A Path Planning Method Based on Robot Automatic Grinding of Drills

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Abstract—This paper proposes a path planning method for grinding excess material after PDC bit repair using industrial robots. Firstly, a 3D scanning instrument is used to obtain point cloud data of the bit to be ground, secondly, this data are imported into Geomagic Studio for processing to obtain the triangular sheet file of the area to be ground. Finally, the software based on MATLAB is used to process the file and calculate the motion path of the robot end-effector. The generated path is imported into ROS for simulation. By comparing the generated path with the grinding area, it was verified that the generated path could be used in actual operation.

1. Introduction

PDC drill bit is a composite drill bit composed of diamond and bit body for drilling operations. Its production cost is high and it is the main consumable in drilling operations, but its repairability is strong, and the use effect after repair can reach more than 80\% of the initial design, so PDC bit repair has great economic research value. Among them, the use of laser cladding to repair PDC drill bits is a popular research direction. Its repair effect is good and the repair speed is fast, and it is easy to realize automation\textsuperscript{[1]}. After laser cladding is used for repair, there must be a small amount of excess material that needs to be removed. The traditional treatment method is to use manual grinding, but the material used to repair the PDC drill bit has the characteristics of high wear resistance and high hardness after cladding. Most of the shapes that need to be ground and removed are irregular, and the PDC bit itself is heavy. The manual polishing operation is difficult and takes a long time. Therefore, this article proposes a path planning method that can be used to grind and remove excess materials using robots.

2. Point cloud data acquisition and processing

2.1. Acquisition of point cloud data

To realize automatic grinding, it is first necessary to obtain accurate position data of the drill to be ground. The data acquisition tool used in this article is a non-contact blue light scanner Q3 designed and manufactured by high-tech. This instrument has a fast scanning speed and a scanning accuracy of 0.005 mm. The blue light has stronger penetrability, and it can also be used in complex light environments. Can work normally. Then install the device on the KUKA robotic arm (as shown in Figure 1), in order to obtain a flexible scanning angle, which can completely obtain the point cloud data of the entire drill bit. The original point cloud data obtained by scanning is shown in Figure 2.
2.2. Point cloud data processing

The blue light scanner can automatically splice the pictures scanned each time. When a complete scan of the drill bit is performed, the original point cloud structure obtained contains millions of data points. The point cloud structure cannot be directly used to generate a drill bit model, because it may contain non-drill data points, and the model needs to be preprocessed to filter non-drill data points.

At the same time, there will be some data redundancy in the drill bit data. This part of the data are not helpful for modeling and will reduce the processing efficiency, so it will be streamlined\(^2\).

The processed point cloud data are still in discrete form, which cannot accurately display the actual surface of the drill bit, and it is difficult to accurately obtain the area to be removed by grinding. For this reason, Geomagic Studio is used to encapsulate the point cloud file into a polygonal model. The
polygonal model generated by the package still has many defects, such as holes, wrinkles, etc., which need to be repaired through commands such as hole filling, deletion, and mesh repair [3]. After the previous series of processing, the scanned model obtained is shown in Figure 3. After this, the original model that can be compared is obtained.

2.3. Obtaining the model of the surface to be ground
Import the drill bit of the corresponding model in the model library (included in the factory design) into Geomagic Studio, match and align the drill bit with the original model of the drill bit processed above, and make the two models overlap by specifying the feature points. At this point, the area that needs to be polished will be revealed. Then use the Boolean operation tool in Geomagic Studio to obtain the redundant material model that needs to be polished and save it as an STL file.

3. Path Planning Method

3.1. Model slicing
The end posture of the robot is an important part of the grinding path planning, and it is the reference source for the robot control. During the grinding process, the grinding head will coincide with the normal vector of the point to be processed, and the moving direction of the end effector should be consistent with the tangent vector of the grinding point. With these two constraints, it is possible to determine the robot's working posture during grinding. The surface to be ground obtained above has a certain thickness, and each layer is planned to be ground 0.05mm, so the surface to be ground needs to be layered first.

MATLAB uses the stlread function to read the STL file generated by Geomagic Studio, which contains two large coordinate matrices, namely the index matrix and the vertex matrix. Take out the vertex index number and the three-dimensional coordinates of the vertices in order, sort them according to the size of the z direction value, and organize them into a new matrix of Vnx9: [x1, y1, z_min, x2, y2, z_min, x3, y3, z_max]. Each row represents the information of a triangular face, there are a total of N triangular faces. Then sort in the ascending order of the value of z_max. When z_max is the same, put the smaller value of z_min first. According to the previously planned 0.005mm $\Delta Z$, each layer calculates the contact with the triangle surface Z coordinate data, and selects the triangle surface set that only intersects with the current tangent plane. After dividing all triangles into layers, the layering task is completed, and the three-dimensional model becomes multiple planes [4].

Fig. 4. The relationship between the triangular facet and the grinding layer
Fig. 5. Layered model of the area to be polished
3.2. Single layer path planning
The irregular shape is transformed into the coordinate points of a two-dimensional area, and the problem is transformed into a traveling salesman problem for solution. The description is as follows: Knowing the simplified position of each redundant material area, it is necessary to traverse the coordinate points of each area to find the shortest arrangement of the total path, so that the total stroke of the end grinding actuator needs to be the shortest. This paper uses genetic algorithm to deal with single-level path planning. Genetic algorithm is to simulate the evolution process of nature. Through operations such as selection, crossover and mutation, it continuously searches for individuals with high fitness values, and continuously increases their number in the group. The process of finding the optimal solution is to find the best solution in many places. In the regional processing path planning, the integer permutation coding method is adopted. For the problem of m areas to be polished, the chromosomes are divided into m segments, and each segment is a code corresponding to the area to be polished. For example, the code “25143” means that the overall processing order of the area positions of codes 1 to 5 is 2 to 3. In the process of multi-region processing, the genetic preliminary ranking reduces each region to a point to determine the overall processing order [5].

![Fig. 6. 50 point TSP path planning](image)

3.3. Single layer path planning
After the path planning is completed, trajectory planning is also required. The two motion planning problems faced in the grinding process of the manipulator are the sequence of multiple areas to be ground and the trajectory planning between the positions to be ground. Trajectory planning is divided into joint space trajectory planning and Cartesian space trajectory planning. Joint space trajectory planning is to transform the joint variables of the robotic arm into a function of time, and then constrain the angular velocity and angular acceleration; Cartesian space trajectory planning is to transform the displacement, velocity and acceleration of the end of the robotic arm in Cartesian space into pairs. The function of time. This paper uses fifth-order polynomial interpolation function for trajectory planning [6].

4. Simulation
The process of generating the grinding path of the robot is as follows: First, obtain the STL file of the area to be ground through Geomagic Studio, and import the file into the MATLAB software, and calculate the position information and posture information of the robot through the toolkit in the software.
Then, the single-level grinding path point interpolation and the multi-level grinding diameter-level interpolation are optimized respectively to generate the motion trajectory of the robot end effector.

In the Ubuntu system, a grinding simulation system is built through the ROS platform to realize the functions of collision detection, process simulation, singularity detection, etc. At the same time, the robot posture information and the path of the program are added for simulation analysis, and the path is further optimized. According to the planned path generated in the previous article, it runs normally in the simulation system. The generated path is compared with the area to be polished. The path it passes is the area that needs to be polished, and there is no abnormal phenomenon.

5. Conclusion
This paper proposes a path planning method that can automatically remove excess material on the PDC bit. This method first needs to obtain the coordinate information of the area to be polished, and then use MATLAB to convert the coordinate information into path information that can guide the robot to polish. The path is simulated and verified by ROS, and it is determined that the generated path has strong security. Grinding by this method can effectively avoid the problem of damaging the normal area of the drill bit during manual grinding, and has a strong research value in actual engineering.
Acknowledgments
This work was co-supported by Science and Technology Major Project of Guangxi province (No. AA17204018), Natural Science Foundation of Guangxi Zhuang Autonomous Region of China (grant No. AD18281031), Guangxi Natural Science Foundation (2018GXNSFBA281126), Guangxi Key Laboratory of Manufacturing System & Advanced Manufacturing Technology, School of Mechanical and Electrical Engineering, Guilin University of Electronic Technology (The contract label :19-050-44-002Z).

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