribute data, adding the map elements, the creation of special dynamic effect such as color transform, continuous flashing and object moving, and realization of interactive function. Finally, the paper shows the dynamic map of sea level rising influence on Qingdao, the Typhoon Soulik traveling map and other dynamic map effect at the end of the article.

Keywords: *spatial visualization, dynamic expression model, key frame transform algorithm, dynamic visual variable, interactive function*

1. Introduction

Map is the second language of geography and a graphical symbol model of geoinformation, which uses ikonic and vivid color graphic symbol to convey the spatial information to people by abstracting the real world correctly and appropriately [1, 2]. Map is also a tool of spatial cognition, and it is the only tool. It can find the spatial existence relationship between the things and the objects in the visual moment [3]. Map in the traditional sense is usually shown in static form, which represents the information of geographic entities at a certain moment in dynamic environment. But objectively, the geographic space is always changing. In addition, the request of the people for refinement, imagery and dynamic of map service rise continuously. Thus the dynamic map expression has become a new form of expression and research content in Cartography. The dynamic map expression is a kind of map expression method [4] that can help to obtain dynamic visual perception of spatial position and attribute characteristic of geographical entity from the view of the user reading maps. And it can use the multi-dimensional visualization model and dynamic map symbols, etc. to express a continuous changing process of geographic entity, ordynamic natural phenomenon and social economic phenomenon [5, 6]. With the development of the computer interaction technology [7] and the improvement of the spatial information visualization theory, the dynamic map expression has been developed and achieved a series of results.

Dong [8] discovered that, the efficient value of color, size and framerate on large format display is less than the value on the small format display, which suggests the frame rate on the small format display should be reduced. This study is of help in the design of dynamic map symbols for geographical information visualization. Cheng [9] put forward a design method of dynamic map symbols based on rich Internet and achieved the dynamical substitution of point symbols on the map published by ArcGIS Server with ArcGIS API for Flex. Possum [10] proposed beyond the sharp distinction of animated and static maps by combining the qualities of both in one new representation method and put forward the concept: semi-static animations.

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The core idea of the concept is to make all information visually available to the user at any given time of the animation. Duarte [11] presented a new tool to produce ground water vulnerability to pollution dynamic maps under a GIS open source environment. And this application was developed within the QGIS software.

However the visual effect of dynamic map expression is restricted by key frames and the number of frames. That is, the more the number of animation frames is given, the more continuous without jumping the visual effect is, but the greater the amount of data is. So the selection of key frame is particularly important. Simultaneously, the existing research results are in the lack of systemic results for symbolic models of dynamic map expression.

2. Materials and Methods

2.1. Construction of Dynamic Expression Model Based on Symbols

2.1.1. Dynamic Visual Variable

Bertin [12] has put forward eight basic visual variables of map symbol, which are shape, size, direction, lightness, density, structure, color and position. In order to adapt to the dynamic map expression and increase the dynamic characteristics of symbols, we define dynamic visual variables of symbol including start time, duration, speedof change, and frequency of change, order of change and rate of change on the basis of summarizing the result [13, 14] of dynamic visual variables. It is important to note that the first four variables are single symbol visual variables and the last two variables are group symbol visual variables. And the end time of the variables can be derived from the start time and duration.

2.1.2. The Dynamic Symbol Attributes

The feature of geographical entity includes four aspects: attribute feature, geometry feature, position feature and topology feature. The geometry feature which includes geometry shapes and size may be sorted in attribute feature with respect to position features, but it is classified as a single item to emphasize the geometry attribute. Dynamic features of geographical entity [15] means to be the changes of the above four features, that is the change feature of attribute feature, geometry feature, spatial position (movement) feature and topological relation feature.

Dynamic visual expression based on symbols is to use graphics snapshot within recognition limit of human eyes to simulate and display dynamic feature of the change and movement of ground entity and phenomenon in a certain period by choosing appropriate time resolution. That is, using the overlap of the eight basic visual variables and the proposed six dynamic visual variables displays the changes of attribute features, geometry features, position features and topology features of geographical entity.

2.1.3. Construction of Dynamic Expression Model Based on Symbols

The model uses the time interval of less than 0.1 second as a unit of time (time frame) to control the process of animation referencing the thought of animation design in the Flash. Spatial feature of ground object phenomenon at different time point is expressed using map symbols and used as a key frame [16]. With the help of the persistence of vision of human in physiology and psychology, the pictures frame of the key frame and intermediate frame are played in succession according to chronological order and certain constraint rules, and the time relationship between the key frames determines the change order of the symbols. The transformation function among the key frames can be used in different change forms such as constant velocity change, acceleration change, deceleration change, period change. A dynamic expression model based on symbols is constructed, as shown in Figure 1.

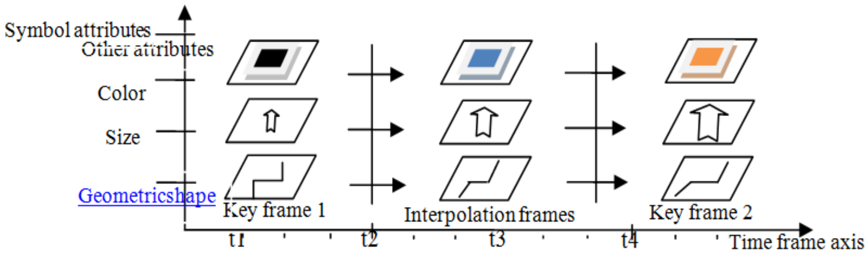

Figure 1. Dynamic Expression Model Based on Symbols

2.2. Design of Key Frames Transform Algorithm for Dynamic Expression

The transformation mapping among the key frames controls the interpolation generation of the intermediate frame of the symbol [12], which is the key to achieve dynamic symbols expression. The symbol feature of each key frame includes attribute feature, geometry feature, position feature and topology feature. The transform algorithm of the key framesat particular moment is designed based on the dynamic expression model of symbol, which is as following.

Firstly, set C for symbol frame at intermediate moment and judge if there is a time Ti which meets $T_i \leq T_c \leq T_{i+1}$, $\mathrm{i} \in [1, \mathrm{END}-1]$, and if there is no time to meet the conditions, that means the symbol frame C is beyond the change range of the current symbol and cannot generate the intermediate frame. Then calculate the time proportion of the position of intermediate frame $\mathrm{t} = \frac{(T_c - T_i)}{(T_{i+1} - T_c)}$, put it into symbol rate dynamic model $\mathrm{K} = \mathrm{F(t)}$, and calculate the weight coefficient K.

Several typical dynamic models of symbol rate are presented here for the request of different rates:

(1) In the case of symbols changing first rapidly and then slowly, use the symbol rate dynamic model $\mathrm{k} = \mathrm{t}^{\frac{1}{a}} \mathrm{a} \in (2,3,4,5, \ldots)$, and in which the larger “a” is, the faster the symbol changes on early stage.

(2) In the case of symbols changing first slowly and then rapidly, use the symbol rate dynamic model $\mathrm{k} = t^a$, $\mathrm{a} \in (2,3,4,5, \ldots)$, in which the larger “a” is, the faster the symbol changes on later stage.

(3) In the case of symbols changing at a constant speed, use the symbol rate dynamic model $\mathrm{k} = t$, and where “t” and “K” should meet the following conditions:

$$\begin{cases} K = 0, \mathrm{Tc} - \mathrm{Ti} = 0 \\ K = 1, \mathrm{Ti} + 1 - \mathrm{Tc} = 0 \\ 0 \leq K \leq 1, 0 < t < 1 \end{cases}$$

Secondly, for the non-geometrical attributes, calculate all the non-geometrical attributes of intermediate frame after getting the weight coefficient Kaccording to the attribute transformation formula:

$$\mathbf{Attribution}_c = (\mathbf{1} - \mathbf{K}) \times \mathbf{Attribution}_i + \boldsymbol{K} \times \mathbf{Attribution}_{i+1},$$
$$\mathbf{Attribution} \in \{\text{颜色，大小，等非几何属性}\}$$

For the geometrical attributes, generate the geometrical attributes of intermediate frame C by using two-dimensional Murphy Transformation according to the geometrical attributes of the two frame before and after intermediate frame C: Gigand Gi+1. For illustration purposes, it is thought that the complex graphics can be obtained through the combination of the Euclidean geometry geometric point, line and plane three basic graphics. The intermediate graphic between two different graphics can be generated by the graphics transformation matrix. In the matrix element $\mathrm{M(i,j)}$, i and j represent the original element types two adjacent frames. And their corresponding functions are the corresponding graphics transformation functions.

The implementation of algorithm has consistency. The specific process is as follows.

1. Judge whether the geometric attributes Type_Giand Type_Gi+1 of adjacent two frame graphics are same or not. If they are different, unify graphic types by unifying the point to line or polygon, the line to polygon. It is considered that the point is the line or polygon whose nodes are coincident, and line is the polygon whose two nodes are coincident.

2. Make Gi and Gi+1 have the same number of nodes through uniform interpolation and establish one-to-one mapping relationship.

3. Use interpolation formula $G_c = (1 - K)G_I + K \times G_{I+1}$ separately for each pair of mapping points to get the geometrical attributes of intermediate frame.

3. Experimental Results

Application examples of graphics dynamic expression is stated in the part. We takes the making process of the dynamic change map of the proportion of urban population of cities in Shandong Province from 2000 to 2004 as an example, and introduce the basic method of dynamic map making by Flash MX3.

3.1. Digitization of Base Map

Digitization of the map can use different software. The map digitized using Flash MX3 can be used directly and the map digitized by other software such as ArcInfo、Coreldraw need to be transformed to the format that can be recognized by Flash MX3, then it will be imported to Flash MX3. Create a new movie clip element and named as the "subject" in Flash MX3, import the base map in JPG format into the bottom layerthen load the vectorized maps of cities into corresponding layers and adjust its size and location to coincide with the base map.

3.2. Attribute Data Collation

The amount of urban population and rural population of cities in Shandong province five years from 2000 to 2004 is counted and input into Microsoft Excel form. The total population, the proportion of urban population and the chain growth rate in each year are calculated as shown in Figure 2. The numerical range of the proportion of urban population of citiesis also calculated (15%-52%) to reserve.

	A	B	C	D	E	F	G
1	CITY	YEAR	AGRICULTURAL POPULATION	URBAN POPULATION	TOTAL POPULATION	URBANIZATION PROPORTION	GROWTH PROPORTION OF URBAN POPULATION
2	Jinan	2000	3295516	2331027	5626543	41%	
3		2001	3178833	2511133	5689966	44%	8%
4		2002	2891778	2858303	5750081	50%	14%
5		2003	2853544	2972068	5825612	51%	4%
6		2004	2821216	3079552	5900768	52%	4%
7	Qingdao	2000	4142936	2923454	7066390	41%	
8		2001	4083097	3021778	7104875	43%	3%
9		2002	4025200	3131337	7156537	44%	4%
10		2003	3907200	3299606	7206806	46%	5%
11		2004	3801605	3509623	7311228	48%	6%
12	Zibo	2000	2334567	1745307	4079874	43%	
13		2001	2309252	1795717	4104969	44%	3%
14		2002	2344636	1775712	4120348	43%	-1%
15		2003	2365703	1825651	4191354	44%	3%
16		2004	2306360	1843516	4149876	44%	1%

Figure 2. The table screenshot of urban and rural population of cities in Shandong province in 2000-2004

3.3. Adding Map Elements

1. Adding dynamic title. We put "subject" element into the scene in Flash MX3, and create a new layer and add the title "Dynamic map of urban population proportion in cities of Shandong Province from 2000 to 2004" in a suitable place. At the same time, we write the city name on each administrative region. By clicking on the tool T on the toolbar, we can add text and also adjust the text format through property bar. After the above steps, the map is shown in Figure 3. Then, we insert the key frames between the 5th and the 25th frame on the time axis of title layer, and select the first frame, zoom out the proportion of the title center position to a certain extent and then create tween animation between the first frame and the fifth frame.

Figure 3. Vectorizationof base map after adding map elements

2. Creating and adding the legend. We create graphic element named "ruler" and draw a ratio scale of urbanization by rectangular drawing tool and gradient color tool. In this example, the urbanization proportion scale is divided into 4 big levels and 39 small levels. On the premise of scientificity, the color changes of each administrative region should be taken into account. The colors should not be in the same color gamut, otherwise it makes the whole map into a color and difficult to distinguish the color. And the map should notuse too much color gamut, otherwise too messy. For the other legends such as compass, scale and seat of government, wemay import the existing legend resources into resource library. After creating a legend layer, the needed legend resources will be put into the scene. Finally, we make them suit the maps by adjusting color, size and location.

3.4. The Creation of Special Dynamic Effects

1. Color transformation effect. Taking Jinan city as an example, it surbanization proportion in the five years are 41%、44%、50%、51%、52% respectively. We set the length of animation to 25 frames and insert a key frame for every 5 frames. Each frame corresponds to the change of ayear, and the color of each frame will be set to the corresponding color in the legend of urbanization proportion corresponding year. and then we create shape tween animation to realize the color transformation of administrative region. We create a new layer and a 25-frame long animation, also insert a key frame for every 5 frames and add the digital information of urbanization proportion to the layer. Similarly, we create the dynamic maps of all the administrative regions. The results are shown in Figure 4.

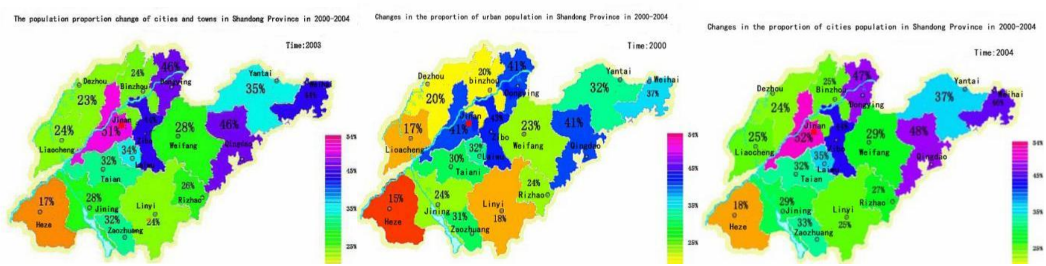

Figure 4. Dynamic map effect

2. Continuous flashing effect. The design scheme is that when the urbanization proportion of an administrative region in a year is higher than the given threshold, make the map flash firstly for attention and then play the subsequent animation. The urbanization proportion of Jinan from 2001 to 2002 in the example rises from 44% to 50%, since we insert the key frame between the eleventh frame and the twelfth frame and set the color transparency of the administrative region at eleventh frame to 60%. In this way, it will generate flashing effect when playing the tenth frame.

3. Objects moving effect. Various administrative regions involve two kinds of change in this example. The one is using the change of background color of administrative region indicates the change of urbanization proportion; The other is taking building icons expresses the total change of urban population. When the urban population number of a certain administrative region changes more than 10000, the building icons will increase or decrease.

3.5. The Realization of the Interactive Function

Create a new component named “pause” whose type is button. When clicking on the component, it is divided into 4 frames: “key up”, “pointer past”, “press”, “click”, which can also be drawn according to the requirements. The button “play” and “stop” are created in the similar way. After completing drag the buttons into the scene on a suitable place. Right click the “play” button to choose the action option and add the certain codes to the button. The user can realizes the simple interactive control of the dynamic map in this way. So far, dynamic map of urban population proportion in cities of Shandong Province from 2000 to 2004 has been completed.

4. Discussion and Conclusions

Based on the above constructed symbolic dynamic expression model, we adopt the key frame algorithm to select and process the key frames to better balance the visual effects and the amount of data of the dynamic map. And the effect of partial the dynamic maps produced is shown as follows.

Figure 5. Dynamic map of sea level rising influence on Qingdao

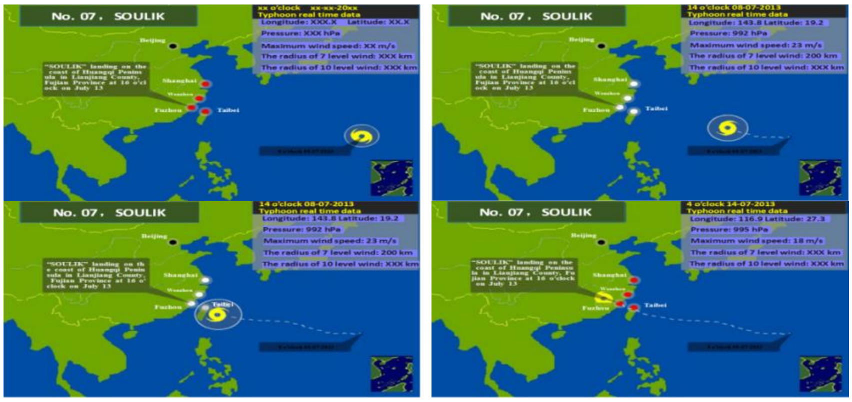

Figure 6. Typhoon Soulik advancing map

Compared with traditional static maps, dynamic map can reflect the continuous dynamic changes more effectively, and transmit more abundant geographical spatial information and attribute information that changed with time. It has stronger interaction and presentation and greatly expands the application function of the traditional static maps. This paper builds the dynamic map expression model based on symbol and designs the key frame transformation algorithm. Compared with the existing production methods of dynamic map, this result can improve the visual effect of dynamic map expression, effectively carry out the selection and transformation of key frames and reduce the difficulty of key frame selection. On the basis of the above theoretical study, the method and process of making dynamic map using generals of tware are demonstrated in detail by examples. The research in this paper will be beneficial to combine the dynamic map expression with the matic map and 3D expression, and promote the study and application of the matic dynamic expression and three-dimensional dynamic expression.

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