Design of a Simple 3D Surface Measurement System Based on Laser Sensor

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Abstract - Based on the principle of laser triangulation method, a surface measurement system aiming at the surface characteristics of small handicraft is constructed. The system controls rotation motion and vertical motion of laser displacement sensor to scan the object. Depending on the collected information of two-dimensional distance and the hardware system motion equations, the three-dimensional model of the surface of the object is established. Thereby the three-dimensional reconstruction of the object is completed.

Index Terms - Three-dimensional measurement Laser sensor Simple Point structured light

1. Introduction

In the modern manufacturing and processing industries, it is usually obtain the surface of the measured object data and reprocessing by using the reverse design when work piece model must be designed after the experiment test or batch products the manual designed handcrafts [1].

In measurement process, the photoelectric detection is an important method because of its good features such as non-contact, high efficiency, easy to implement, process automation and high measurement accuracy, etc. For its fast and convenience measurement, laser scanning has become the most important non-contact measurement means in recent years. Laser triangulation is a typical photoelectric detection technology, and used widely in the industry of length, distance and three-dimensional topography and other testing since this method has the advantages of simple structure, test speed, real-time processing ability, flexible and convenient to use [2].

The small craft attracts many young people and occupies increasing proportion in the market because of its low price and different shapes. In order to expand the market, companies need to reform and reprocessing by collecting the surface profile data of existing products. At present, more and more companies and institutions research in this area using various technologies. Although the precision of many products is very high, the cost is high in general. However, there is the problem of "blind area" by using linear structured light project on the surface of an object. Focusing on the above problems [3], a simple 3D surface measurement system has been designed based on laser sensor with low cost, engineering and high practically.

2. Working Principle

The principle of laser triangulation method is as follows: project the visible red laser light through the laser transmitter to the measured object surface, the laser reflected by the object surface is received by the internal CCD linear camera. The linear CCD camera can "see" the laser spot in different angles according to different points. Using the angle and the distance between the known laser and the camera, digital signal processor can calculate the distance between sensor and the objects that are measured. Laser triangulation method consists of point structure light scanning and line structured light scanning. The schematic diagram is shown in Fig.1.

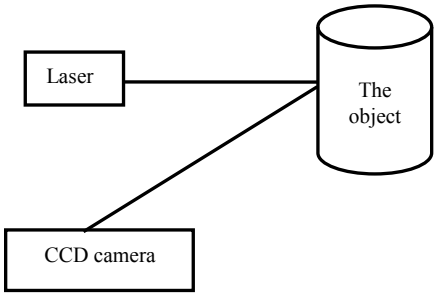


Fig.1 Structure light ranging principle

On linear structured light scanning, the proportion coefficient between light stripe image offset and detecting depth depends on the distance between the laser transmitter and CCD. Therefore, greater spacing is required to measure depth more precisely, which will cause the CCD "blind area" where depth cannot be detected [3].

Due to the measured object surface features prominent, if using linear structured light scanning will appear a lot of "blind area," while the point structured light does not, and the point structured light meet rapid on-line detection and real-time requirements. But it can obtain the position of only one point each time and less amount of information, so it is usually used in rapid scanning.

Fig.2 shows detect result of a handcraft by a line structure laser scanning machine, where (a)is the handicraft, (b)is the detection result, (c)and(d)are the enlarged "blind area" in (b).

(a) (b)

(c) (d)

Fig.2 Schematic data missing parts

The detecting result shows that the object surface data which obtained by linear structured light scanning is incomplete. Through the analysis, it is found that the problem is caused by the "blind area" which is generated in the linear structured light scanning. In order to avoid the "blind area", the 3Dsurface measurement system proposed in this paper chooses point structured light scanning.

The principle of measurement is: combine the rotational movement of the turning platform and the vertical movement of the laser displacement sensors, to complete the distance of measurement from the center of laser displacement sensor to the surface of the object. Using the principle of the cylindrical coordinate system for processing thee collected data to obtain surface coordinate point data, and finally completed the 3D surface reconstruction. The principle of cylindrical coordinate system is shown in Fig.3, M(x, y, z)is a point in the space, P(r,θ) is the projection of the M in the XOY plane,(r,θ,z)is the cylindrical coordinates of point M, and the relationship between the cylindrical coordinates and rectangular coordinates is as follows:

$$x = r\cos\theta;$$

$$y = r\sin\theta;$$

$$z = z;$$

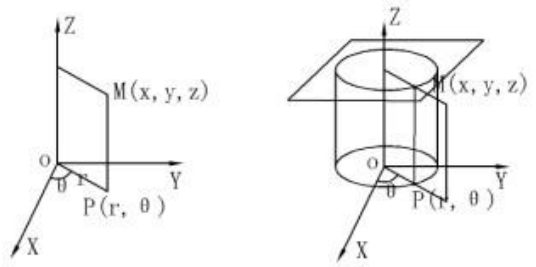
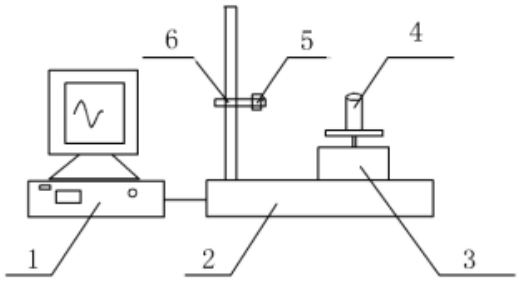


Fig.3 Cylindrical coordinate system

3. Hardware Design

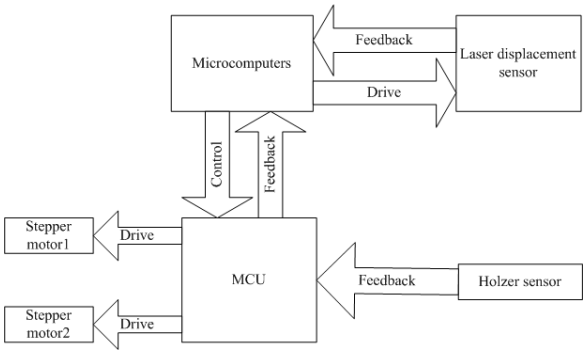
As known by the principle of system of measurement, r is the distance between the center of the laser displacement sensor and each point in the surface of the object, θ is the rotating angle of the turning platform, and z is the distance of vertical movement of the screw in cylindrical coordinates. Fig.4 (a) is the system composition diagram, and (b) is the system relationship diagram.

The vertical motion platform which led movement of the laser displacement sensor is manly composed by the screw and the straight shaft.



1-Microcomputer, 2-Motion control box,3-turning platform, 4-The object,5-Laser displacement sensor, 6-Vertical motion platform

(a) Composition of the system



(b) System relationship diagram

Fig.4 The system hardware design

4. Software Design

To complete the measurement of the surface of the object by the 3D measurement system, the system ought to obtain the measurement data and control the turning platform motor and the screw motor respectively. Secondly, in order to obtain measurement data conveniently, the system can control the speed of turning platform and screw, and can set the parameters of laser sensor. Finally, the system needs to record the initial position of the collected data in order to improve the accuracy of the measurement through the repeated measurement. The control of the 3D surface measurement system is based on MCU(Micro Controller Unit, also known as Single Chip Microcomputer) and PC[4], which is communicated through RS-232 to achieve the above objectives, and the work flow is as follows: starts the system to work, set the parameters, collect data during the turning platform turns, stop the data collecting and save the data after the turning platform finishes a circle, and then move up the screw. After the screw reaches the position, repeat the two steps above until the whole object is scanned. Finally, process the collected data to complete the 3D reconstruction. The workflow diagram of measurement system is shown in Fig.5.

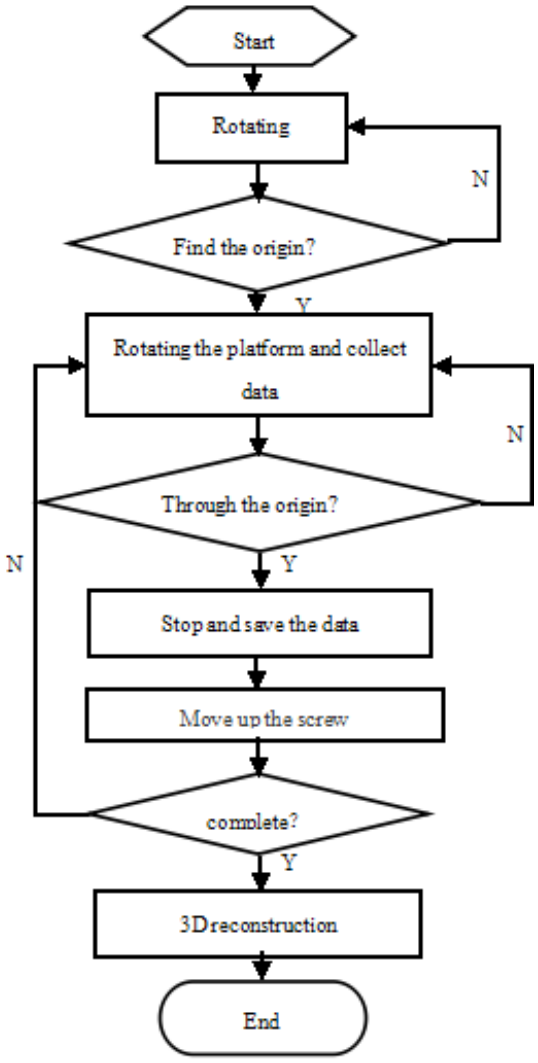
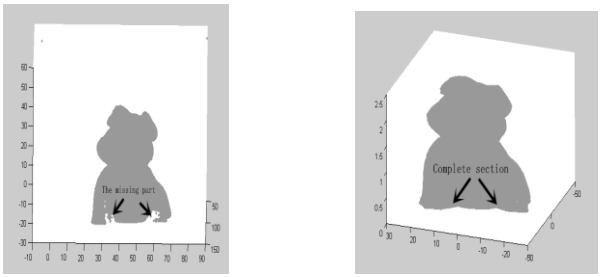


Fig.5 The work flow diagram of measurement system

5. Experiments and Results Analysis

In the experiment, the parameter selection in the 3D surface measurement system software is based on the measured object surface characteristics. The more prominent features of the measured object surface, the higher the sampling density is. The sampling density is determined by the rotary speed, screw moving distance, sampling frequency of laser displacement sensor and the number of data. The speed of turning platform and the moving up distance of screw is inversely proportional to the collection density, while sampling frequency of laser displacement sensor and the number of data are proportional to the sampling density.

Fig.6 shows the measurement result by the proposed 3D surface measurement system of the same object as shown in Fig.2. Compare the two measurement results, it is found that data collected by point structured light scanning of three-dimensional measurement system is more complete than the linear laser structural scan, and there is no "blind area," too.



(a) (b)

Fig.6 The results of data analysis and processing

A partially enlarged schematic diagram is shown in Fig.7, (a) is the missing part enlargement, and (b)is the complete section enlargement.

(a)The missing part enlargement

(b) Complete section enlargement

Fig.7 Partial enlarged view

The image reconstruction workflow of 3D surface measurement system is as follows: firstly, read the data from the measurement system work file in turn. Secondly, analysis and processing the read data, preservation valid data, excluding invalid data. Finally, reconstruct the 3D image according to the processed data to obtain 3D profile of the measured object. The program flow chart is shown in Fig.8.

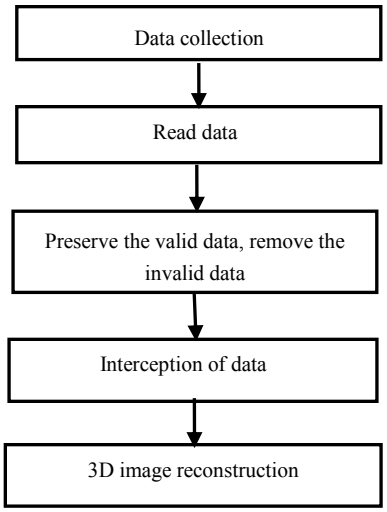


Fig.8 The flow chart of image reconstruction

In the experiment, the laser displacement sensor sampling frequency is set as collect 10 times per second, and save once paper 10 the collected data, the screw moves up 0.25 pitch(pitch P=5mm)every time. The test result is shown in Fig.9.

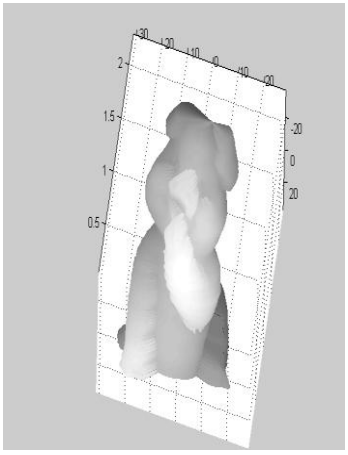


Fig.9 Reconstruction drawing objects

The experimental result shows that the 3D surface measurement system solves the "blind area" problem effectively in the process of linear structured light scanning, and achieve the expected requirements.

6. Conclusions

A 3D measurement system is designed based on laser sensor using point structured light scan, avoid the problem of "blind area" effectively. Use the cylindrical coordinates, which is obtained by MCU controlled stepper motor to complete the 3D image reconstruction, and then implement a low-cost and convenient measurement system.

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