ACQUIRING INITIAL VALUE OF MULTI-VIEW METRICAL DATA INTEGRATION

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ABSTRACT:

Acquiring the initial value of all profile of the object is essential for the integration of metrical data. It is described a new smart approach to acquire the initial value of all profile of the object in this paper, which is only to compute the calibration parameters of CCD camera and the projector in every angle, but not to do the complicated coordinate conversion. In the origin position the CCD camera and the projector are calibrated by using the relation of 2D-DLT and collinearity equation orderly. And the CCD camera is calibrated in every visual angle by the rotating grid table. While the positions of the camera and the digital projector are both never removed in the whole process, the calibration parameters of the projector are computed successfully through the transformation matrix. The experimental results indicate that the proposed method is helpful to the multi-view metrical data integration in the 3D measurement.

1. INTRODUCTION

The CCD camera and the projector are to be calibrated before 3-D measurement, and then it is not adjusted for the interior and exterior orientation elements of the CCD camera and the projector again. For the limitation of the view range of measurement, which does not meet the need of the whole object measurement, there are two solutions to resolve the problem. One makes use of the rotating table, the other dose not. There are two methods by using the rotating table. One is obtained the exact position by the precise servo mechanism, where vision sensor is fixed on and its measurement pose is adjusted scheduled orientation by detecting and programming of multi-sensors. The other is offered by the rotating table and revised by the software, where the object is rooted the rotating table and rectified the relative position with the vision sensor by turning the rotating table. It is presented the binocular stereovision system based on CCD camera and projector, in which the exterior orientation elements of CCD camera and projector in every angle can be calculated by making use of rotating grid table. Then it makes it possible to multi-view data integration, but avoids coordinate rotation and initial match. This paper is structured as follows: in section 2, reference frame is presented. Then section 3 explains the new smart approach to acquire the initial value of point cloud in every side of the model. Section 4 presents some experimental results and section 5 discusses the conclusion.

2. REFERENCE FRAME

2.1 System Configuration

In this paper, the 3-D measurement system is composed of five components: a charge coupled device（CCD）camera, a digital projector, rotating grid table, an object to be measured, and a personal computer with an image grabbing and processing board, as shown in Fig.1. The rotating grid table can be controlled by the personal computer to rotate arbitrary angle, which are flexible, precise and fully software programmable.

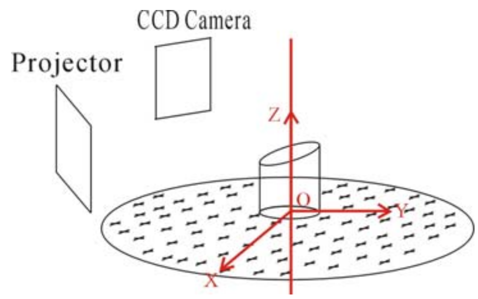

Fig.1 reference frame in the measurement system

2.2 Reference Frame

The whole 3D measurement process is not separated from the reference frame. Taken Fig.1 as an example, there are generally five reference frames.

1）Reference frame in original position of the rotating grid table

Reference frame in original position of the rotating grid table $OXYZ$ is reference frame in zero position, where the center of the rotating grid table is the origin of the reference frame. Then the axis of X and Y constitute the plane which is in the rotating grid table. The direction of Z axis is vertical to the plane each other.

2）Reference frame in arbitrary position of the rotating grid table

Reference frame in arbitrary position of the rotating grid table is reference frame of the rotating grid table which is turned to an angle. The new reference frame is obtained from circling the axis of Z in $OXYZ$ and rotating an angle. In the mergence of traditional metrical data, the metrical data, which is got by rotating certain angle on the rotating grid table, is to be transformed to reference frame in original position. And every model data is corresponding to every rotating angle of rotating grid table. Therefore coordinate transformation is needed to merge all model data.

3）Reference frame of the object

Reference frame of the object takes the object as reference object. In spite of the change concerning other reference frame to the object, its point coordinates are still fixedness.

4）Reference frame of the CCD camera

Reference frame of the CCD camera is the reference frame which is considered the observer as the center.

5）Reference frame of the projector

Reference frame of the projector is the reference frame which is considered the observer as the center, which is different from that of CCD camera. So they are respectively two disparate coordinates. To avoid coordinate transformation for the complicated metrical data and complete the data integration[1,2,3] of multi-view, it is operated only in one reference frame. It always takes the rotating grid table as a reference object, that is to say it is fixed. Considering coherence of reference frame among arbitrary position of the rotating grid table, CCD camera and projector are running. Then working out their exterior orientation elements and calculating every model point in every angle of view by space intersection. Thereafter all the point cloud unified to one reference frame, which doesn't need to coordinate transformation and provides good initial value to data integration for every point cloud of the model[4,5].

3. ACQUIRING INITIAL VALUE

3.1 Calibration of CCD Camera and Projector in Origin Position

The purpose of camera and projector calibration is to find the relations between 3-D space and 2-D planes(camera image plane and projector slide plane). This calibration step is very important since the coordinate computation depends on the accuracy of calibration.

As the rotating grid table is firstly designed to be able to get the coordinates of the points of the grid, and the image of the planar grid captured from camera is acquired, the camera is calibrated by using the relation of 2D-DLT and collinearity equation. A light stripe projected from the projector is usually called as a virtual image. The light stripe captured by the CCD camera is the intersection of the light stripe plane and the object surface. Before the calibration of the digital projector, the rotating grid table should be covered by a white paper or other things, which make the primary planar grid seems to be a white plane. The calibration of the projector is used structured light with light stripe pattern as the pattern has its characteristic. For the calibration of the digital projector, the camera is required to have been calibrated already or its intrinsic parameters are known in advance. A target grid slide is designed first so that the coordinates of its grid points can be got as the known datum for the projector. The camera is used to take an image of the planar grid table while the positions of the camera and the projector are always fixed. The coordinates of the grid points in the image projected on the planar grid table, which are considered as the space 3-D coordinates of the grid points, are worked out by using the image processing method. As the space 3-D coordinates of the grid points projected have been got by the process, and the image coordinates of these points in the target grid slide are known as is designed in advance, the calibration parameters of the slide projector can be computed by using the relation of 2D-DLT and collinearity equation[6]. Furthermore, the values of the lens distortion existing in the commercial projector are simultaneously calculated.

3.2 Initial Value Acquisition in Every Angle of View

If not depended on the rotating grid table, to acquire initial value in every profile of the object to be measure is to calibrate the CCD camera and projector in every different position. So it is to remove them and repeat the operation in the origin position, which need human intervene and reduce the degree of automation. According to the turning angle by the rotating grid table, the special point coordinates of the crosses relative to those in origin position is calculated. And the correspondence coordinates of the images are got by the interior and exterior orientation elements of the CCD camera and the projector in origin position, which is considered as the initial coordinates of the images. It is completed the corresponding problem between the special point and the image point for the angle change. Then taking the rotating grid table as reference frame, where the special points are fixed all the time, the CCD camera is calibrated in every different position since the special point coordinate and the corresponding image coordinate are known.

The camera and the projector in the original orientation is calibrated by using the approach of 2D-DLT(two dimensional direct linear transformation) and collinearity equation. Take the original orientation of the rotating table as the reference frame, while the table is rotating, the exterior orientation element Z_s of CCD camera in every angle is never variable and X_s, Y_s is changed by the angle. Known the exterior orientation elements of CCD camera in the original orientation, its exterior orientation elements in every orientation are reckoned by its angle, as shown in Formula(1), (2)and(3). Then extracted precisely the center of the cross, its exterior orientation elements in every orientation are calculated accurately by resection as known its interior orientation elements, the space point coordinate of the center in the cross and the corresponding mage coordinate.

Assumed that capturing the $i-1(i \geq 2)$ th image, the grid table contrarotates θ by Z axes, then the orientation of the CCD camera corresponding to the i th image is:

$$\begin{pmatrix} X_{S_i} \\ Y_{S_i} \\ Z_{S_i} \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \sin\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X_{S_{i-1}} \\ Y_{S_{i-1}} \\ Z_{S_{i-1}} \end{pmatrix} \tag{1}$$

The corresponding rotation matrix is:

$$R_i = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \sin\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} R_{i-1} = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \sin\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{pmatrix}$$
$$= \begin{pmatrix} a_1\cos\theta + b_1\sin\theta & a_2\cos\theta + b_2\sin\theta & a_3\cos\theta + b_3\sin\theta \\ -a_1\sin\theta + b_1\cos\theta & -a_2\sin\theta + b_2\cos\theta & -a_3\sin\theta + b_3\cos\theta \\ c_1 & c_2 & c_3 \end{pmatrix} \tag{2}$$

According to the rotation matrix, the three rotation angles are respectively as follows:

$$\tan \varphi_i = -\frac{a_{3i}}{c_{3i}} = -\frac{a_3 \cos\theta + b_3 \sin\theta}{c_3}$$
$$\sin \omega_i = -b_{3i} = a_3 \sin\theta - b_3 \cos\theta$$
$$\tan \kappa_i = \frac{b_{1i}}{b_{2i}} = \frac{a_1 \sin\theta - b_1 \cos\theta}{a_2 \sin\theta - b_2 \cos\theta} \qquad (3)$$

The direction cosines in Fomula(3) is that of the i th image.

While the position of the projector and CCD camera is fixed, the transformation matrix[7] between them can be calculated in the first place. Then the calibration parameters of the projector in every angle can be computed as the calibration parameters of CCD camera is known in every corresponding angle. Equation (4) indicates that the rotating matrix of the projector in every angle, where R_{P_i} and R_{C_i} are respectively the rotating matrix of the projector and CCD camera in the i th angle, $R_{C_1}^{-1}$ is a corresponding inverse of the rotating matrix R_{C_1} of CCD camera in the first place, R_{P_1} is the rotating matrix of the projector in the first place. In the equation (5), Xs_{Pi} , Ys_{Pi} , Zs_{Pi} and Xs_{P1} , Ys_{P1} , Zs_{P1} are respectively the three position elements of the projector in the i th angle and in the first place, while Xs_{Ci} , Ys_{Ci} , Zs_{Ci} and Xs_{C1} , Ys_{C1} , Zs_{C1} are respectively the three position elements of CCD camera in the i th angle and in the first place.

$$R_{P_i} = R_{C_i} \cdot R_{C_1}^{-1} \cdot R_{P_1} \qquad (4)$$

$$\begin{bmatrix} Xs_{Pi} \\ Ys_{Pi} \\ Zs_{Pi} \end{bmatrix} = \begin{bmatrix} Xs_{Ci} \\ Ys_{Ci} \\ Zs_{Ci} \end{bmatrix} + R_{C_i} \cdot R_{C_1}^{-1} \cdot \begin{bmatrix} Xs_{P1} - Xs_{C1} \\ Ys_{P1} - Ys_{C1} \\ Zs_{P1} - Zs_{C1} \end{bmatrix} \qquad (5)$$

While the calibration parameters of CCD camera are computed by space resection[8, 9] with iterative method after rotating an angle, simultaneously the calibration parameters of the projector are done in the corresponding position. Calculated the interior and exterior orientation elements of CCD camera and the projector in every angle, the point cloud of the model in every view is obtained by space intersection. Then all the point cloud is in the same reference frame and it provides perfect initial value to the next seamless registration.

4. EXPERIMENTAL RESULTS

Table 1 lists the results computed in origin angle, which are the interior orientation elements of the CCD camera and the digital projector

parameter	CCD Camera	Digital Projector
f	3807.86904 pixel	2819.00516 pixel
x0	650.77228 pixel	510.07340 pixel
y0	498.95924 pixel	381.77845 pixel

Table 1 the interior orientation elements of CCD camera and the digital projector=

Based on the above depicted, it is calculated the calibration parameters of the CCD camera and the digital projector in every angle of view. And it is charted as shown in Fig.2 and Fig.3, which are distributed regularly. For it is circled by the plane of the rotating grid table, the change of the Zs value is almost invariable from Fig.2 and Fig.3, and the other five parameters distribute regularly in such as sinusoid, cosine, etc. And it is obtained the initial value owing to the calibration parameters of the CCD camera and the digital projector in every angle of view. Furthermore it can be also forecasted in every visual angle from them. And Fig.4 is shown the result of 3D model of sheetmetal part.

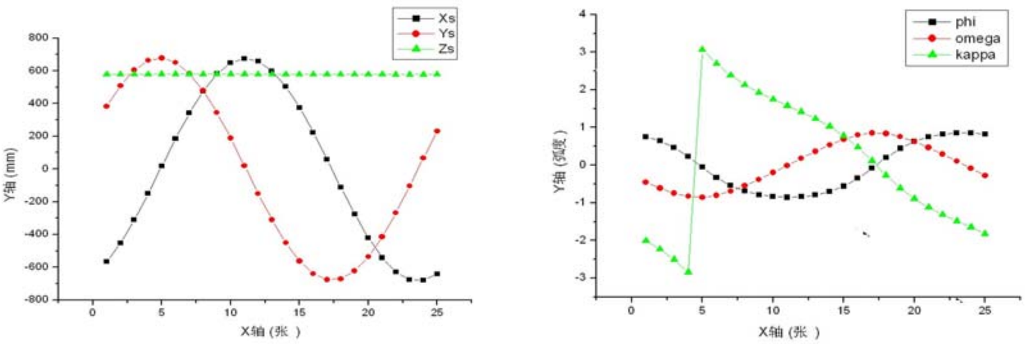

Fig.2 the exterior orientation elements of CCD camera in every visual angle

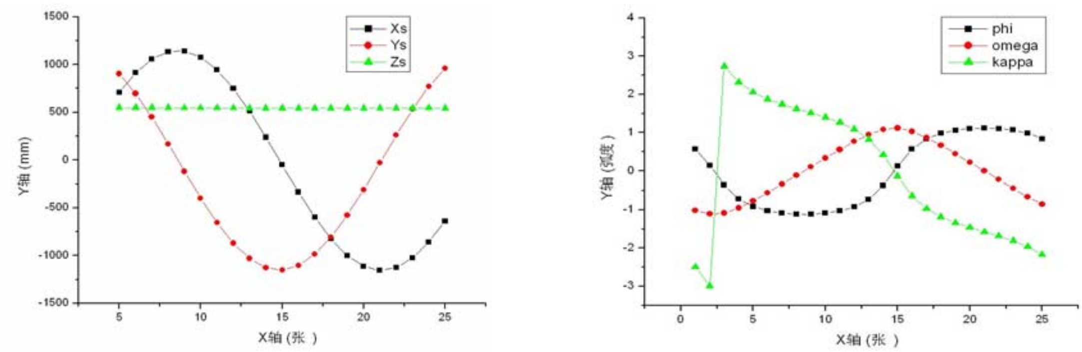

Fig.3 the exterior orientation elements of the digital projector in every visual angle

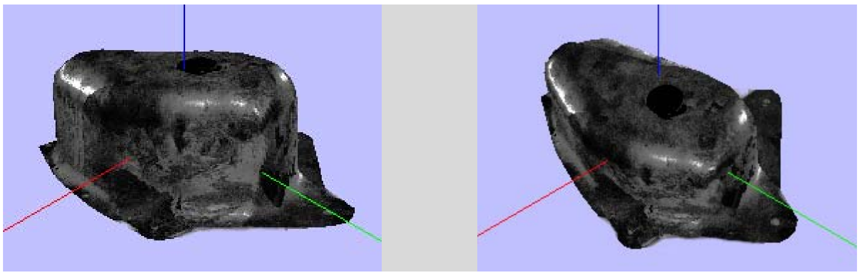
Fig.4 The result of 3D model of sheetmetal part

5. CONCLUSION

It is presented a new smart approach to acquire the initial value of all profile of the object in this paper, which is only to compute the calibration parameters of CCD camera and the projector in every angle, but not to do the complicated coordinate conversion. In the whole process, the positions of the camera and the digital projector are both never removed. The untouched method which has high efficiency and strong automation is essential to merge the metrical data of all the model. And the experiments indicate that the proposed method plays an important role in the multi-view metrical data integration of the 3D measurement.

6. REFERENCES

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