Research in Vector Spatial Data Compression for WebGIS

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Abstract This paper introduces author's work in compression to vector spatial data, which will be transported in Internet. On the basis of vector spatial data compression method, which is proposed by professor Li[1], the authors proposes next four innovation: (1) Not only integer, but also short data can be used to replace traditional double or float data. (2) The map data are mapped to a 'virtual screen', the width of 'virtual screen' is dispWidthPixel*maxEnlargeRatio / stepWidth ① . (3) In the mapping process, execute 'filtering compression' to pattern points of arcs (including polygon's boundary arc and line object arc). In the formula ① , if stepWidth=1, the compression has no loss in precise, if stepWidth>1, the compression loss precise. (4) 'Long segment adding point' to deal with exception of 'long edge', which offset of adjacent two points in an arc is larger than 127 in 'offset compression' to pattern points in arc. After these compressions, a map vector data may be compressed to 1/5 or less.
Keywords: WebGIS , vector spatial data , data compress

0. Introduction

Vector spatial data has the advantage of small quantity, high precision, easy to inquire and link with theme data. So, vector spatial data take a very important position in GIS (Geographic Information System) software. With Internet popular, WebGIS take interactive electron map to Internet. In Internet, people hope to view multi-scale map (from outline to detail) fast. But the data transport speed in Internet is slow in current. So, the techniques of vector map data compression are paid a lot of attention to by the developer of WebGIS.

Many years ago, in computer graphics, integer and short data are used as graphics coordinator to quicken the operation. Offset method is also used to compress image data. But in topography and cartographic, date precise of geographic location is required very accurate, often to 7-8 digit after decimal point. So, most GIS expressing spatial coordinate with float data even double data, only translate the coordinate data to integer or short data before drawing to screen or plotter.On the character of WebGIS application, Prof. Li Qi (2000)[1] proposes a idea of vector map compressing for WebGIS, (1) mapping double or float coordinate to int coordinate, (2) the begin point coordinates (x, y) of every arc (including the arc of area object boundary and the arc of line object) are stored in int, the following points coordinates (x, y) of the arc are replaced by coordinate offset (x-offset, y-offset) of adjacent two points, the offset can be stored as byte data. Because the main parts of a map data are arc points. By the method of Prof. Li, the data of one map can be compressed to about 1/8 of original data. The authors take the method in their WebGIS software, i.e. "Geo Windows" Web version. The authors have some new development in the work. This paper introduces authorial new points of view.

1. Replace Float or Double with Short

The authors think that in store and transport map vector coordinate for WebGIS, not only integer but also short data can be used to replace traditional float or double data. We know that the range of short is -32768 ～ +32767, or 0 ~65536. If map coordinates are mapped to short data, could we lose map precision? Let us analyses this problem. (1)When users view a map, they generally first view whole map, then enlarge it to detail. If size of computer screen is 800*600 pixels, short expressed data can let a map of 800*600 enlarged to 80 times without any precision loss. (2) From another point of view, many spatial data of WebGIS are digitized from traditional paper maps. If a paper map's width is 1000 mm, 1 mm is divided to 10 map units (digitized precision is only so), the total map width is 10000 units. If width of a paper map is 6000mm(rarely so large map), the map total width is 60000 units, it is still smaller than short data range 65536. Obviously, for displaying a single map, short data can meet most WebGIS needs. To map coordinates of expressed by longitude and latitude, precision will not loss obviously in mapping transform. When an area is made up of thousands of maps, we can add an offset in head of every map. In practice, the map data can be stored and transported by short, when reached to client, the data are added a offset and transformed into int. By this way, even for many maps displaying, enlarging and panning, there will be no problem.

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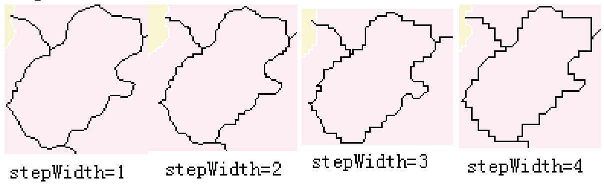
2. Mapping Range

Mapping is transforming a spatial point, which is expressed by float or double data in original geo-coordinate (or map-coordinate), into a spatial point, which is expressed by short data in a virtual screen. The arithmetic is similar to draw on a computer screen, but it is drawing on a virtual screen (actually is stored to a array of arc). After mapping, virtual screen is expressed by short data, the maximum range is -32768 ~ +32767 or 0~65536. Need virtual screen to be set maximum range of short? Answer of the authors is no. It can be seen that ratio of cutting down on points in "filtering compression" to arc points is inverse ratio to virtual screen size. The smaller of virtual screen, the more points are cut down on, the higher of compressing ratio is and the more precision lose, vice versa. If virtual screen is larger enough, "filtering compression" can't cut down on any point, compression ratio of 'filtering compression' is zero. How to determinate range of virtual screen? One uttermost is client screen range of displaying map as virtual screen range. In this way, ratio of data compression is very high, but when map is enlarged, obvious saw-teeth (or steps) will appear in the arc. Another uttermost is setting virtual screen range as -32768～+32767. If the range of map displaying is 600*600 in client computer screen, when the map is enlarged to 100 times, no saw-tooth or step appears in the arc, i.e. no precision is lost. Generally, system has some limited, couldn't allow user to enlarge unlimited, when enlarged to a fixed ratio, can't continue enlarging or system calling maps of next grade. In most case, this maximum enlarging ratio is far smaller than 100. When the maximum enlarging ratio is far smaller than 100 (such as 16), if set virtual screen range to -32768 ~ +32767, it will has great waste to "precision", in other word, there are many points, which are transported to client, will never be used. In the case of slow transport speed and long waiting time, it is necessary to balance in speed and precision. Sometimes, it is needed to reduce precision to exchange faster speed, i.e. it is accepted that arcs have some saw-teeth in the maximum enlarge ratio. Since pixel is basic unit of map, no matter curve or incline beeline, enlarging to pixel grade, saw-teeth will appear in arcs. When width of step is one or two pixel, it is not ease to be distinguished by naked eye, when width of step reaches 3 pixel, naked eye can distinguish it, when reached to 4 pixel, the step or saw-teeth are very obvious even by naked eye. Figure 1 is a part detail of a 1:4000000 map in maximum enlarging ratio of 16 times (When larger than 16 times, it will call 1:1000000 map). In the enlarging ratio of 16 times, if stepWidth is 1, there is no saw-tooth, else if step is 2, there is no obviously saw-tooth, else if stepWidth is 3, there is saw-teeth appear in arcs, else if stepWidth is 4, the



Smooth case of different setpWidth (Figure 1)

saw-tooth of arc is very obvious. If considering when enlarged maximum ratio, next grade (1:1000000) map will be called immediately, if client could bear with the step of 4 pixels in maximum enlarging ratio (when enlarging ratio smaller than 16, the step width of saw-tooth is smaller than 4 pixels). By filtering point, the number of the map arc's point may be reduced 47.5%, it will reduce near a half of waiting time. So, the saw-tooth has its value. The authors propose a formula to calculate virtual screen width as follows:

virtualScreenWidth
=dispWidthPixel*maxEnlargeRatio/stepWidth①

Here:
virtualScreenWidth: virtual screen width of mapping
dispWidthPixel: client screen displaying width pixels.
maxEnlargeRatio : maximum enlarging ratio.
stepWidth: step width of saw-tooth in maximum enlarging ratio

Calculating formula of virtualScreenHeight is similar to formula①.

3. 'Filtering Compression' on Virtual Screen

When the mapping range is determined, taking the mapping range as a virtual screen can do filtering compression. The theory base of 'filtering compression' is that in original map data, the pattern points in arc are very dense, when mapping them to virtual screen, it is so dense that several following points in one arc are fall to one pixel of the virtual screen. In one arc, these following points which are fall to the same that pixel, only one is needed, others is redundant, since they has no contribution to increase fine within the maximum enlarging ratio. The redundant points should be cut down. 'Filtering compression' is to cut down these redundant points. The method of 'filtering compression' is very simple, it is only needed to compare every new point, which could be added to the arc point string in mapping to the virtual screen if the point has different virtual screen coordinate with last added point, the new point will be added to the arc point string, otherwise, the point will be thrown away, i.e. not being added to the arc point string. The filtering is an effective way to compress vector arc data. In the formula ①, if stepWidth is 1, the filter has no loss in precision, else stepWidth larger than 1, the filtering has loss in precision. People can make a selection in fine and speed. This is an example, a Chinese map, the total point number of the all arcs, which includes the arcs of polygon boundary and the arcs of line object, is 598483. If the display range of a map is 600 pixels in clients, the maximum enlarge ratio in client is 16, in maximum enlarging ratio, step widths of arc saw-tooth give 1,2,3,4, calculated the width of the virtual screen of the on the formula ① are 9600、4800、3200、2400. The numbers of the residual points are 594561, 485234, 382087 and 313924. The point which are filtered is 3922, 113249, 216396, 284559. The compression ratios by the different stepWidth in filtering are 0.7%, 18.9%, 36.2% and 47.5%, as show in the table2. The map displaying effect is show in Figure 1.

Step Width	Virtual Screen Width	Left point number	Reduce point number	Compress ratio
0.4	24000	595977	2506	0.4%
0.8	12000	595335	3148	0.5%
1	**9600**	**594561**	**3922**	**0.7%**
2	**4800**	**485234**	**113249**	**18.9%**
3	**3200**	**382087**	**216396**	**36.2%**
4	**2400**	**313924**	**284559**	**47.5%**
8	1200	186424	412059	68.9%
16	600	106651	491832	82.2%
32	300	60891	537592	98.6%

Table1. The Relation of step width, virtual screen width, Left point number, Reduce point number and compress ratio

‘Filtering compression’ can be used in draw on screen too. Compare operation (‘if ’ operation) in filter point to construct array of polygon boundary or line object needs spend some time, but it can reduce more draw operation. We know that computer has more fast speed in ‘if’ operation than draw operation, so ‘filter point’ operation can improve displaying speed.

4. ‘Long Segment Add Points’ to Deal with Exception in ‘Offset Compression’

Prof. Li giving ‘offset compression’ is based on the fact that after mapping in virtual screen, the distance of two connected points in map’s arc (including polygon boundary and line) are not large. Most of them are smaller than 127. The basic thought of ‘offset compression’ is that for a arc, after mapping into virtual screen, begin point (x, y) is need recorded, the other following points only the offsets in two connected points are recorded, i.e. except begin point, two bytes can express a pattern point in an arc. In this way, it can reduce data quantity to 1/2 (short to byte) or 1/4 (int to byte) on the base of double mapping into int reduce 1/2. Because most to data are come from arc (including polygon boundary and line), ‘offset compression’ is a very effective way to reduce data quantity. But some exceptions should be noticed in use ‘offset compression’, some offset in two following points of an arc may be larger than 127 or less than –127, such as or bus route or polygon which map boundary as its boundary. These exception segments may be only a little, but if not taking especially protected method, these exception points may induce map displaying into mess-up in. So the authors propose ‘long segment adding points’ to deal with the long segment which larger than 127. ‘Long segment adding point’ is adding some points into a long segment make the long segment to several short segments witch every segment is shorter than 127. It may be need to increase some points, but the long segment, which need to deal with, are few and far between. So, after mapping into virtual screen, in the same time of ‘offset compression’, do ‘long segment adding point’, the increasing data is far less than reducing data.

5. Effect of Compression

In the example, original point data is float. The map is composed of 5 files, including arc points, arc index, topology, line, polygon and annotation. The total size of the file is 1363,401 byte. The authors regroup and compose them, then write them to a new file. In the compression, the methods of ‘short replace float’, ‘filter compression’ and ‘offset compression’ are used. The width of virtual screen, size of compressed file, compression ratio, and possible understanding for the width of virtual screen (dispWidth* maxEnlargeRatio /stepWidth) are show in table2.

VirtualScreenWidth	File size	Compress Ratio	Width*Ratio/ stepWidth
300	55,295	95.95%	600*1/2
600	82,061	93.99%	600*2/2
1200	119,659	91.22%	600*4/2
2400	**185,461**	**86.40%**	**600*8/2**
3000	**213,551**	**83.29%**	**600*10/2**
4800-	**276,173**	**79.74%**	**600*16/2**
9600	**284,466**	**79.14%**	**600*36/2**
12000	284,517	79.14%	600*40/2
24000	284773	79.13%	600*80/2

Table 2. Relation of screenWidth and fileSize

When the width of virtual screen range varies from 300 pixels to 24000 pixels, the size of compressed files varies from 55295 bytes to 284517 bytes. The smaller of the virtual screen range, the smaller of the compressed file size is. When the width of virtual screen range reaches to 4800, the size of compressed file increases very small. 4800 of virtual screen width means that if width of client screen display map is 600 pixels, enlarging ratio is 16 times, the step of saw-tooth in arc is 2 pixels, just show in figure2

Firgue 2. virtualScreenWidth=4800, dispWidthPixel=600, enlarging ratio=16, step of saw-tooth in arc=2 pixels

6. Conclusion

The authors believe that in current Internet transport speed, too slow response is a restriction to WebGIS application. To improve response speed, an important way is decrease transport data in Internet, i.e. compressing vector map. The effective way is mapping traditional point coordinator from double or float into short type virtual screen, the width or height of virtual screen is calculated as:

Width=dispWidthPixel*maxEnlargeRatio/stepWidth

In the process of mapping, 'filter compression' and 'offset compression' are done, to exceptional long edge being deal with by 'long edge adding point'. After these operations, the size of map file can be compressed to less than1/5. After the map data are transported to client, the first operation is comeback offset arc data to normal arc data. In this way, the data can be largely compressed, and has not disturbed to displaying and inquiring.

Next points should be noted. (1) Calculating virtual screen width in 'filter compression', if step<=1, there is not precision loss, if step>1, there is precision loss. (2) There is not precision loss in 'offset compression'. The method of 'long segment adding points' deals with a small quantity exception of long segment which offset larger than 127. When virtual screen width set to too large, or too many long segment (such as regular bus route map or architecture plan map), 'offset compression' has not effect of compression, because too many long segment may counteract reducing quantity in 'offset compression'. (3) No matter 'filter compression' or 'offset compression' has not compression effect to data of annotation, index and topology. (4) Mapping map coordinate form double or float to short has compression to coordinate of annotation, but has not effect to content of the annotation.

Reference

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