Pen tablet as a tool of handwritten fonts

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ABSTRACT

The paper is presented a new method for modeling of handwriting font. To construct the handwriting alphabet we use a pen tablet (digitizer) - a device to input images by hand directly into the computer. Result of the movement of the pen digitizer is a family of variable radius circle centered on a smooth trajectory. For the mathematical description of the trace of the pen is used fat curves (a curve of variable width). The fat curve is a trace of circle with variable radius moving along a smooth trajectory of the finite length called as an axis. A possibility to input handwritten characters in real-time with control of smoothness is present. A prototype of a font editor of fat curves was developed by the authors of this paper. The offered approach can be implemented as the plug-in for font editors of hand-written characters.

Keywords

Fat B-spline curve, personal handwritten font, pen tablet, character circular representation.

1. INTRODUCTION

To represent computer fonts use Bézier curves of the second (TrueType) and third (PostScript) orders as boundary description [Knu86]. This is true both for all types of fonts used in a personal computer, as typesetting and handwritten (fig. 1).

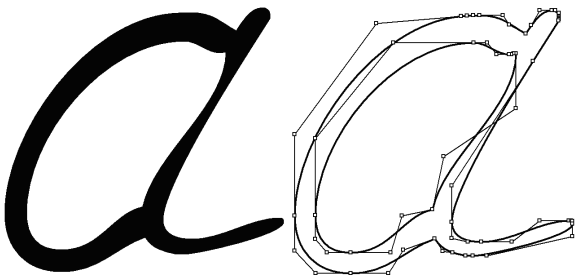

Figure 1. The hand-written character (the letter «a»), described by Bézier curves.

Method of obtaining handwritten font usually includes the following main steps. An author writes handwriting individual letters of the alphabet on a sheet of paper. Using the scanner characters are entered in the form of images to a computer. A designer creates a boundary description in the form of Bezier curves for each character. This work is classified as an offline task and it may take a long time. In this paper we propose a new solution to this problem in the real-time mode – font creation is the direct input data. To achieve the goal is supposed to use a pen tablet. This device is connected to your computer and includes a pen and a flat plate. The main feature of the tablet is the touch sensitivity surface. All the movements of the pen on the tablet surface repeats mouse on a computer screen. This device records the coordinates of the position and pressure of the pen on the tablet surface. If force pressure of the pen interpreted as the radius of the circle then the trace of the pen will be a discrete set of circles [Mes00]. An input data for creation personal handwritten font can be made familiar to the human way (fig. 2).

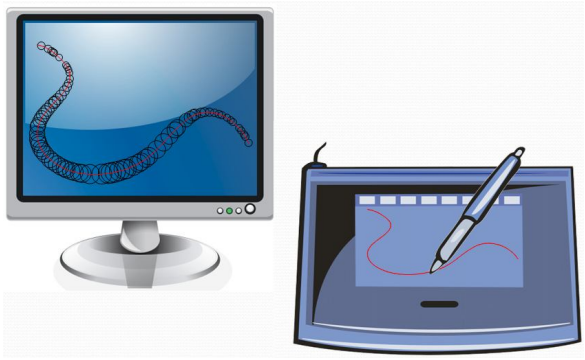

Figure 2. Pen tablet as a personal font tool.

Also, getting the font can be achieved from a sample of handwriting on a paper. It's enough to put the paper on the surface of the tablet and digital pen carefully trace the shape of each character. The resulting family of circles of variable radius can be approximated by continuous primitives such as fat curves – trace of a pen having a width [Kli08]. A fat curve can be seen as a brush stroke, which has a variable width, for example, depending on the pressure [Gho84]. Representation of cursive using a model of trace of a pen «with width» (fig. 3) potentially gives more possibilities for creation of personal «computer handwriting» [Kla93].

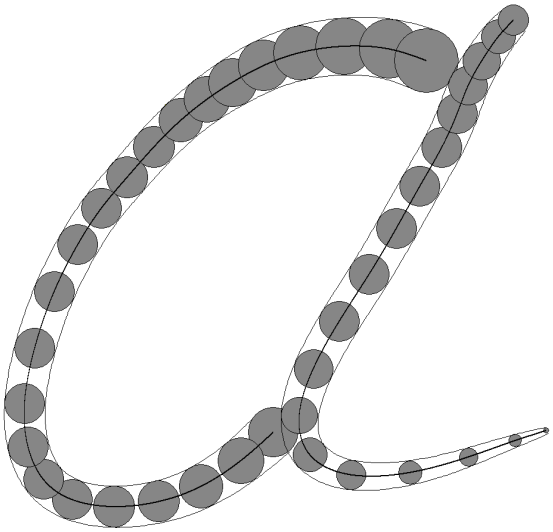

Figure 3. The handwritten character, described by fat curves.

2. FAT CURVES

The main feature of the problem is a large number of circles contained in the trace of the pen. For example, modern pen tablet has a resolution about of 2500 dpi. This means that the line a few centimeters on the surface of the tablet "turns" into a discrete set containing tens of thousands of points. As a result is the task of reducing the dimension of the trace of the pen. It can be solved by approximating family circles using fat curves. A fat curve describes as a trace of circle with variable radius moving along a smooth trajectory called as an axis of this fat curve. B-splines of the third order are used as a mathematical apparatus for description of fat curves.

Elementary B-spline fat curve of the third order [Yao91] is specified by the following vector equation

$$C(t) = (x(t), y(t), r(t)) = \frac{1}{6}\sum_{i=0}^{3} B_i(t) H_i ,$$

where $t \in [0,1]$ – a curve parameter, $H_i = \{H_{ix}, H_{iy}, H_{ir}\}$ – a set of control circles centered in points (H_{ix}, H_{iy}), with radiuses H_{ir}, $B_i(t)$ – base functions of the third order B-spline satisfying the following conditions [Boo72]:

$$B_0(t) = (1-t)^3$$
$$B_1(t) = 3t^3 - 6t^2 + 4$$
$$B_2(t) = -3t^3 + 3t^2 + 3t + 1$$
$$B_3(t) = t^3$$

The example of elementary B-spline fat curve with control circles $\{H_0,...,H_3\}$ is shown in fig. 4. The fat curve (as a trace of moving circle) is presented by grey color, the axis of the fat curve - by black color, control circles - by dotted line.

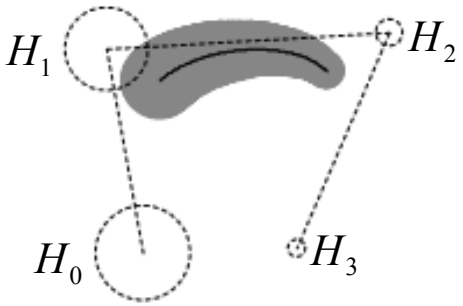

Figure 4. The elementary B-spline fat curve.

Elementary curves can unite into more complex graphic primitives - compound fat curves. Let a curve γ, presented as an association of elementary cubic B-spline fat curves $\gamma^{(1)},...,\gamma^{(m-2)}$, be a compound cubic B-spline curve with common set of control circles $H = (H_0,...,H_m)$, where $H_{k-1}, H_k, H_{k+1}, H_{k+2}$ - control circles of curve $\gamma^{(k)}$. There is the compound B-spline fat curve constructed of 6 elementary sections and having 9 control circles $H_0,...,H_8$ is presented in fig. 5.

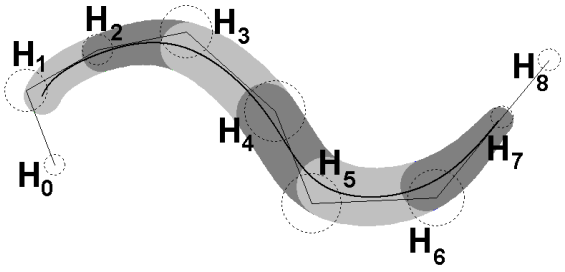

Figure 5. The compound B-spline fat curve.

3. METHOD DESCRIPTION

The fat curve is an ideal primitive to approximate the trace of the pen. The problem of fat curve approximation is the following. Let a sequence of circles $G_0,...,G_{n-1}$, each of which is described as a three-dimensional vector $G_j = (G_{jx}, G_{jy}, G_{jr})$, where (G_{jx}, G_{jy}) – coordinates of the center circle, and G_{jr} – its radius. Is necessary to construct a composite fat B-spline curve, such that it passes close enough to the circles G_j. Below is an example of approximation sequence of variable radius circles by a fat compound B-spline curve (fig. 6).

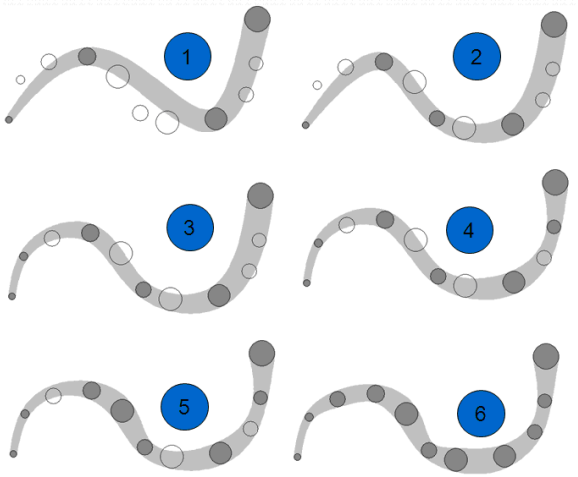

Figure 6. The approximation steps by fat curve.

As an approximation error is screen pixel. There are two possibilities for character input when moving the pen on the tablet surface:

- writing characters is without interruption of the pen on the tablet work surface;
- writing characters based on the principle individual strokes.

The second style of writing found in people who try to carefully character output. Most people use a writing style in which the pen is not detached from the tablet surface. As a result, the task of "splitting" the pen trace to the individual strokes is shown. Further, each individual stroke must be approximated by a fat curve. The criterion of the "splitting" can take the change in the vector tangent to the trajectory of the pen trace. For example, consider the pen trace of symbol "a", which was created without taking them off the tablet. In the illustration (fig. 7) shows that a trace of the pen can be represented by two strokes. Initially, it is necessary to approximate the pen trace by set of straight line segments.

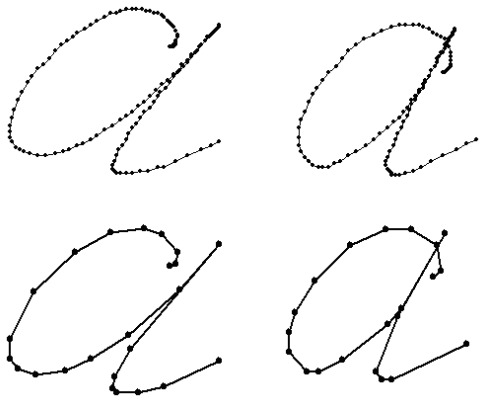

Figure 7. The pen traces (on the top) and the piece-wise linear approximation (on the bottom).

The main idea of piece-wise linear approximation is the following. Suppose we have a sequence of points P_i, $i = 0,...,N-1$, which are the points of the axial pen trace, and determine the accuracy of the approximation ε.

Step 1. Solve the problem of piece-wise linear approximation of the set of points P_i, $i = 0,...,N-1$ by the line segment;

Step 2. Determine the point of the set P_i, the maximum distance from the resulting segment;

Step 3. If the maximum distance is greater than the specified accuracy of the approximation ε, then original set is divided into two subsets by point of maximum distance from the constructed line segment. And the approximation problem is solved recursively for each of the resulting subsets.

This approach allows us to split the original sequence of points on the individual strokes. Below is an example of such an algorithm for a simple pen trace. On the left is the original sequence of points (pen trace). On the right shows the piece-wise linear approximation with an accuracy 3 pixels. We see that the original sequence of points of the pen trace was split into three elementary fragment by points 2 and 5 (fig. 9).

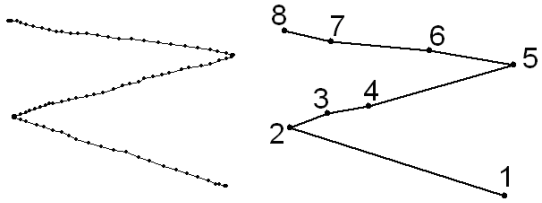

Figure 9. The piece-wise linear approximation and splitting.

Then each single stroke of pen trace should be approximated by a fat curve. Below is an example of constructing handwritten letter “m” (fig. 10).

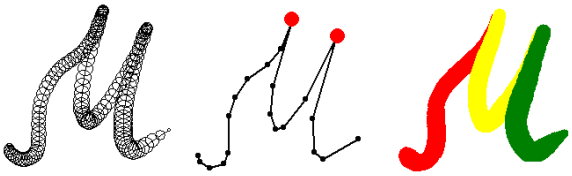

Figure 10. The approximation of character by fat curves.

The "alive" of font is making small variations in the shape of characters. The creation of various tracings of the same character allows you to see a live handwriting at printing. The mathematical apparatus of fat curves allows for simulation of "live" handwriting by making small dynamic changes in the shape of letters. Printed out text of this font will appear as a "live" letter written by hand. Making a small variations in the shape of a characters is performed by editing fat curves (the change of the center and the radius of control circles). An example of editing fat curve is presend in fig. 11. Shape deformation of fat curves can be described mathematically as a change the parameters of the control circles: $H_i^{'} = H_i + \xi_i$, where $H_i = \{H_{ix}, H_{iy}, H_{ir}\}$ – a set of control circles, $\xi_i = \{\xi_{ix}, \xi_{iy}, \xi_{ir}\}$ – a random noise.

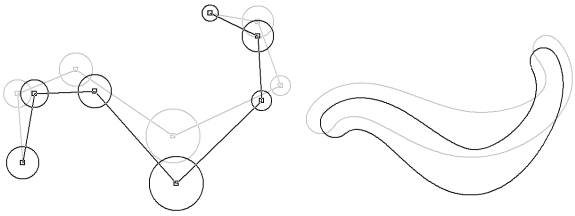

Figure 11. Editing of fat curve.

We can suggest another way to change the shape of characters – a transformation of bounding box. The main idea of such transformation is showed in fig. 12.

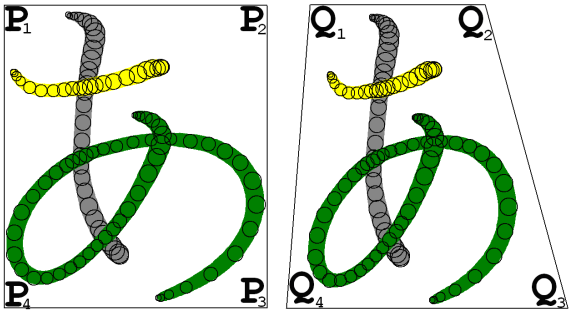

Figure 12. A transformation of bounding box.

The quad transformation is described as: $\begin{cases} Q_{ix} = a \cdot P_{ix} \cdot P_{iy} + b \cdot P_{ix} + c \cdot P_{iy} + d \\ Q_{iy} = e \cdot P_{ix} \cdot P_{iy} + f \cdot P_{ix} + g \cdot P_{iy} + h \end{cases}$, where a, b, c, d, e, f, g, h – is 8 unknown variables, $Q_i = (Q_{ix}, Q_{iy}), P_i = (P_{ix}, P_{iy}), i = \overline{1...4}$.

When printing a text, we can achieve that identical letters to look differently. The transformation method of the character’s shape can be selected randomly with random parameters.

4. CONCLUSIONS

The proposed approach can be used to construct the handwritten fonts. This way of data input can be used in the problem of personal identification by signature. When the user is using a digital pen and tablet to play in real-time his signature. In this case, to identify the signatures can be considered different numerical indicators: force of pressure at specific points of the pen trace, correctness of path (drawing) characters, calculation of the smoothness and curvature of the axis of the pen trace.

5. ACKNOWLEDGMENTS

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