Research on Assembly Path Planning Method of Low Speed Diesel Engine Based on Hoisting Characteristics

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Abstract. In assembly planning, it is important to select and determine the best path of assembly. An automatic assembly path planning method of low speed diesel engine based on hoisting characteristics is proposed in this paper. By analyzing the hoisting characteristics of low speed diesel engine components, the algorithm of automatic assembly path planning is designed and programmed in Python. The program can output the assembly path automatically according to the position information of assembly components, and it can also detect clashes in assembly paths. The test results are verified by virtual assembly, which proves that the method is reasonable and effective.

1. Introduction

Assembly path planning is the process of finding an appropriate path in a specific assembly environment⁴. Component can follow this path from its starting point to its end point without any clashes. Assembly path planning is the main research direction of computer aided process planning (CAPP)². Reasonable assembly path can improve assembly efficiency and quality, and it is of great significance in production management and quality control.

Assembly path planning based on virtual assembly can be carried out intuitively according to the constraint relationship and position relationship of components in virtual assembly environment⁴. However, the assembly path planning method based on virtual assembly needs to be performed through human-computer interaction, which is heavy and time-consuming⁴. An automatic assembly path planning method of low speed diesel engine based on hoisting characteristics is proposed in this paper, it can plan assembly path automatically according to assembly environment and components’ position.

2. The principle of component pose description in assembly path planning

The form of assembly path can be divided into three types: line, rotation, line and rotation. In the assembly process, the assembly path of each component is one or combination of these three forms. When all components are assumed to be rigid bodies, we can transform the transformation of the position and attitude of the component into the translation and rotation of its coordinate system. The three motion of coordinate system is shown in figure 1. In the research of path planning, rotation matrix and Denavit-Hartenberg (DH for short) matrix are often used to describe the spatial pose information⁵. Because the components of low speed diesel engine can only rotate in a small range during hoisting, it can be assumed that the hoisting process of parts is a translation process, and...
component doesn’t rotate during the process. Therefore assembly path can be described by translation matrix.

3. Automatic assembly path planning method of low speed diesel engine

3.1. Hoisting characteristics of low speed diesel engine

Unlike other complex mechanical products, most components of low speed diesel engine are heavy and need to be hoisted by crane. By analyzing the working characteristics of the crane and the relevant standards of the factory, the principles of the path planning method for hoisting components are as follows:

- Assembly path shall be connected by line segments parallel to three coordinate axes x, y and Z of spatial coordinate system.
- There should be as few the times of changing the direction in the assembly path as possible.
- The direction of the first segment at the beginning of the assembly path must be vertical upward.
- Before the end of the assembly path, a safe distance shall be reserved according to the assembly direction.
- When assembling along the assembly path, components and hoisting appliances shall not clash with obstacles.
- The components at the starting point is adjusted to the same pose as the end point, so the rotation matrix is 0.

3.2. Research on assembly path planning method

The structure of low speed machine is complex, which brings great difficulties to path planning. Simplifying the shape of components can greatly reduce the calculation of path planning. Place the bounding box of the component as a simplified component in the same position in assembly space. The envelope box of other components in the assembly space expands according to the size of the component which should be hoisted, and a C-Space is established. The establishment process of C-Space is shown in figure 2.
In order to ensure safety, transport will be selected on the central axis of the workshop passage. In order to prevent collision due to inertia, a safe point needs to be set before reaching the assembly end point, and the distance from safe point to the end point is set to 1 meter. The ideal path with the least number of times to change the direction of motion in the hoisting process: 1. Lift vertically from the assembly starting point of the components. The lifting height is 1m; 2. Slide horizontally to the position of the workshop passage's central axis; 3. Slide along the workshop passage's central axis to the position closest to the safe point on the channel central axis; 4. Move vertically upward to the position consistent with the safe point height; 5. Move horizontally to the safe point; 6. Move along the straight line to the assembly end point. The ideal hoisting path of the cylinder liner is shown in Figure 3, and the red dotted line is the assembly path.

The work flow chat of the assembly planning algorithm is shown in Figure 4. Firstly, determine the unit size to discretize the assembly space, and build the map in the three-dimensional coordinate system according to the position of each component. Components are composed of points in coordinate system. Secondly, select the component which should be hoisted and other components automatically expand according to the size of the component to generate the C-space. Then the component which should be hoisted is simplified as starting point. In the example, this point is the center of the bounding box. Additionally the assembly path is generated according to the coordinates of workshop passage’s central axis, safe point and end point. According to the characteristics of hoisting, the road finding function is established to find out the ideal path, which consists of six sub paths. Finally each node on the path is recorded in the list Road [], and the translation matrix of each sub path is output.
The clashes are checked by querying the intersection of the node list Path [] and components list Components[]. When Path [] ∩ Component [] = ∅, it means there is no clash in the path. If Path [] ∩ Component [] ≠ ∅, there are some clashes in the path, and set the collision point in the node list Clash[]. When the assembly path planning of the component which should be hoisted is successful, the map is updated automatically according to the successfully assembled component. The planned component is deleted from the map, and the path planning of the next component can be carried out.

3.3 Algorithm programming and case study
In this paper, python is used to program the path planning algorithm, and the hoisting of low speed diesel cylinder liner is tested as an example. The discrete C-Space and assembly path are displayed in 3D coordinate system by using Matplotlib library to visualize the data. The results of the test are shown in Figure 5.

The virtual assembly software is used to carry out assembly simulation according to the translation matrix output by the program, and the assembly route generated by the program completely conforms to the path planning principle of hoisting, and the simulation route is shown in Figure 6.
4. Conclusion

According to the principle of path planning of hoisting, an automatic assembly path planning method is proposed in this paper, and it is programed by Python. Finally, the feasibility and efficiency of this method are verified by the test. The method of automatic assembly path planning greatly shortens the time of assembly simulation and improves the accuracy of assembly path.

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