

On-line three-dimensional point cloud data extraction method for scan-tracking measurement of irregular surface using bi-Akima spline



Ye Tao ^{a,*}, Yong-Qing Wang ^b, Hai-Bo Liu ^b, Meng Li ^c

^a School of Manufacturing Science and Engineering, Sichuan University, China

^b School of Mechanical Engineering, Dalian University of Technology, China

^c FAW-Volkswagen Automotive Company, Ltd, China

ARTICLE INFO

Article history:

Received 20 July 2013

Received in revised form 30 May 2016

Accepted 7 June 2016

Available online 22 June 2016

Keywords:

Point cloud data

Data extraction

Scan-tracking measurement

Bi-Akima spline interpolation

ABSTRACT

Point cloud data extraction is an important process in scan-tracking measurement. In this paper, a new method of on-line three-dimensional point cloud data extraction for scan-tracking measurement is proposed for reducing extremely dense sampled data while maintaining data accuracy during the real-time scan-tracking measuring process. It is inspired from sketch paintings: First outlining the broad contour of the curve and then revising local details till the interpolated curve satisfies the required accuracy. This method adopts bi-Akima spline interpolation for connecting acquired points in NC machining or for point data fitting in reverse engineering. It can reduce efficiently the amount of point data with a smaller data reduction ratio and a smoother machined/fitted surface than conventional three-dimensional chordal method.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Surface scan-tracking measurement technology is one of the key technologies in Numerical Control (NC) copying manufacture systems and is also an important method for processing irregular surface parts in reverse engineering [1–5]. Experts and researchers all over the world are concerned about this technology increasingly. Point cloud data acquisition is an important step in scan-tracking measuring process [4,5]. Nowadays, methods for acquiring point cloud data used in scan-tracking measurement mainly include contact measurement and non-contact measurement. There are problems in using these acquiring methods since they produce extremely dense point data at a great rate, and not all of these point data is necessary [6]. Moreover, bottlenecks are created owing to the inefficiencies in storing and manipulating them. Describing measuring objects with the least point cloud information is in expectation. In general, the larger curvature change is, the denser the point cloud is, and vice versa. Thus, a high-efficiency, high-quality point cloud data reduction method is being pursued all the time [7]. Sampling algorithms for scan-tracking measurement generally include isochronous sampling and equidistant sampling. These algorithms are easy to implement but cannot adjust the number of sampled points according to the changes of

surface curvature, which consequently leads to the loss of some important geometric information. Consequently, they cannot meet the requirements of guaranteeing precision and saving memory at the same time, and only suitable for the condition of the curvature changing little or nothing [5].

In response to the above situation, point cloud data reduction methods are currently being studied by many researchers all over the world. Lee et al. [7] introduced a procedure for handling point cloud data acquired by laser scanners. This method uses one-directional or bi-directional non-uniform grid to reduce the data size. Fujimoto and Kariya [8] proposed an improved sequential method using an angle parameter for data reduction which can control the distance between input and output data. This method also it possible to accept a large amount of data in a small-size system. Chen et al. [9] suggested a method to reduce the point data by reducing the number of triangles required in a polyhedral model. They demonstrated their algorithm by reducing the number of triangles in an STL file of a human face digitised by a CMM machine. Martin et al. [10] proposed a data reduction method by using a uniform grid in their EU Copernicus project. Their method uses a “median filtering” approach, which has been widely used in image processing. Hamann [11] presented a method of data reduction for triangulation files based on an iterative triangle removal principle. As a measure of file size reduction, each triangulation is weighted on the basis of the principal curvature estimates at its vertices and interior angles. Hamann and Chen [12] proposed a

* Corresponding author at: School of Manufacturing Science & Engineering, Sichuan University, No. 24 South Section 1, Yihuan Road, Chengdu 610065, China.
E-mail address: yetao@scu.edu.cn (Y. Tao).

method to reduce the point data in making various planar curves, compressing 2D images, and visualising volumes. Major research efforts of above methods focus on manipulating polyhedral models. Various schemes are also used to reduce the amount of point data from the initial point clouds. However, none of these methods can achieve on-line point data reduction during the real-time measuring process, they could only reduce the overall point cloud data for post-processing after data acquisition process.

Up to date, only chordal method can achieve on-line point cloud data extraction of the cross-sectional curve during the real-time data acquisition process [5,6]. It has the ability of accepting and rejecting sampled data reasonably based on the curvature changes and it can guarantee a required accuracy with less sampled data. Unfortunately, this method assumes that adjacent acquired points are connected by a straight line, which specifies the interpolation form must be a linear type in machining process and in data processing process. Conversely, if we use spline curves (e.g. NURBS spline) to connect these points acquired by chordal method, the required accuracy cannot be guaranteed. Moreover, when using linear interpolation to connect discrete dense sets of sampled points in NC machining, the curve is not smooth and there are many cusp points, thus leads to sudden changes in feed velocity and acceleration of NC servo systems [13]. Machining accuracy and surface quality of mating surfaces will be affected to some extent. In addition, the reduction ratio of the chordal method needs to be further improved.

To avoid these problems, this paper presents an on-line three-dimensional point cloud data extraction method for scan-tracking measurement of irregular surface using bi-Akima spline interpolation, which can reduce the amount of point data acquired during the real-time data sampling process.

2. A brief description of chordal method

2.1. Two-dimensional chordal method [5,6]

For ease of understanding and for convenience, we first describe two-dimensional chordal method. The basic principle of this method is shown in Fig. 1. At first, the scan-tracking measuring system records the coordinate value of the first point P_i as the initial reference point. Then in every sampling period, the control system samples the current coordinate value and works out the maximum chord height $h_{\max}$ from the chord that connects current sampling point with previous recorded reference point to the arc trajectory. The maximum chord height $h_{\max}$ is made by computing the corresponding chord heights $h_{i+1}, h_{i+2}, \dots, h_{i+m}, \dots, h_{i+n-1}$ of all the points between the current sampling point P_{i+n} and the reference point P_i . The chord height h_{i+m} at point P_{i+m} can be successfully evaluated as Eq. (1):

$$h_{i+m} = |A(x_{i+m} - x_i) - B(y_{i+m} - y_i)| / \sqrt{A^2 + B^2}, \quad (1)$$

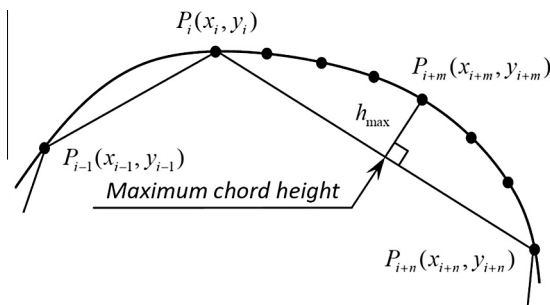


Fig. 1. Two-dimensional chordal method for cross-sectional curve.

where $A = y_{i+n} - y_i$, $B = x_{i+n} - x_i$, (x_i, y_i) is the coordinate value of point P_i , (x_{i+m}, y_{i+m}) is the coordinate value of point P_{i+m} , (x_{i+n}, y_{i+n}) is the coordinate value of point P_{i+n} . Then taking the maximum of all the chord heights $h_{\max}$ to compare with the required accuracy ε . If $h_{\max}$ is less than the required accuracy ε , the corresponding sampling point will not be recorded. While the point P_{i+n-1} sampled in the former sampling period should be recorded in the point cloud data file. After that, this recorded point will be used as the new reference point to repeat the above cycle until the termination of the sampling process.

2.2. Three-dimensional chordal method

Two-dimensional chordal method can only reduce the point data of certain cross-sectional curve in two-dimensional plane, but cannot handle the point cloud data of complex surface in three-dimensional space. Therefore, three-dimensional chordal method is proposed in this paper. It is an extension of two-dimensional chordal method. As shown in Fig. 2, the only difference between these two methods is that the chord height h_{i+m} at point P_{i+m} for three-dimensional chordal method is calculated by Eq. (2),

$$h_{i+m} = |\overline{P_i P_{i+n}} \times \overline{P_i P_{i+m}}| / |\overline{P_i P_{i+n}}|, \quad (2)$$

where the coordinate value of point P_i, P_{i+m}, P_{i+n} is $(x_i, y_i, z_i), (x_{i+m}, y_{i+m}, z_{i+m}), (x_{i+n}, y_{i+n}, z_{i+n})$, respectively.

The chordal method achieves data reduction under the premise of ensuring accuracy (i.e. the required accuracy ε). But it can only use a polyline connected by the recorded points to approximate the original curve. Therefore, for ensuring the machining accuracy of a mating surface, the NC interpolation form must be a linear type rather than spline curve type. When linear interpolation is used to connect dense point cloud data, unexpected oscillation of the mechanical system may appear in NC real-time interpolation process, which may affect the machining accuracy and surface quality of mating surfaces.

If we choose a spline curve fitting method to connect the recorded points and to accept and reject the sampled data according to the maximum deviation between the fitting curve with the original sampling point, there will be no edges and corners in the smooth cutter path of NC machining process, which can effectively avoid the oscillation of the mechanical system. What is more, the reduction ratio of point cloud data might be further reduced.

3. Overview of spline interpolation for NC machining

There are currently three types of spline interpolation supported by commercial NC systems [13], as shown in Fig. 2.

- (i) **NURBS (non-uniform, rational basis) spline.** The NURBS spline does not pass directly through the data points [14]. The programmed positions are merely a set of control points

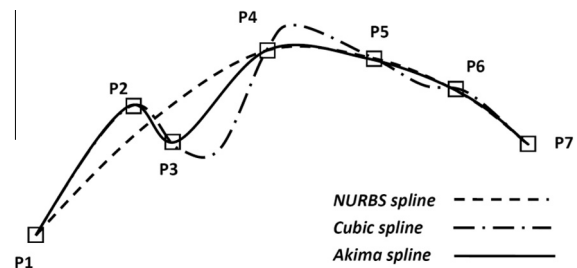


Fig. 2. Comparison of three spline types with identical interpolation points.

Download English Version:

<https://daneshyari.com/en/article/7123141>

Download Persian Version:

<https://daneshyari.com/article/7123141>

[Daneshyari.com](https://daneshyari.com)