High Value Bit Model Reconstruction and Damage Identification Based on Binocular Robot

Jingsen Yan¹, Weidong Hao², Daoguo Yang³, Ruiqing Wang⁴

¹Guilin University of Electronic Technology, Guilin, Guangxi, CHINA
²Guilin University of Electronic Technology, Guilin, Guangxi, CHINA
³Guilin University of Electronic Technology, Guilin, Guangxi, CHINA
⁴Guilin University of Electronic Technology, Guilin, Guangxi, CHINA

bemail: emegyd@guet.edu.cn

Abstract: In order to achieve high value bit repair, bit model reconstruction and damage identification must be carried out. In this paper, the binocular camera and the industrial robot were combined to realize the point cloud acquisition, model reconstruction and damage identification of the bit. The bit damage data obtained by this method was applied to the repair experiment of the bit and the repaired bit met the requirements of re-use.

1. Introduction

Drill bit is a kind of drilling tool commonly used in oil drilling industry. It is the main consumable material with high value, large usage and easy wear. Polycrystalline Diamond Compact bit (PDC bit) has the characteristics of high wear resistance, high strength and impact resistance. The use of PDC bit is huge, more than 100,000 per year in China. The PDC is very repairable and can restore 80% to 90% of the performance after repair but the cost is only about one-third of the cost of buying a new bit. Drilling bit repair can avoid resource waste, the economic and social benefits are very significant[1]. In the process of bit repair, accurate 3D modeling and defect identification are the important prerequisites to ensure the repair effect. In this paper, combined with the engineering practice, the use of binocular camera to complete the bit 3D modeling and defect identification.

2. Principle of Binocular Measurement

The measurement principle of binocular stereo vision is to observe the same object from two viewpoints to obtain the perception image in different perspectives. The three-dimensional information of the scene is obtained by calculating the position deviation (parallax) between the image pixels through the triangular geometry principle[2]. The ideal binocular camera imaging model is shown in figure 1. The imaging plane of both cameras is on the same plane, the focal length is the same and the abaxial is parallel. Points O₁ and O₂ in the figure are optical centers of the left and right cameras, α and β are the imaging planes of the left and right cameras. For target points P(x, y, z) in space, the imaging points in the camera are P L(xL,yL) and P R(xR,yR). The straight-line distance from the imaging point of the left camera optical axis on the α plane to P L is denoted by “xL”, similarly, the straight-line distance from the imaging point of the right camera optical axis on the β plane to P R is denoted by “xR”. Set up the
coordinate system as shown in the figure with the optical center of the left camera as the origin. The distance from \(O_L\) to \(O_R\) is denoted by “\(b\)” and the focal length of both cameras is denoted by “\(f\)”. 

![Figure 1 Binocular camera imaging model](image)

According to the geometric relation in the figure and the triangulation method, the following relation can be obtained:

\[
\frac{z}{f} = \frac{x}{x_L} = \frac{b-x}{x_R} = \frac{y}{y_L} = \frac{y}{y_R}
\]  \(1\)

The coordinates of \(P(x, y, z)\) can be obtained from equation (1):

\[
x = \frac{b \cdot x_L}{x_R + x_L}, \quad y = \frac{b \cdot y_L}{x_R + x_L}, \quad z = \frac{b \cdot f}{x_R + x_L}
\]  \(2\)

3. Model Reconstruction and Damage Identification

3.1 Collect point cloud data

Accurate data often comes from the equipment and measurement method used in the measurement process. In this paper, the Blu-ray binocular non-contact 3D scanner designed by TECHLEGO is used for point cloud data acquisition. The scanner has an accuracy of 0.005mm, a scan time of less than 0.3 seconds and the use of blue light as a light source effectively prevents ambient light from interfering. The scanner has the advantages of accuracy and efficiency. In order to avoid the blind spot in the scanning process, the binocular camera and the industrial manipulator are combined to form a hand-eye measurement system. By taking advantage of the robot's characteristics of flexible movement and convenient control of space position and pose, the omnidirectional and multi-angle acquisition of the bit point cloud data is realized. The result of scanning point cloud is shown in figure 2.
3.2 Data processing
The point cloud obtained by a complete scan has millions of data points, some of which are unnecessary for model reconstruction and redundant for subsequent analysis and calculation. Excessive amount of data will affect the effect of model reconstruction and even make it impossible to carry out three-dimensional reverse. In order to reduce the amount of data to be processed and improve the processing efficiency, simplify the processing of the obtained point cloud is necessary [3].

In the process of scanning the drill bit by the system, factors such as surrounding scenes and equipment themselves will affect the scanning results, so that some unnecessary data will be mixed in the acquired point cloud, such as objects outside the drill bit and interference data in the environment will be scanned. Discrete points in the point cloud that do not represent the geometry of the bit can be removed by commands such as "Outliers" in reverse software Geomagic Studio or manually selected, while "Reduce Noise" and "Uniform sample" commands can effectively reduce noise and redundancy in the point cloud. Through the corresponding processing of the measured point cloud data, the quality of the subsequent bit model reconstruction can be positively affected [3-4].

3.3 Reverse model reconstruction
The performance of geometric features of the bit point cloud model is not intuitive enough, it is very difficult to use the point cloud model to identify and align features and obtain the bit damaged body. In order to solve the above problems, the point cloud should be transformed into a polygon model. Reverse model reconstruction is to build the topological relationship between points through algorithm and connect a large number of point data into grid data according to rules [5]. In fact, the polygon model is the connection of each point in the point cloud to form the interconnected polygon (triangle) surface [4]. The processed bit point cloud data can be transformed into the bit polygon model as shown in Figure 3 through the "Wrap" command.
Figure 3 Bit polygon model (left) and hole area enlargement (right)

As can be seen from Figure 3, the generated polygon model of drill bit has many different types of defects, such as holes and nails. It needs to be optimized by “Remove Spikes”, “Fill Holes” and other further operations. After processing, the drill bit model is shown in figure 4. The deviation ratio between the reconstructed model and the standard model is shown in figure 5. It can be seen that most of the area is not deviated from the standard bit, especially the Gauge Protection and Groove deviations used for model registration are within 1 mm.

3.4 Obtain the damaged body model
The damage data can be obtained by comparing the model of the damaged bit with the standard bit model. The bit repair needs to determine the repair area and plan the repair path based on the data obtained. Accurate acquisition of damaged body is an important prerequisite for bit repair. First, match and align the two models. Use Geomagic Studio's "Manual Registration" command to align two models by specifying feature points to match as shown in figure 6. After the model of the damaged bit is aligned with the standard model and the Boolean subtraction operation is carried out, the resulting model is the damaged body of the bit to be repaired.
Through the analysis of the damage data obtained, it can be concluded that the surface of the bit has been damaged to different degrees after a period of use. The gray area in figure 7 is the position of the partially damaged body on the bit. Figure 8 shows the partially damaged body model.

4. Experimental Verification

After analyzing the damage data obtained, the model is slicing analyzed and path planning is carried out according to the cladding process requirements. Finally, the program file that can be executed by the robot is obtained and the instructions are sent to the robot for execution. The whole cladding process is shown in figure 9. The robot first moves quickly from software zero point to the top of the area to be repaired and controls the powder feeder through its own output port to start feeding powder. The robot then slowly approaches the work piece to prepare for repair work. When the robot moves to the starting point of the repair path, the control laser turns on to start the repair work. During the whole working process, the chiller needs to work all the time to cool the laser and laser lens. After finishing all the work, the robot sends the stop command to the powder feeder and the laser and returns to zero to wait for the next command.
Figure 9 Diagram of robot laser cladding system

The above experiments verify the method described in this paper. Figure 10 shows the measurement working scene of the binocular robot. According to the data obtained by this method, the experiment completes the bit work, and the repaired bit can be put into use again through simple polishing. Figure 11 shows the bit waiting to be used after repair.

5. Conclusions
In this paper, the model reconstruction and damage identification of high-value drill bits are realized based on binocular robot. The combination of robot and binocular camera can effectively avoid the
measurement blind area and improve the accuracy of cloud collection. The streamlined processing of point cloud can effectively improve work efficiency. In the final repair experiment, damage data were extracted according to the method described in this paper and the obtained data were used to complete the repair work of the bit. After the repair of the drill through the actual test to meet the requirements of re-use.

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