Research on Aircraft Skin Defect Identification Method based on Point Cloud Processing

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Abstract

The outer surface of aircraft skin may be subjected to external impacts during aircraft service, such as hail, stones, birds, etc., which can cause surface depressions and have very serious consequences. In order to detect these defects, this article uses a binocular camera to obtain damaged skin point clouds and detect defects. Firstly, the binocular camera was calibrated using Zhang Zhengyou's calibration method. Then, the defect point cloud was preprocessed by point cloud filtering and point cloud simplification, and a standard point cloud model was fitted using the defective point cloud; The point cloud feature descriptor sub algorithm based on Fast PointFeature Histogram (FPFH) and the Nearest Point Iteration (ICP) algorithm were used to perform coarse and fine registration on two point clouds. Finally, the Euclidean distance was calculated on the registered point clouds to complete defect detection.

Keywords

Binocular Vision; Point Cloud Denoising; Point Cloud Registration; Defect Recognition.

1. Introduction

The aircraft skin, as a streamlined outer surface fixed to the aircraft skeleton, plays a role in protecting the internal structure and reducing flight air resistance. During the service process of aircraft, the outer surface of the aircraft skin will inevitably have concave defects formed by the impact of hail and stones, which require regular damage detection and maintenance of the aircraft skin. At present, the detection of aircraft skin is mainly based on manual visual inspection, which heavily relies on manual experience and has low efficiency. 3D point cloud processing technology can effectively identify defects and is very suitable for skin defect detection.

At present, binocular vision technology is widely used in defect detection.Zong Yulong[1] established a three-dimensional surface defect recognition system based on binocular vision. This system first calibrates the binocular camera, establishes a mapping relationship between three-dimensional point clouds and color images, and uses the mapping relationship to segment the defect area using graphic segmentation algorithms and point cloud segmentation algorithms to obtain the three-dimensional point cloud feature parameters of the defect area. Wang Kaixuan[2] used a binocular camera to obtain the point cloud inside the gas cylinder, designed different defect detection methods based on the

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characteristics of different protruding defects, and completed three-dimensional reconstruction of the inner wall.

Regarding the 3D point cloud defect detection algorithm, Zhao[3] simplified the obtained steel cylinder point cloud data using a filter from the Point Cloud Library (PCL) and reconstructed it in 3D, ultimately obtaining the position of the concave depth on the cylinder surface. Li [4] used point cloud processing technology to detect rotor surface defects. Firstly, a three-dimensional measuring instrument was used to obtain the point cloud data of the test rotor surface. The ICP algorithm was used to unify the standard rotor point cloud and the test rotor point cloud into the same coordinate system, and point cloud registration was performed. Identify defects by comparing the feature differences between two point clouds. Han Ruilu[5] studied the defect problem of aircraft engine blades and designed a defect feature recognition method based on Euclidean distance by comparing the difference between the defect point cloud and the standard point cloud. Defects of different sizes were identified with different colors. Li Xin错误!未找到引用源。 used drones to install visual equipment and proposed an algorithm based on rear vision positioning to obtain global 3D information of aircraft skin. Combined with the YOLOv4 object detection structure, the 3D position information of aircraft skin defects was obtained, achieving defect localization. Zhang Yan错误!未找到引用源。 used the region growth segmentation algorithm to obtain the point cloud of aircraft skin defect areas, achieving precise positioning of the defect point cloud, and projected the 3D defect point cloud onto a plane to solve for defect size information, achieving defect localization and quantitative characterization of the 3D point cloud.

This article takes defective skin as the research object, and first uses Zhang Zhengyou calibration method to calibrate the binocular camera, achieving the acquisition of point clouds. Furthermore, point cloud filtering and point cloud simplification preprocessing were performed on it, and a standard point cloud model was fitted using defective point clouds. Furthermore, the point cloud feature descriptor sub algorithm based on Fast Point Feature Histogram (FPFH) and the Nearest Point Iteration (ICP) algorithm were used to perform coarse and fine registration on two point clouds. Finally, defect detection is completed by calculating the Euclidean distance of the registered point cloud. Research has shown that the 3D defect detection algorithm in this paper can quickly and effectively extract point cloud data of aircraft skin defects, laying a good foundation for future defect point cloud size calculation.

2. Double Target Experiment based on MATLAB

This paper uses Zhang Zhengyou checkerboard binocular calibration method to calibrate binocular cameras, which needs to use the calibration toolbox in MATLAB software to obtain the internal and external parameters of binocular cameras. The detailed process of its calibration is as follows:

Firstly, a calibration plate with a side length of 5mm was selected for calibration experiments, and diagonal points were detected. Finally, the reprojection error was obtained as shown in Figure1.

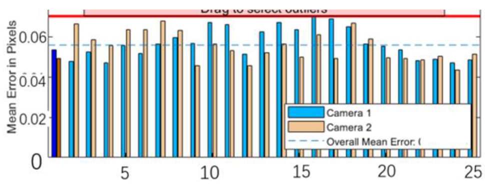

Figure 1. Calibration error results

After output calibration results, we can see that the internal parameter matrix of the left CCD camera is:

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$$\begin{bmatrix} 7946.86867 & 0 & 1275.51732 \\ 0 & 7947.94504 & 1024.86205 \\ 0 & 0 & 1 \end{bmatrix}$$

The internal parameter matrix of the right CCD camera is:

$$\begin{bmatrix} 7946.35324 & 0 & 1240.28645 \\ 0 & 7945.42565 & 1015.73696 \\ 0 & 0 & 1 \end{bmatrix}$$

The external parameters result in:

$$\boldsymbol{R} = \begin{bmatrix} 0.9571 & -0.0162 & -0.2893 \\ 0.0169 & 0.9999 & 0.0096 \\ 0.2892 & -0.0049 & 0.9573 \end{bmatrix}$$

$$\boldsymbol{T} = \begin{bmatrix} -53.7707 \\ 0.3287 \\ 7.7224 \end{bmatrix}$$

Finally, three-dimensional point clouds are obtained, as shown in Figure 2.

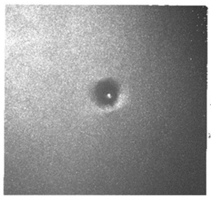

Figure 2. Defective point cloud model

3. 3D Point Cloud Data Preprocessing

A Identification of Aircraft Skin Defects

The specific steps for defect detection are as follows.

(1) 3D point cloud data preprocessing:

For these features, this paper adopts a statistical filtering algorithm to eliminate outliers. The statistical filtering algorithm[8] is to find all point clouds and calculate the average distance between each point and its nearest k neighboring points. In this paper, the voxelized grid method[9] is adopted to simplify the point cloud.

(2) point cloud registration:

First,this paper adopts RANSAC algorithm[10] to obtain the standard point cloud model.Reuse point cloud registration[11] technology to register standard point clouds and defect point clouds.

(3) Aircraft skin defect identification:

After the coarse and fine registration of the defective point cloud and the non-defective point cloud, the two point clouds at this time have overlapped, and the different points after the coincidence are the defects to be identified. This paper aims to identify the damaged defects caused by foreign body impact, and adopts European distance to identify the defect point cloud.

Finally, the defect location is displayed, and the defect part is marked in red, as shown in Figure 3.

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(a) Front view (b) Defect magnification map

Figure 3. Defect display diagram

4. Conclusion

In view of the concave damage caused by long-term exposure of the outer surface of the aircraft skin to the external environment during the service period, a defect detection algorithm based on three-dimensional point cloud was proposed. Firstly, binocular equipment was calibrated to obtain the point cloud with defects, then the defect point cloud was filtered to remove outliers, and then point cloud simplification was carried out to improve computing efficiency. Then the RANSAC algorithm is used to obtain the fitting point cloud without defects, and the fitting point cloud and the defective point cloud are coarse and fine registration operations. Finally, the Euclide distance of the two point clouds is calculated and compared with the set threshold value. The defects are displayed in red to realize the visualization of the defects, which lays the foundation for the next step to measure the size of the defects.

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