Research and Application of Two-peak Changing Law of Electronic Map Load

JIANG Nan*, Sun Qinghui*,CAO Yani*, Zhang Hao*, Gu Yuhang*

* Information Engineering University, Zhengzhou, 450052, China

Abstract. Electronic map load is one of the most important factors that influence the clarity, smooth and gradation of the multi-scale display; and is also an important indicator in multi-scale map representation modeling. All of these make the research of electronic map load more significance. This article analyzed differences of the map load variation between paper map and electronic map, using RGB values-based approach to obtain a large number data of electronic maps, explored two-peak changing law of electronic map load by making further research; discussed the curve shape and influencing factors of two-peak changing law of electronic map load. In the end, established a more scientific and practical electronic map multi-scale model, and has achieved a preferable experiment results.

Keywords: Electronic Map, Map Load, Two-peak Changing Model of Map Load, Multi-Scale Display Model, S-Style Curve Model of Map Load

1. Introduction

Map load, also known as the capacity of the map, is generally understood as the amount of symbols and annotation within the map border, it is measured by the number of symbols and annotation in unit area. Obviously, map load limits the map content; once the map symbol is explicit, the larger the map load is, the more the map content are(Zhu, 1980). It has been a long time since the concept of map load was defined, but the definitions are confined to concept, calculation method and magnitude range that given by paper map(Zhu 1980,Ke 1987, Zou 1991). So far, people prefer to S-Style Curve as the law of paper map load changing with scale variation(Wu 2008, Li 2006, Wu 2004). Many scholars developed researches on key scale of multi-scale display(Li, 2006), and automated map generalization(Wu, 2004) which are based on the changing law of s-style curve map load. In fact, under the circumstances of electronic maps, due to the change of the electronic map cognitive environment and usage method, there are many differences between electronic map load changing law and paper map load changing law. However, on the one hand, researches on the electronic map load changing law is still relatively few; on the other hand, electronic map load is the key factor that influence the clarity, smoothness and gradation of multi-scale display of electronic map, and also more an important index of the multi-scale display model. Therefore, in the following passage we steep from the practice, following cognitive rules of the electronic map, using mathematical statistical analysis and image processing technology, make quantitative analysis of the changing of electronic map load, explored changing law of electronic map load with the scale variation, and on this basis to establish a more scientific and practical electronic map multi-scale model.

2. Adaptive Analysis of S-style Map Load Changing Law Under Electronic Map Condition

2.1. The Definition and Characteristic of S-style Curve Map Load Changing Law

S-style curve changing law of map load is defined by calculating the load of different scales and interpolation, all of which are under the conditions of paper map and series map scale (1:10000, 1:25000, 1:50000, 1:100000, 1:200000, 1:500000, 1: 100 0000) , as shown in *figure 1* below(Li, 2006).

scale of paper map(ten thousand)	1:1	1:2.5	1:5	1:10	1:20	1:50	1:100
Load of paper map	3.7	7.3	12.1	17.5	19.4	22.6	23.3

Table 1. Map load of multi-scale paper map.

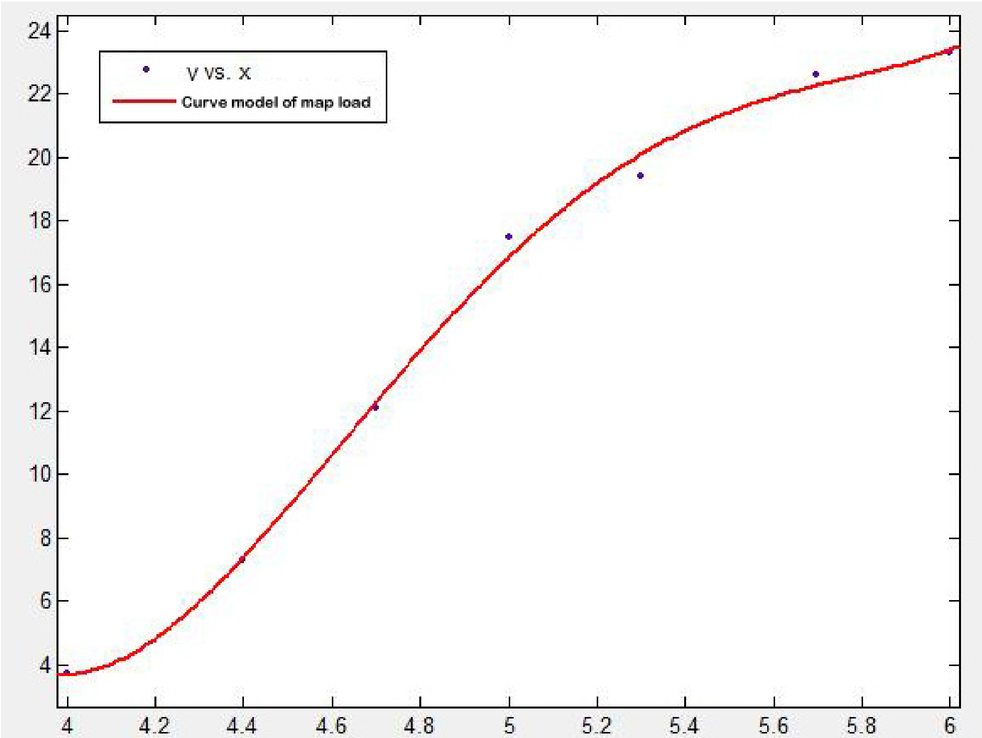

Figure 1. S-Style curve model of map load.

The definition and variation of S-style load have the following characteristics:

(1) The S-style curve is fitted from map load under the full-scale map. For series scale maps, the change of map contents and types of map feature of every scales is small, that is, elements such as residential areas, topography, water systems, roads, boundary, and so on, are shown to users all the time.

(2) From the large scale to small scale map, map load is increased gradually. For paper maps, when its geography features were downsized from large-scale map to small-scale map, the drawing is bound to be more and more crowded due to decreases of map area; that is to say, the map load becoming larger and larger. The changing of map load is in line with the S-style curve.

(3) Since the maximum load capacity of the paper is limited, map load changing with the map scale variation is a typical kind of restricted growth. Given that the clarity and legibility of map load is defined, the carrying capacity of the drawing is limited(Li, 2006).

2.2. Analysis the Trait of Changing Law of Map Load Under the Condition of Electronic Map

Many map researchers believe that the map load variation of electronic map and paper map were both present S-style curve(Jiang 2010, Bai 2009). However, through years of research and application of electronic map, I think that this conclusion is reasonable when it is used to specific map or partly map scales range, not suitable for full-scale map range. We think that variation of electronic map load value is mainly influenced by the following aspects:

(1) The electronic map using way is changing from passive to active. In electronic map, the expressed map content and application of electronic technologies are related closely, not only in the content which expressed on the map sheet. In addition, electronic map provide users with various way of map display methods to search what they mainly care about, those methods include stratification browse, amplify display, dynamic flicker, and so on. Since the map content can vary with the operation of different map user, it is necessary for us to make the map load under control and find the key scale to make sure the clarity and artistic of electronic map.

(2) Content of electronic map turn from changeless to diversification. When it comes to the topographic maps of scale series, such as paper maps, the main content of map changes little, and the variation range of paper map load value is small. Now, due to the variety of different applications and users, the content expressed in electronic map increase rapidly and the expression methods are various, On the other hand, thanks to the development of computer graphic and image technique, it is convenient for users to choose what they interest in, and the change of symbol system and annotation of electronic map is large; so, the variation range of map load value is relatively large.

(3) Electronic map scales range from partly scale to full scale. Research of paper map load mainly focused on topographic maps of the seven series map scale(in China). For electronic map, due to the advantage of zoom-less technology, studies of map load should transfer to full-scale range map; the more the map scale levels spans, the more complex influencing factors are. Currently, the national number of network electronic map scale can reach a scale levels of 20, which greatly expand the number of series scale map.

In conclusion, there is a great difference of map load changing law between the paper map and electronic map.

3. The Two-peak Changing Law of Electronic Map Load

In order to find the variation law of map load, we have done a lot of computation of muti-scale electronic map load and mathematical statistics analysis. Then, come up with the "Two-peak Changing Law of Electronic Map Load".

3.1. Calculation and Data Acquisition of Electronic Map Load

We calculated the load of electronic map area automatically, basing on geo-feature extraction of color elements on RGB, that is, using chromatic aberration of target color and background color as weights to involve in the calculation of area load. The method is:

$$La = \frac{\sum_{i=1}^{n} s_i}{S_{scr}}$$

In this formula, $s_i (i = 1, 2, \cdots, n)$ stands for the total area occupied by geo-features, S_{scr} stands for the total area of the screen.

In order to ensure the results more scientific, we analyzed electronic maps of the popular map-websites. In the full-scale range, using 18 levels of the electronic map as the sample, we sampled electronic maps of different levels from each map site, and obtained data of electronic map load within multi-scope scale, then calculated the map value as shown in *table 2*.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Google	0.15	0.15	0.20	0.21	0.21	0.30	0.33	0.29	0.38	0.43	0.55	0.42	0.44	0.41
bing	0.07	0.08	0.15	0.12	0.21	0.21	0.26	0.29	0.24	0.42	0.49	0.54	0.70	0.64
Baidu	0.08	0.06	0.12	0.15	0.15	0.15	0.18	0.23	0.38	0.47	0.68	0.51	0.54	0.40
Sogou	0.37	0.04	0.03	0.09	0.11	0.31	0.40	0.31	0.45	0.52	0.58	0.77	0.73	0.54
Tiandi	0.06	0.20	0.10	0.10	0.09	0.12	0.21	0.35	0.27	0.49	0.46	0.49	0.34	0.51
I want to	0.03	0.08	0.08	0.12	0.11	0.30	0.47	0.55	0.50	0.45	0.34	0.37	0.33	0.28

Table 2. Map load of different type electronic map on Beijing.

From *table 2* can we see, electronic map load of different map-sites have the same trend, but differences appear when it comes to a certain map scale, all this have relationship with the difference of data sources and visualization symbols.

3.2. Electronic Map Load Data Processing and Variation Curve Fitting

Taking the difference of different map websites and different regions into account, we made pretreatment of dozen sets of data as following: firstly, removed erroneous data; secondly, transformed the scale level to real scale and averaged the same scale data; finally, given that scale denominator span a larger scale, so I made a 10 logarithmic transformed of the denominator and got the electronic map load value of full-scale range, shown in *table 3*.

Scale	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0
Map load	0.25	0.33	0.35	0.36	0.34	0.29	0.22	0.17	0.11	0.13	0.15	0.19	0.22

Table 3. Mean value of full-scale electronic map load.

Use the data in *table 3*, we draw the map load curve that changing with the variation of scale, it can be more intuitive for our variation analysis of electronic map load. Here, we use Matlab to calculate the curve, the specific process is as follows:

(1) Data preprocessing

Data preprocessing is divided into two steps: isometric step interpolation and smooth processing. The interpolation uses target interpolation. In accordance with the above-mentioned interpolation, we process data from *table 3* with interpolation which shaft 0.1 of the step length, the result data are shown in *table 4*, the table contained 47 sets data totally, which improved the smoothness of the curve fitting effectively.

Tab.4 Map Area Load of Equal Step Interpolation

Scale	Load	Scale	Load	Scale	Load	Scale	Load
3.4	0.25	4.7	0.32	6	0.12	7.3	0.18
3.5	0.27	4.8	0.31	6.1	0.13	7.4	0.17

3.6	0.30	4.9	0.29	6.2	0.14	7.5	0.17
3.7	0.33	5	0.26	6.3	0.15	7.6	0.16
3.8	0.33	5.1	0.24	6.4	0.15	7.7	0.15
3.9	0.34	5.2	0.22	6.5	0.17	7.8	0.12
4	0.35	5.3	0.20	6.6	0.18	7.9	0.10
4.1	0.35	5.4	0.19	6.7	0.19	8	0.08
4.2	0.36	5.5	0.17	6.8	0.20	8.1	0.08
4.3	0.36	5.6	0.15	6.9	0.21	8.2	0.07
4.4	0.36	5.7	0.13	7	0.22	8.3	0.07
4.5	0.35	5.8	0.11	7.1	0.21		

Table 4. Map area load of equal step interpolation.

(2) Curve Fitting

On the basis of data interpolation and smoothing, after consulting of literature data and repeatedly trial we found that the higher the order of the polynomial, the more precise of the fitting. Therefore, we use the nine-order polynomials for curve fitting, *figure 2* illustrated this fitting curve.

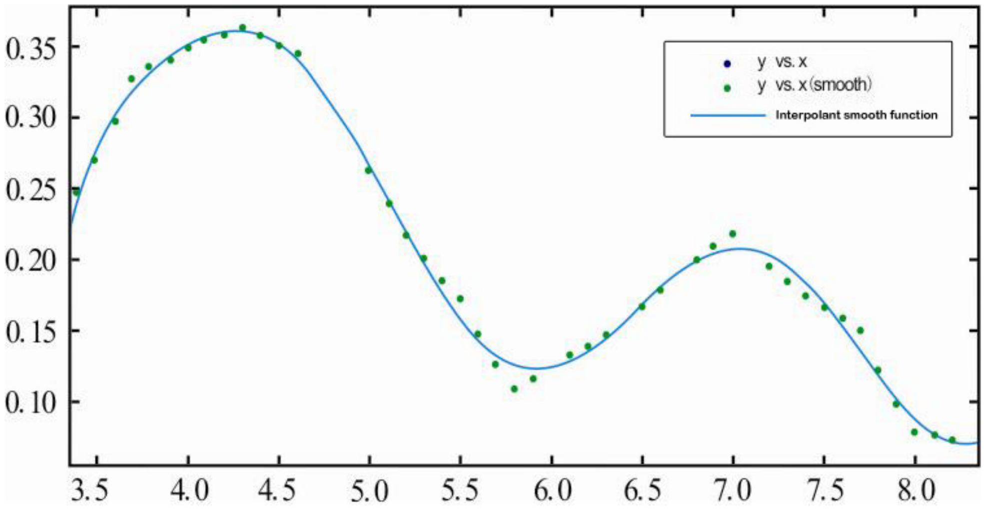

Figure 2. S-Style curve model of map load.

3.3. Analysis of Two-peak Changing Law of Electronic Map Load

It can be find from *figure 2*, there is large difference between the fitting curve and S-style curve, which has two troughs and two peaks, and it can be called two-peak curve. Our analysis following this curve draws some useful conclusions:

(1) Analysis of variation trend of electronic map load with the scale changing

Changing curve of electronic map load has two peaks and one trough, of which peaks are located at the point of $x=4.3$ and $x=7$ (i.e., scale 1:20,000 and 1:1000), and the trough is located at $x=5.9$ (i.e. scale of 1:8 million), and the first peak is higher than the second peak. When the map scale is greater than 1:20000, the map area load gradually decreases, and it showed a decreasing trend when the scale is less than 1:20000 but greater than 1:800000, while when the scale is less than 1:800000 but larger than 1:10 million, the map area load showed an increasing trend, the area load gradually decreases when the scale is less than 1:10million. Therefore, the overall trend is rendered as this: gradually increases until it increased to the maximum, then begins to decay; and then shows ups and downs in the process of decay.

(2) Influencing factor analysis of the peak

figure 3 and *figure 4* are Google map which are at the two peaks point of map load changing curve, is corresponding to 1:20,000 and 1:1000 000 respectively, and the corresponding load value was 0.36 and 0.22. The load value was relatively higher when compared with other map scales. In my opinion, this phenomenon is mainly due to the following two points:

1) There are many types of map features to be expressed. The study found that feature content of maps under these two scales is relatively higher, map of 1:20,000 scale shows various types of map features in detail, as well as important elements of POI(point of interest) features, in addition to detailed annotation information configuration. While map of 1:10 million scale has road of all levels, places of residents, many other geometry and annotation information in details. All of these cause a rapid increase of the map load.

2) The symbol style expressed has relatively larger area. Study also found that the expression of map elements under these two scales takes larger part of the sheet. For example, in 1:20000 electronic map, city blocks, roads and object annotation almost fill the entire map sheet. While in the 1:1000 000 electronic map, road network have a higher density compared with

other scales, and resident's annotation is more. As a result, the map load increases rapidly.

Figure 3. 1:20000 Google Map.

Figure 4. 1: 10000000 Google Map.

Figure 5. 1: 800000 Google Map.

(3) Influencing factors analysis of the trough

Figure 5 is a Google map of 1:800000; this map scale corresponding to the trough of map load changing curve. We found that 1:800000 maps only expressed the approximate position of city and distribution of main road, which have fewer elements, annotation and symbols. In addition, most of the residential areas were expressed in peripheral contour shape, and highlighted the orientation relationship between map area location and geographic features, that made the map load little.

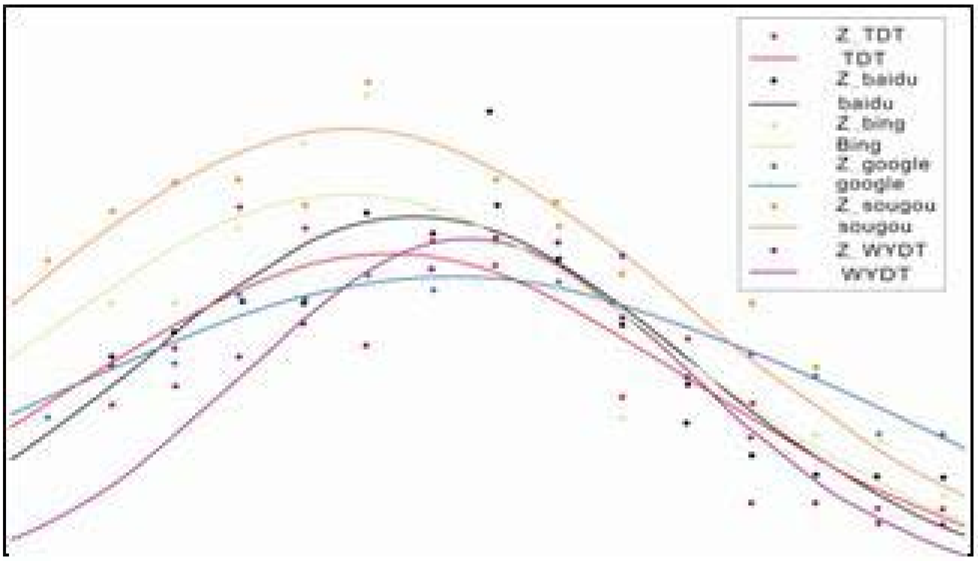

Figure 6. First peak law of different web maps.

(4) Curves analysis of electronic map load from different website

Although we get a common variation curve of electronic map load, however, for different electronic map products, their feature position is different. As shown in *figure 6*, comparing the first peak position of six websites map in map load curve, Sogou map and Bing map are approximately at 1:15000, Tiandi map and Baidu Map are approximately at 1:18000, "I want to" map and Google map are at 1:20000. It can be seen from *figure 6*, although the curve peak position is different, they are mainly at 1:20000, in line with the variation of the first peak.

(5) Electronic map load curve analysis of different density areas

Because of the uneven distribution, geographic features on the map are sparse in some places, but dense in other places. Even in the same electronic map products, map load of different regions can be different in the same scale yet. *figure 7* shows variation map load curve which coming from Beijing, Guiyang, Gansu Tianshui and Tibet Nagqu respectively. It can be seen from the figure that difference of load value is little for small scale, which are about 0.2. But difference is large at the larger scale part, the peak of Beijing is reach to 0.69 while that of Nagqu is just 0.14. This make the two peaks of the map load variation curve of dense area quite different, even the second peak is not obvious in fitting curve, but there are almost no difference in two peaks of load variation curve in sparse areas, and even the first peak value is smaller than the second peak. However, even in geographic features sparse region, variation of map load remain two-peaks.

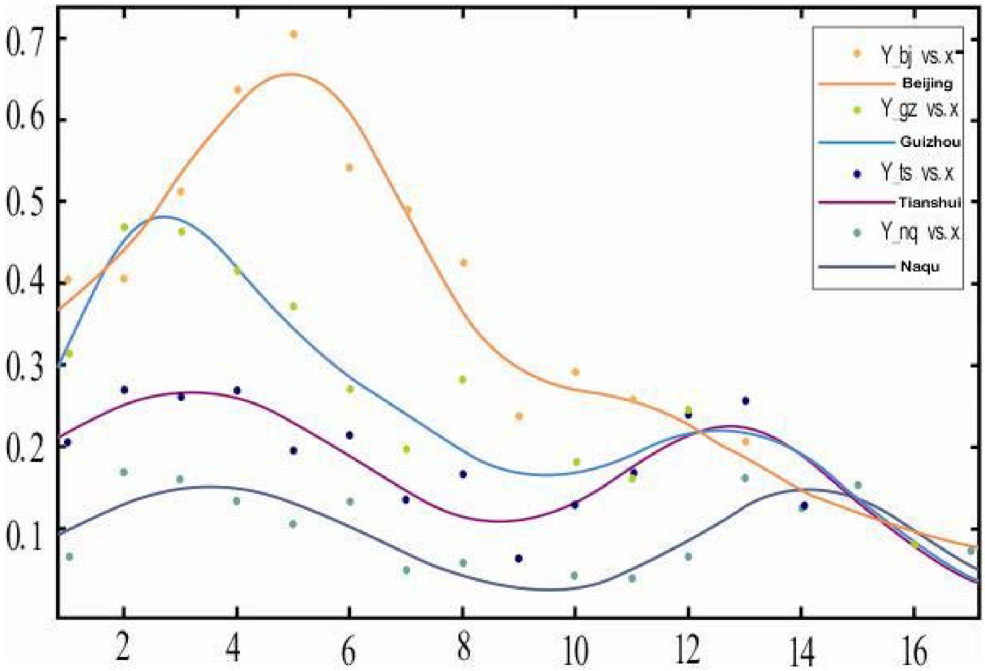

Figure 7. Electronic map load changing curve contrast of different feature density areas.

4. Two-peak Changing Law of Electronic Map Load Application

Two-peak changing law of electronic map load can not only provide comprehensive quantitative indicators of geo-features for automatic cartographic generalization(Qian, 2006), but also provides the calculating basis for determination of the content of electronic map. We try to establish a more scientific electronic map multi-scale display model, basing on electronic map load changing curve; and set the map display scale quantitatively, to provide a quantitative basis for determination of types and levels of map elements to be displayed, thus ensuring clarity of electronic map display.

The multi-scale display model is a mathematical model which can reproduce spatial distribution characteristics of geographic features on the screen display properly and clearly in a certain range of display scale (minimum scale for the maximum display scale). It is composed of a number display scales, and the process of the reproduction is accompanied with the changing of map scale. In other words, within a certain range of scale, only under the control of several displays scale can we ensure the display clarity, map content appropriateness and electronic map display level. While in the same scale electronic map is just drawing the rigid zoom, there is no substantial change in geographic features. The establishment of multi-scale model is to reach the critical scale, as well as to show the critical value of the scale (upper and lower screen scale) and the number of scales(Jiang 2010, Bai 2009).

Make 1, 2-order derivative for the results of curve fitting of *figure 2*, and determine the inflection point of the curve and the maximum curvature points. The X coordinate of the feature point that we got is like this.

$X_A = 3.4, X_B = 3.92, X_C = 4.48, X_D = 5.1, X_E = 5.78,$
$X_F = 6.48, X_G = 7.12, X_H = 7.7, X_I = 8.3,$

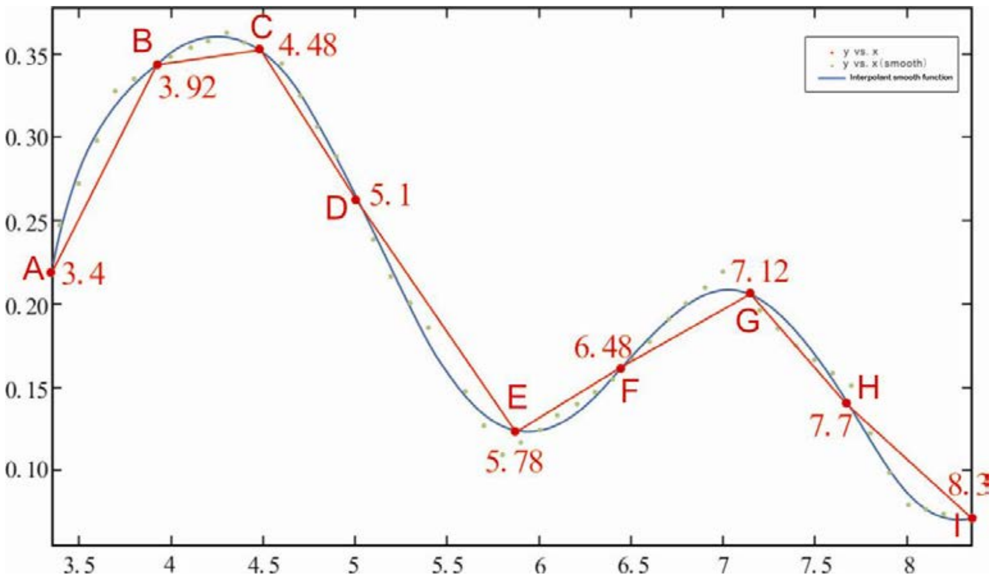

Figure 8. Primary points of map load curve.

Connect main feature points, after observing the curve in *figure 8*, we can find that lines between the point, of which are point A to I , which stand for main features, can reflect the approximate trend of the curve. But between some points the curvature difference is too obvious to reflect the distribution trend of the curve. So it is necessary to go to a steep further to determine the sub-important feature points, so we can summarize the characteristics of the curve much better. Besides the main feature points, Sub-feature point can further describe the detail characteristics of the curve. The way to determining sub-feature point is take the point on the curve which has the largest distance to the two main feature points as the secondary feature point, when the difference of the curvature of two adjacent main feature points is too large. If the second feature points have been determined, and the difference of curvature between the sub-feature points and the main feature points is still too large, we can do further determination about the sub-feature points, and so on. Under normal circumstances, the sub-feature point should be determined if curvature difference is more than 13. In accordance with the above-described method, our compute achieved three sub-feature points: $X_{AB} = 3.7, X_{DE} = 5.7, X_{FG} = 7$ shown as it is in *figure 9*. All of the twelve feature points summarize the distribution characteristics of the curve preferably. At this point, we have got 12 feature points already, and their X coordinates were: 3.4, 3.7,3.92,4.48,5.1, 5.7, 5.78,6.48,7,7.12,7.7,8.3.

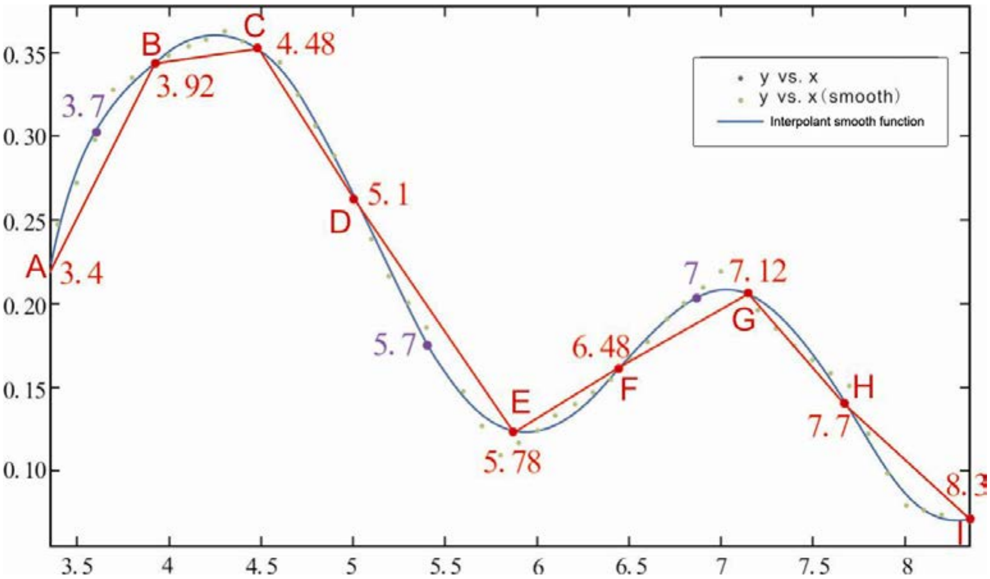

Figure 9. Primary and minor points of map load curve.

According to the feature points obtained by the above calculation, use 10 as the base and the X coordinate as index to calculate to obtain the denominator of the key scale, and do a certain trade-offs rounded. The result is shown in *table 5*.

X coordinate	3.4	3.7	4.02	4.48	5.7	6.0	6.48	7.12	8.3
denominator of the key scale(10000)	0.25	0.5	1	3	50	100	300	2000	20000

Table 5. Key scale value of multi-scale electronic map.

Determine 12 display dimensions according to the 12 key scales, and create a multi-scale display model, as it is shown in *table 6*.

Display scale	Range of Scale	Display scale	Range of Scale
U_1	$[1:200000000, 1:50000000)$	U_2	$[1:50000000, 1:20000000)$
U_3	$[1:20000000, 1:10000000)$	U_4	$[1:10000000, 1:3000000)$
U_5	$[1:3000000, 1:1000000)$	U_6	$[1:1000000, 1:500000)$
U_7	$[1:500000, 1:125000)$	U_8	$[1:125000, 1:30000)$
U_9	$[1:30000, 1:10000)$	U_{10}	$[1:10000, 1:5000)$
U_{11}	$[1:5000, 1:2500)$	U_{12}	$[1:2500, \infty)$

Table 6. Multi-Scale electronic map display mode.

The experiment conducted according to the multi-scale display models established based on this paper, which display full-scale navigation electronic map and the national boundary electronic map with multi-scale, has obtain a better display effect.

5. Conclusion

Under the condition of electronic maps, the changes range of electronic map scales, displayed content, displayed presentation and application characteristics, making the S-style model of traditional paper map load can not express changes and calculations of the electronic map load accurately in some extent. For this reason, we have expanded the traditional S-style model and studied the variation of electronic map load. Start from the calculation methods of electronic map load and practical data acquisition, we come up with the variation curve of two-peak changing law of electronic map load, as the basis for the establishment of a multi-scale electronic map display model under full-scale range, which achieved excellent results from practical application.

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