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TrueType Bezier
TrueType de Casteljau
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Optimization algorithm of linear approximation for outline of TrueType fonts in laser marking systems

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In order to improve the efficiency of marking vector texts in laser marking systems, an optimized algorithm of linear approximation for TrueType font outline was proposed by analyzing the structure of TrueType font outline and properties of Bezier curve. Theoretical analysis and experimental verification were carried out. Firstly, Bezier curves in the outline of TrueType fonts were divided on the basis of de Casteljau recursive algorithm. Then they were replaced with the lines between start and end points. Finally, all the lines were interpolated to generate laser marking point. Through comparison between linear approximation contours and standard TrueType outlines, the results show that the algorithm can generate fewer nodes and improve the efficiency of marking vector texts under the condition of meeting accuracy.

Key words: laser technique; laser marking; algorithm optimization; linear approximation; TrueType font; de Casteljau recursive algorithm

TrueType TrueType TrueType TrueType

[1]

TrueType TrueType CHEN [2] TrueType TrueType LIU Windows GetGlyphOutline [1] TrueType TrueType LIU [1] YANG Beizer [3]

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SONG Bezier

TrueType TrueType

TrueType

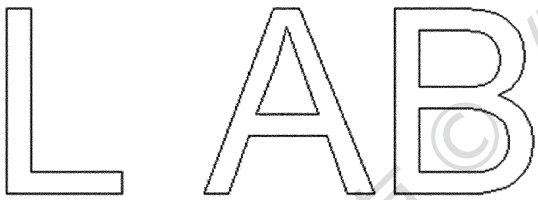

Fig. 1 Characters with one, two, three contours respectively

Bezier Bezier Bezier

Bezier Bezier

Bezier TrueType

YE Bezier [6]

KUANG [7]

XU [8]

Bezier de Casteljau Bezier Bezier

Bezier 4 P_0, P_1, P_2, P_3

$P(t) = (-t^3 + 3t^2 - 3t + 1)P_0 + (3t^3 - 6t^2 + 3t)P_1 + (-3t^3 + 3t^2)P_2 + t^3P_3$ (1)

$t \in [0,1]$

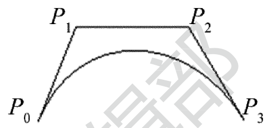

Fig. 2 Cubic Bezier curve

(1) de Casteljau $n+1$ P_i $(i = 0,1,2,\ldots,n)$ de Casteljau

$$P_i^{(r)} = (1-t)P_i^{(r-1)} + tP_{i+1}^{(r-1)} \tag{2}$$

$r = 1,2,\ldots,n$; $i = 0,1,\ldots,n-r$; $P_i^{(0)} = P_i$, $P_0^{(n)}$ Bezier

$n = 3$ Bezier de Casteljau

$$\begin{cases} P_{10} = (1-t)P_{00} + tP_{01} \\ P_{11} = (1-t)P_{01} + tP_{02} \\ P_{12} = (1-t)P_{02} + tP_{03} \end{cases} \tag{3}$$

$$\begin{cases} P_{20} = (1-t)P_{10} + tP_{11} \\ P_{21} = (1-t)P_{11} + tP_{12} \end{cases} \tag{4}$$

$$P_{30} = (1-t)P_{20} + tP_{21} \tag{5}$$

$P_{0i} = P_i$, de Casteljau P_0P_1 $P(t)$ P_0P_1 $t:(1-t)$ 3 P_0 P_1 $P(t)$

$$P(t) = P_0 + t(P_1 - P_0) = (1-t)P_0 + tP_1 \tag{6}$$

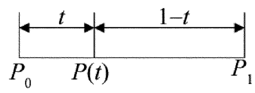

Fig. 3 de Casteljau recursive algorithm

1 P_{1i} $(i = 0,1,\ldots,n-1)$ 2 P_{2i} $(i = 0,1,\ldots,n-2)$ n P_{n0} Bezier [9]

Bezier Bezier

Bezier

Bezier

Bezier P_{00} P_{10} P_{20} P_{i0} Bezier P_{i0} P_{iR} Bezier

Bezier

Bezier

Bezier

$d(P, P_0P_3)\leqslant$ (7)

$d = \max(|x_R - x_{R1}|, |y_R - y_{R1}|)\leqslant$ (8)

$d = \max(|x_0 - x_1|, |y_0 - y_1|, |x_2 - x_3|, |y_2 - y_3|)\leqslant$ (9)

de Casteljau

Bezier

Bezier

Bezier 4

P_{00}, P_{01}, P_{02}, P_{03} 3 Bezier

$P_{00}P_{03}$ Bezier

de Casteljau P_{30}

Bezier Bezier

P_{00}, P_{10}

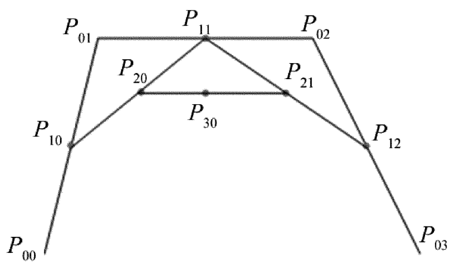

Fig. 4 Principle of linear approximation for cubic Bezier curve

P_{20}, P_{30}, P_{30}, P_{21}, P_{12}, P_{03}

Bezier

Bezier 1 Bezier P_{00}, P_{01}, P_{02}, P_{03} (2) $P_{00}P_{03}$

3 $t = 0.5$ Bezier

de Casteljau Bezier

P_{00}, P_{10}, P_{20}, P_{30} P_{30}, P_{21}, P_{12}, P_{03} 4

1 ~ 4

Bezier

$$
\begin{cases}
P_{00}(0.5) = P_0 \\
P_{10}(0.5) = 0.5P_{00}(0.5) + 0.5P_{01}(0.5) = 0.5(P_0 + P_1) \\
P_{20}(0.5) = 0.5P_{10}(0.5) + 0.5P_{11}(0.5) = 0.25(P_0 + 2P_1 + P_2) \\
P_{30}(0.5) = 0.5P_{20}(0.5) + 0.5P_{21}(0.5) = 0.125(P_0 + 3P_1 + 3P_2 + P_3)
\end{cases}
\quad (10)
$$

$$
\begin{cases}
P_{30}(0.5) = 0.5P_{20}(0.5) + 0.5P_{21}(0.5) = 0.125(P_0 + 3P_1 + 3P_2 + P_3) \\
P_{21}(0.5) = 0.5P_{11}(0.5) + 0.5P_{12}(0.5) = 0.25(P_1 + 2P_1 + P_3) \\
P_{12}(0.5) = 0.5P_{02}(0.5) + 0.5P_{03}(0.5) = 0.5(P_2 + P_3) \\
P_{03}(0.5) = P_3
\end{cases}
\quad (11)
$$

5 5 GetGlyphOutline

100mm

5a

Beizer

75

7.9375000mm 5b Beizer

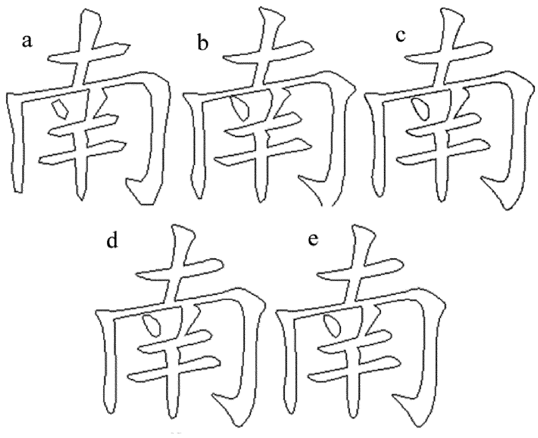

Fig. 5 Difference between character outlines

225 5c Beizer 1mm Bezier 3885 5d Beizer 1mm Bezier 1295 0.9921875mm 5e Beizer Windows PolyBezier

1. Bezier 2. Bezier 3. Bezier 4. 5d 5e

100mm 5b 50mm 5a ~ 5d 75 225 670 2010 10mm 5a ~ 5d 75 225 162 486

Bezier Bezier

Bezier [10] [11-12] [13]

TrueType

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