Generation and Optimization of interpolation approximation algorithm based on Laser Icon Contour Generation

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Abstract. Point-by-point comparison interpolation is a widely used algorithm in laser marking system. This algorithm plays a very important role in controlling the laser trajectory and fitting the image trajectory. Because the point-by-point comparison interpolation method has the characteristics of intuitive operation, uniform pulse output and convenient adjustment, it is a kind of interpolation algorithm which is more suitable for the application of marking machine system. In order to improve the marking efficiency of vector text in laser marking system, by analyzing the outline structure of TrueType font and the properties of Bezier curve, an optimization algorithm for straight line approximation of TrueType font outline is presented, and the theoretical analysis and experimental verification are carried out. Firstly, the Bezier curve in the TrueType font outline is segmented according to the deCasteljau recursive algorithm, and then the curve is replaced by the connection of the head and tail control points. Finally, the approximate line segment is interpolated to generate marking data, and the straight line approximation outline is compared with the standard TrueType font outline. The results show that under the condition of satisfying the accuracy, the algorithm has the advantages of simple calculation process and a small number of nodes, and improves the marking efficiency of vector text. The traditional point-by-point comparison interpolation algorithm has some problems such as low precision and slow speed. In order to improve the performance of the algorithm, the traditional point-by-point comparison interpolation algorithm is improved, and the calculation and simulation are carried out. The results show that the accuracy and speed of the improved interpolation algorithm are obviously improved. The patch is extracted from the point cloud data, and the feature patch is generated by patch growth and fusion, and the feature line is constructed quickly according to the proposed patch two-way index method, and finally the point cloud plane contour is generated. Experiments show that this algorithm can generate point cloud contours quickly, accurately and effectively.
1. Introduction

3-D laser point cloud processing technology is undergoing a revolution, along with the development of the point cloud rapid modeling technology, the traditional by point to the line, to the surface and the solution of the model is broken, the rest of the new another detection technology, rapid growth, rest of another fusion method, and facilitate the rapid point cloud model, it also grounds model to the contour of the reverse solution provides technical basis[1]. At present, researchers at home and abroad mainly use the neighborhood information of points to describe the geometric features of each point, and then connect points with similar geometric features into line segments. Then, the line segments are detooth [2], smoothed and filled to generate a complete contour. Xiao-jun cheng and so on is put forward based on the slice contour characteristic line fast generation algorithm, the method of using digital image projection will point cloud to digital raster graphic, by the index of the image connected structure characteristics of the fast line, the algorithm with high computational efficiency, but did not solve the characteristic line in larger point cloud hole in a row and noise caused by the characteristic line local sawtooth [3].

The main font types of text marking are dot matrix font and vector font. It is difficult to meet the requirement of high precision marking because the scaling of bitmap font is easy to distort. Vector font is described by a series of mathematical curves, which contains the key points on the font boundary [4], the derivative information of the line, etc., and has the advantage of arbitrary scaling without deformation. TrueType fonts are the most widely used vector fonts. It uses mathematical functions to describe the outline of a font, which can be used for both printing and screen display.

The point-by-point comparison interpolation method is a kind of interpolation method which is widely used in contour control marking by laser marking machine. The interpolation error is no more than one pulse equivalent, the pulse output is uniform, and the adjustment is convenient. It is suitable for the interpolation of two-coordinate controllers such as laser marking machine [5]. In the process of controlling the contour track, the marking machine can calculate and judge the marking deviation point by point, and constantly compare the relative position between the laser and the marking image contour, so as to judge and control the coordinate feed, and mark out according to the specified graph. The interpolation method has three directions, X direction, Y direction and the 45° - line direction of simultaneous feed of X and Y axis, which is fitted with multiple segments of tiny straight lines. If the x and y feed directions are given, the interpolation accuracy will definitely be affected. The traditional feeding method has the defect of low precision and slow speed [6]. There are many methods to improve how to choose feed direction, but most of them are only qualitative analysis, without quantitative calculation to determine which direction of feed will make the minimum error and the fastest speed.

2. Algorithm description

2.1. Normal vector estimation

For each point p in the point cloud, search k neighborhood points closest to it, and use these points to calculate a local plane \( S \) based on the least squares criterion. The mathematical expression of the plane is as follows:

\[
S(n, d) = \arg\min \sum_{i=1}^{k} ||n^* p_i - d||_2
\]

In the formula, \( n \) is the normal vector of plane \( S \), and \( d \) is the distance from the origin to plane \( S \). As you can see, the plane \( S \) passes through the center of mass of \( k \) neighborhood points \( p \) minus, and the normal vector \( n \) satisfies \( n^2 = 1 \). Therefore, the estimation problem of the normal vector of point \( P \) can be transformed into eigenvalue decomposition of the covariance matrix \( M \) in Equation (2) to obtain the eigenvector problem corresponding to the minimum eigenvalue of \( M \), and the obtained eigenvector is the normal vector of point \( P \).
The plane fitting method of normal vector estimation has the characteristics of low-pass, so the normal vector estimation of sharp features is not obvious, which has a great influence on the methods that rely heavily on the point cloud feature neighborhood to generate contour lines, but the method in this paper is almost unaffected. Since the normal vector obtained by the plane fitting method does not have consistent directivity, it is necessary to redirect the obtained normal vector, as shown in Figure 1.

\[ M = \frac{1}{k} \sum_{i=1}^{k} \left( p_i - p \right) \left( p_i - p \right)^T \]  

Fig 1. Normal vector estimation redirection

2.2. Cubic Bezier Curves and De Casteljau Recursive Methods

Cubic Bezier curve is defined by four control points (P0, P1, P2 and P3), as shown in Fig. 2. The expression is as follows:

\[ P(t) = \left( -t^3 + 3t^2 - 3t + 1 \right) P_0 + \left( 3t^3 - 6t^2 + 3t \right) P_1 + \left( -3t^3 + 3t^2 \right) P_2 + t^3 P_3 \]

Fig 2. Cubic Bezier curve

According to Equation (1), the coordinates of any point on the curve can be directly calculated, but the Decasteljau recursive calculation method is much simpler and has obvious geometric significance. Given space n+1 control points Pt (1 = 0,1,2..., n) and parameter t. The formula of Decasteljau recursive calculation is:

\[ P_n(t) = (1-t)P_{(t-1)}(t) + tP_{(t+1)}(t) \]  

2.3. Calculation of error range

For contour lines with different slopes, the Angle of the line to the x-coordinate axis is different. The equation of contour line can be expressed as AX + BY = C, and the equation of two dashed equidistant
lines can be expressed as \( Ax + By = C \pm 0.5 \delta \sqrt{A^2 + B^2} \). Two dotted lines to allow the distance to the contour error, length of permissible error is marked as a, a perspective for alpha, on the other side to b's right triangle \( \Delta ABC \). According to the Pythagorean theorem, the sine formula and the Angle relation, the correlation formula can be listed as

\[
\begin{align*}
\alpha^2 + b^2 &= c^2 \\
\sin \alpha &= \frac{a}{c} \\
2 \times c &= 1
\end{align*}
\]

(5)

3. Results analysis

3.1. The calculation of traditional algorithm and improved algorithm

We calculate the traditional point-by-point comparison interpolation method and the improved point-by-point comparison interpolation method, and the calculation results are given below. On the platform of VisualStudio2017, using C++ language to code the improved algorithm, the number of steps forward in the time period, we can see that under the same number of steps, the improved algorithm can arrive faster and greatly save time. The figure shows the error of the distance profile of each point. It can be seen that the errors of the improved algorithm are all within the range of 1 prime 2 pulse equivalent, and the error value is smaller (unit is pulse equivalent). The hierarchy of the model is clear, and the data conversion process is simple and easy to implement.

![Fig 3. Simulation diagram of the relationship between time and steps](image)

3.2. Plane contour cutting

Cutting technology in order to prove the rest based on another point cloud contour generation algorithm can really meet actual production needs, this article they pick a piece of 188 cases, a total of 487 homes, the area of about 2 billion point cloud, the building contains a random noise, the target point cloud point, point cloud empty, absence etc all kinds of complicated geometry, has certain representativeness and guiding significance. In the test, 103 feature points in this region were collected by the traditional measurement method. The precision of the coordinates of the collected feature points was compared with the feature points of the plane contour drawn by the method in this paper.
In with big characteristics of point cloud data processing algorithms, geometric features of surface reconstruction algorithm based on point cloud is a hotspot of research in recent years, however the processing includes irregular noise and a weak point cloud and geometry problems such as missing the point cloud, often present a partial surface of the blade and interruption phenomenon, more seriously and has more practical meaning in dealing with the sharp characteristics of point cloud, will be drawn into a continuous line, appear different degree of distortion, precision and accuracy is difficult to guarantee.

By comparing the font contour, the number of nodes and the maximum error in each figure, we can see that:(1) If there is no straight-line approximation of the third Bezier curve in the font contour, the number of nodes will be less and the calculation process will be simple, but the error will be too large and lead to font distortion;(2) If the three-time Bezier curve in the font contour is straight-line approximation, the number of nodes generated increases, but the error is small, and the font contour is smoother and more beautiful;(3) No matter whether the cubic Bezier curve is approximated in a straight line or not, the number of nodes generated by replacing the whole curve with two control point lines at the beginning and the end of the curve is significantly lower than that of replacing the whole curve with two adjacent control point lines;

4. Conclusions
Among the point cloud processing algorithms with big data characteristics, the surface reconstruction algorithm based on point cloud geometric features is a research hotspot in recent years. However, when dealing with point clouds with irregular noise, point cloud voids and geometric deficiencies, it often presents local aliasing and surface interruption, and what is more serious is that when dealing with sharp feature point clouds of practical significance, it will be drawn as a continuous broken line. There are different degrees of distortion, accuracy and accuracy is more difficult to guarantee. It can quantitatively determine the range of allowable error, reduce the number of interpolation steps and the number of operations, so as to improve the speed of interpolation. The straight line obtained after interpolation is the same as the contour line, but there is still a small error due to the accuracy and error of the hardware. The improved algorithm is suitable for each quadrant, and the accuracy and speed of other quadrants are exactly the same as those of the first quadrant. Generally speaking, the improved algorithm. It is a relatively optimized laser marking machine control processing algorithm, which has good application value. The problem of local aliasing and interruption of the surface caused by the quality of the point cloud is fundamentally solved. The technology of bi-directional index connectivity and plane contour cutting of patches can realize the automatic generation of point cloud contours quickly and accurately, retain the sharp features of practical significance, and at the same time, have a certain ability of noise suppression.

Fig 4. Comparison diagram
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