An Anti-aliasing Algorithm Suitable to Map Publishing Symbol

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ABSTRACT On the basis of analysis of various algorithms, an anti-aliasing algorithm called brush method was presented, which is suitable to map publishing symbol. After introducing the basic principle and implementation of brush method in detail, the result and efficiency were evaluated through experiments.

KEYWORDS aliasing; anti-aliasing; map publishing symbol; brush method; resolution

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Introduction

In computer graphics, displaying a continuous graphic (e.g., straight line, broken line, Bezier curve and ellipse) on the raster screen needs discretizing the continuous graphic to match with the discrete pixel of the screen. The information distortion caused by using discrete quantity to show continuous quantity is aliasing, while the technique to reduce or eliminate this kind of distortion effect is anti-aliasing[1,2].

Owing to the existence of aliasing, there are two obvious shortcomings of graphics shown on the computer screen: (i) except horizontal line, vertical line and lines with 45° angle, at the edge sawtooth will manifest themselves while most of graphics are displayed; (ii) they can only display the graphics whose width are the integral multiple of the size of the pixel, for the disintegral multiple graphics, they are solved by approximate integral multiple. For the publishing system seeking for "what you see is what you get" and symbol precision, the two problems should not be neglected. It is a pity that, at present, the general publishing systems (e.g., Illustrator, Freehand, Crowldraw, Photoshop and Word, etc.) all adopt anti-aliasing technique when displaying the graphics, while some Chinese and foreign common map publishing system and GIS system (e.g., Microstation, MapGIS, Founder Mirage, ArcGIS, MapInfo, etc.) neglect the problem when displaying the map.

1 Common anti-aliasing method

Since Crow firstly put forward aliasing problem and gave an anti-aliasing method in the computer graphics, many anti-aliasing methods have come into being. According to different algorithm principles, common anti-aliasing methods can be divided into two categories: (1) improving the resolution, namely adding sampling point, which is also called supersampling and post-filtering; (2) regarding pixel as a limited region and carrying out regional sampling are also called pre-filtering[1,2].

1.1 Improving resolution

According to sampling principles, aliasing is a kind of information distortion resulting from insufficiently sampling, the most direct method to eliminate the aliasing is to add the number of sampling point, that is to say, to improve the resolution, including physical resolution and log-
1) Improving the physical resolution is to improve the display resolution. Obviously, the higher the display resolution is, the more delicate the display graphics are, the aliasing condition will be relieved. However, at present, the resolution for most of the displays is 72 dpi, few displays resolution can exceed 150 dpi, this shows that the ability to eliminate aliasing through improving the physical resolution is considerably limited.

2) Improving the logical resolution means carrying out a further subdivision for each physical pixel of the display and getting several logical pixels, which is equal to improving display resolution logically. When scanning and converting the graphics, colored condition of each logical pixel will be determined (for each logical pixel, there are only two conditions, i.e. colored and uncolored condition). And then according to the colored condition of all logical pixels in each physical pixel, making use of the weighted average and non-weighted average method we can get the corresponding color value of physical pixel. Fig. 1 illustrates the basic principle of improving logical resolution (taking straight line as an example), of which, Fig. 1(a) expresses the calculation course, and Fig. 1(b) expresses the displaying result. The rectangle table formed by horizontal and vertical heavy line in figure expresses the real pixel on the screen, while the rectangle formed by fine dotted line expresses the logical pixel of improving resolution. The small circles in Fig. 1(a) expresses the condition of the logical pixel which shall be colored, big circles in Fig. 1(b) expresses the colored condition of the physical pixel, their brightness can be got through calculating the non-weighted average value of logical pixel in each physical pixel. Of course, the weighted average can be also carried out. The basic idea of weighted average is that the colored condition of different logical pixels has a different influence on the brightness of the physical pixel. The influence of logical pixel approaching to the center of physical pixel is large, while the influence of those at edge is small.

![Fig. 1 Principle of higher logical resolution](image)

1.2 Regional sampling

In the algorithm for improving the logical resolution, the graphic is supposed to be an ideal line without width in the sense of mathematics. However, in fact, the lines shall have width. Under many situations, they can not be neglected, especially in the map publishing system, the width of lines has a great significance. For example, for the same brown lines, the width with 0.1 mm expresses intermediate contour, and the width with 0.2 mm symbolizes index contour. In view of the width, lines shall be regarded as a polygon in the sense of mathematics, while pixel is a small region (generally, it is a square region). When carrying out the scanning and conversion of the lines, to determine the colored condition of the pixel, the space relationship between square region formed by the pixel and polygon formed by the lines shall be calculated. If the square region formed by pixel is off the polygon formed by the lines, this pixel will
not be colored; if the square area formed by pixel is contained by the polygon formed by the lines, this pixel will be colored and underlined; if the square region formed by the pixel intersects with the polygon formed by the lines, to the pixel the intermediate color will be added.

The brightness of intermediate color added is determined by their intersected section, it is the pixels of the section that produce anti-aliasing effect.

Fig. 2 illustrates the basic principle of regional sampling. Each coordinate grid stands for a pixel region, polygon formed by the middle heavy line expresses the straight line section with the end points (1,1) and (7,5) and the width with 1.5 pixels (broken, curved line and other lines are similar). As for the pixel (0,0), because it is separated from the polygon, it is not colored; as for the pixel (1,1), because it is contained by polygon, it is underlined and colored; as for the pixel (1,0), because it is intersected with polygon, to it the intermediate color is added, the colored brightness of intermediate color is determined by the intersected section (expressed with hachure in Fig. 2).

2 Brush method

2.1 Principle of brush method

It can be seen from the analysis of last section that anti-aliasing method of improving resolution is very simple and easy to realize, but it has two disadvantages: (1) through improving different multiples of resolution aliasing can only be relieved to a certain extent, the effect of anti-aliasing is limited; (2) regarding the line as ideal line in mathematics can not solve the problem of line width, by contrast with it, using the method of regional sampling can achieve more ideal anti-aliasing effect and facilitate solving of problem of line width, but it has the shortcomings of large amount of calculations and being hard to realize especially when handling the curve, this shortcoming is much more obvious (need to calculate intersection of a square region and an irregular region).

As the map publishing symbol, the lines must have the exact width, so anti-aliasing by way of raising resolution can not meet the requirements. In addition, drawing speed and its display quality of the map publishing symbol are equally important, the algorithm of anti-aliasing shall be as simple as possible on the premise of guaranteeing the display quality. In this way, it is unsuitable to apply the two kinds of common anti-aliasing algorithm mentioned above to the map publishing symbol directly. Through combining above-mentioned two kinds of algorithm, an anti-aliasing algorithm applicable for the map publishing symbol is proposed in this paper, it can be called “brush method” (be equivalent to brushing all over along the center line with a circular brush).

Fig. 3 illustrates the principle of brush method, this figure refers to a random curve \( f(x,y) \), line width \( w \) is 1.5 pixel, the head point and end point of the line are(1,1) and (5,5) respectively. The anti-aliasing processing of \( f(x,y) \) with brush method concludes the following three steps: (1) improving the logical resolution of the display, carrying out the scan conversion of ideal
central line of the graphics under high logical resolution, then getting the discrete logical pixels that describe the ideal central line, they are expressed with small filled dot in Fig. 3 (a); (2) move a circular “brush” along the discrete logical pixel on the ideal central line, center of circle coincides with each discrete logical pixel, the diameter is the line width, the pixel falling into any circular “brush” is marked as “selected”, it is expressed with small blanked dot in Fig. 3 (a) (only the “selected” logical pixel in physical pixels between (0, 0) and (5, 5) is marked in Fig. 3 (a)); (3) calculate the coloring situation of the physical pixel according the “selected” situation of the logical pixel in each physical pixel. If no logical pixels are “selected”, the physical pixel shall be colored with background color; if all the logical pixels are “selected”, the physical pixel shall be colored and underlined; if partial logical pixels are “selected”, the physical pixel shall be colored with intermediate color. The calculating result is shown as Fig. 3 (b).

![Fig. 3 Principle of brush method](image)

**2.2 Concrete implementation of brush method**

2.2.1 Obtaining discrete logical pixels describing ideal center line under high resolution

Firstly there is need to indicate the increased multiple \( R \) of logical resolution. The larger the \( R \) is, the more the grade of intermediate color is, and the better the effect of anti-aliasing is. But the cost is that the \( R \) increases by one times, the buffer memory capacity of frame will increase by four times, the time for scan conversion will increase by nearly 4 times. In this way, we can see that the effect and efficiency of anti-aliasing is a pair of contradictions, when confirming \( R \), the balance of effect and efficiency of anti-aliasing shall be paid attention to. To the map publishing symbol, designating \( R = 4 \) can obtain the more ideal balance effect, the \( R \) value adopted in the test of this paper is 4.

After confirming the \( R \), the physical coordinate system based on the screen physical resolution shall be changed into the logical coordinate system based on the logical resolution, correspondingly, the function \( f(x, y) \) of describing curve under the physical coordinate system shall be changed into the \( F(X, Y) \) of describing curve under the logical coordinate system, where, \( X = RX_x, Y = RX_y \). According to the concrete type of representing curve, different scan conversion methods (for example, for the straight line the algorithm of Bresenham lineation is adopted, for the circles the algorithm of midpoint circle and for the ellipse the algorithm of midpoint ellipse) shall be adopted to obtain the discrete logical pixels of describing \( F(X, Y) \) (the small filled dot in Fig. 3 (a)). Where, scan conversion methods of all kinds of curves are a basic problem in the computer graphics, because the length of the paper is limited, this paper will not discuss it,
2.2.2 Judgment on whether logical pixel is selected or not

In the logical coordinate system, on the assumption that the discrete logical pixels describing the \( F(X,Y) \) center line is \((X_i,Y_i)\) \((i = 1 \sim n)\), \(n\) is the number of discrete logical pixel on the center line, the \(n\) is 20 in the Fig. 3). Taking \((X_i,Y_i)\) as the center of circle, \(W\) as diameter (\(W\) is the width of curve in the logical coordinate system, \(W = RXw\), \(W\) is 6 in the Fig. 3), construct the circular "brushes" with the number of \(n\), and mark "selected" on the logical pixel that falls into any one "brush" (seeing the small blanked dot in the Fig. 3(a)).

2.2.3 Calculation of coloring of physical pixel

In the physical coordinate system, the number of selected logical pixel in each physical pixel shall be counted, and final coloring of each pixel shall be calculated according to the statistical result. On the assumption that the number of selected logical pixel in physical pixel \((x_j,y_k)\) is \(K(0 \leq K \leq R^2)\), so the final coloring of physical pixel \((x_j,y_k)\) is

\[
\text{Result color} = \text{Background color} + \frac{K}{R^2} \times (\text{Curve color} - \text{Background color})
\]

where \(K \in [0,R^2]\).

3 Experiment

The basic platform of experiment is common PC computer (CPU is Pentium IV, internal memory is 512 M, display card is GeForce4, display memory is 64 M), and the programming environment is VC 6.0. The purpose of experiment is to test the effect and efficiency of using the brush method to construct the map publishing symbol with anti-aliasing effect.

Experiment 1 is to test anti-aliasing effect of curve with different width. Fig. 4 is the curve list for making map publishing symbol, and taking mm as the unit, the symbols are made by referring to the criterion of point and line symbol issued by Surveying and Mapping Bureau of the General Staff Headquarters of the PLA. From the figure, we can see that the pixel not only has both coloring and non-coloring, but also has intermediate color because of adopting the brush method to carry out the anti-aliasing processing. Just because of the existence of intermediate color, it has overcome the weakness that the width of curve can only be expressed by that of integral multiple of pixel, the change in dark and light of the intermediate color can describe the curve

\[
\begin{align*}
R_{\text{Result color}} &= R_{\text{Background color}} + \frac{K}{R^2} \times (R_{\text{Curve color}} - R_{\text{Background color}}) \\
G_{\text{Result color}} &= G_{\text{Background color}} + \frac{K}{R^2} \times (G_{\text{Curve color}} - G_{\text{Background color}}) \\
B_{\text{Result color}} &= B_{\text{Background color}} + \frac{K}{R^2} \times (B_{\text{Curve color}} - B_{\text{Background color}})
\end{align*}
\]

with any width.

![Fig. 4] Criterion of point and line symbol (isometry)

Experiment 2 is to test the anti-aliasing effect of map publishing symbol. Fig. 5 is the comparison of some symbols before and after anti-aliasing, for the convenience of comparison, the symbol is magnified, the base curve with 0.1 mm width is represented just by one physical pixel. From the figure, we can see that the symbol after anti-aliasing is more delicate, and the sawtooth phenomenon disappears basically.

Experiment 3 is to test the efficiency of brush method. 1 000 straight lines are drawn repeatedly on the screen from the top left corner to the low right corner, the drawing time required before and after anti-aliasing is recorded in Table 1, the different columns in the table repr-
resents the different width of line (taking the pixel as the unit), the tested maximal width of line is 11 (is equivalent to 4 mm, i.e. the max width of line represented in the Fig. 4), the unit of time is millisecond. From Table 1, we can see that before anti-aliasing, the drawing of basic curve with 1 width is very fast, the drawing speed of curve with other width is the same basically, with the increase of width, the increase of consuming time is very little; after anti-aliasing, the drawing speed of basic curve with the 1 width is reduced by 13.8 times than that before anti-aliasing, the time consuming of drawing curve with other width increases with the width at uniform speed. To the width of lines used for the map symbol, the time-consuming ratio between after anti-aliasing and before anti-aliasing is 5.4-17.8. From the table, we can also know indirectly that a piece of clear map is displayed on the screen, after anti-aliasing treatment by adopting the brush method, the drawing time is generally not over 3 s (on the psychology, it is considered that the 3 s is the time limit that the people wait for the refresh of screen).

|                | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 |
|----------------|----|----|----|----|----|----|----|----|----|----|----|
| Before anti-aliasing | 63 | 234| 234| 235| 235| 235| 250| 250| 250| 250| 250|
| After anti-aliasing    | 875| 1281|1265| 1937|2282| 2625| 2953| 3329| 3888| 4110| 4453|
| Time-consuming multiple| 13.8| 5.4 | 6.9 | 8.3 | 9.8 | 11.2 | 11.8 | 13.3 | 14.8 | 16.4 | 17.8 |

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