Research and Engineering Implementation of Laser Point Cloud 3D Target Recognition Algorithm in Complex Scene

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Abstract. Here are many challenges for target detection in the complex scenes. In the real scene, such as the diversity of the type, quantity and shape of the parts on the workpiece plates, the model construction and rapid detection need to deal with the complex and changeable scene, and the large-scale massive point cloud data challenges the operational efficiency and accuracy of visibility analysis technology. In this paper, the 3D modeling method based on computer graphics is proposed by using the displacement laser sensor as the digital representation of 3D complex scene on the scanning point cloud, which realizes the fast extraction of semantic target feature parameters under complex conditions. The multi-dimensional parameter-based saliency feature and fusion multiple filtering algorithm is built to obtain a fast and high-precision intelligent template recognition detection method. Based on SOC embedded engineering technology, the detection algorithm is realized by software programming. The two-dimensional mechanical motion platform is developed to test the workpiece plate applied to wheel hub of high-speed rail train, and the recognition accuracy is more than 99%.

1. Introduction

At present, the research on the 3D object detection based on 3D point cloud data has made great progress at home and abroad. The common methods are as follows [1-6]:

Prior knowledge method. It mainly uses the prior knowledge of the three-dimensional object to be detected, such as size (length, width, height, area, volume, etc.), shape (plane, column, etc.), reflection intensity, etc., to realize the detection of specific 3D objects by defining a series of semantic constraints or detecting specific structural features. The computational efficiency of this method is high and the speed of 3D target detection is fast. However, due to the similarity between different targets in the scene, the detection performance of this method is generally not good, which will generate a lot of false alarm information.

Shape matching method. This paper mainly uses the overall structural features of the three-dimensional target to be detected, and realizes the detection of specific three-dimensional target by shape matching method. Because the overall structural features of a 3D object are described by local and global features between a series of feature points on the target. This kind of method has higher requirements on the feature description ability and robustness of the feature point description
algorithm. There are also certain requirements for the performance of clustering and segmentation algorithms of 3D point cloud.

Machine learning. This paper mainly uses the training samples of the three-dimensional target to be detected, and trains the samples by machine learning method, and constructs a classifier or probability estimation model for detecting a specific three-dimensional target. By synthesizing the detection results of some structures, the whole structure of 3D objects can be detected. This kind of method usually needs a lot of time in the model training stage, and the calculation time in the three-dimensional target detection phase is relatively high, but the detection performance can be greatly improved.

The design method in this paper is improved on the basis of machine learning method. The general idea is: use the displacement laser sensor to scan the X-Y axis in two dimensions, so as to obtain the coordinate measurement data. According to the measured data, the point cloud imaging technology is used to simulate all the parts of different types and shapes on the workpiece plate into a three-dimensional height distribution image. The highly distributed image is transformed into a gray-scale image by using a pseudo color coding method. Using the related mature technologies and methods of computer graphics, the encoded image is processed by digital image processing, and the feature parameters of the image are extracted. As the training data sample, a three-dimensional target structure model is established. At the same time, based on machine learning method, it can quickly realize the comparison between the measured workpiece plate and the sample model, and achieve the ability of accurately positioning all parts on the workpiece board.

2. Feature Parameter Extraction Algorithm

In this paper, the point cloud data obtained by scanning is transformed into a gray-scale image through a pseudo gray-scale coding

2.1 Coding for Workpiece Height:
Suppose that in a three-dimensional coordinate, the height of the workpiece vertically below the detection point of the displacement laser is \( R(i,j) \), and the plane height of the workpiece plate is \( h_0 \). By simple calculation, the height of the workpiece on the position \((i,j)\) is:

\[
H(i,j) = R(i,j) - h_0 \quad (i = 0,1,\ldots,N_x, \quad j = 0,1,\ldots,N_y)
\]

The gray scale of pixel points in digital image processing is introduced. The height of the workpiece corresponding to the point can be converted into gray scale of the image by coding. The coding algorithm is as follows:

\[
\text{Gray}(i,j) = \frac{h(i,j)}{H_{\text{max}}} \times \text{Scale} \quad 0 \leq h(i,j) \leq H_{\text{max}}
\]

or:

\[
\text{Gray}(i,j) = 0 \quad \text{h}(i,j) < 0
\]

or:

\[
\text{Gray}(i,j) = \text{Scale} \quad \text{h}(i,j) > H_{\text{max}}
\]

\( H_{\text{max}} \): is a parameter. Based on the maximum height dimension of parts in different measured areas (workpiece plate). The parameters can be obtained by preset or by technology after traversing all measurement points.

Scale: The value of the maximum gray scale. Generally, 255 is recommended.

After coding, the 3D point cloud data can be converted into a gray scale image.

2.2 Interpolation and Filtering Combined with Optical Image
 Considering the problem of efficiency and time, the point cloud data collection is limited, or the data collection interval should not be too small. Therefore, the gray-scale image will appear outliers and noises, which may affect the accuracy of modeling and recognition. Numerical interpolation must be used. The specific algorithm is as follows:

Using other equipment, such as high-definition optical camera, to capture and obtain the optical image of the measured area. Using the method of digital image processing, the position and edge of components in this region are obtained.

According to the position information of parts obtained from optical images, the numerical interpolation methods are different in different positions in the region. In the edge position of parts, the parabola interpolation method of power 2 is adopted. In other locations, linear interpolation is used. The different use of the two methods can not only increase the pixels of gray scale image, but also can not introduce large distortion to the edge of parts.

Considering the random interference in the measurement process, the digital image processing is carried out to filter and smooth the gray-scale image after interpolation.

At the edge of the parts, the median filtering algorithm can effectively filter out the noise without causing sensitive distortion.

\[
G(i,j) = \text{Mid}[\text{Gray}(i-2, j-2), \text{Gray}(i-1, j-2), \ldots, \text{Gray}(i+2, j+2)] \\
i = 0, \ldots, N_x, \quad j = 0, \ldots, N_y
\]

In other positions of the measured area, the average smooth low-pass filtering algorithm is used.

2.3 Feature Parameter Modeling

Considering the diversity of the size and shape of the workpiece, the multi-dimensional feature parameters collected by the model include: to size of the workpiece, mainly the length, width, height, area, volume, etc. The shape of the workpiece is mainly round, square, rectangular, trapezoid, pentagonal, hexagonal, triangular and other heterosexual

At the same time, the main characteristic quantity of each workpiece has different importance in the description of the workpiece. Therefore, these feature parameters have different weight coefficients. For the j-th workpiece, it can be expressed as follows:

\[
\Phi_j = \sum_{k=1}^{N} \alpha_k A_k
\]

3. Multi Parameter Fusion Recognition

Through the above calculation formula, we can get that in the process of modeling, the three-dimensional model of the workpiece plate is established in the measured area, the parts are divided into regions independently, the feature parameter extraction of individual parts and the weighted description of multi-dimensional feature parameters. If there are M parts on the workpiece board to be tested, then each part has a model function of \(\Phi_j\) to describe and define. M independent \(\Phi_j\) model functions can be used to describe and characterize the workpiece board completely.

After the modeling is completed, the parts on the workpiece board can be identified and matched directly. The specific algorithm is basically consistent with the feature parameter modeling process. After two-dimensional point cloud data acquisition, gray-scale coding, numerical interpolation and filtering, a gray-scale image is formed. Combined with optical camera, each component in gray scale image is divided independently. Calculate the model function of each part, and match with the template to realize the recognition of parts.

It should be noted that the weight coefficients corresponding to the upper feature parameters of each component are completely different. Optimizing or adjusting these weight coefficients can greatly improve the recognition accuracy of parts.
4. Engineering Realization

The engineering system is based on embedded architecture and technology. The core components mainly include three aspects

4.1 Core Module Based on SOC

The core module is ARM CPU. With the cooperation of flash and DDRAM, data acquisition of laser displacement sensor and high-definition image acquisition of optical camera, gray-scale coding, interpolation and filtering, feature parameter extraction and calculation, template establishment and calculation are realized.

4.2 Digital Signal Processor based on DSP

The core module is a high-speed digital signal processor with 150MIPS of Real-Time processing ability to control the 2D mechanical motion platform.

4.3 Embedded Software Technology

On the basis of Linux operating system, realize the algorithm processing flow and software shown in Figure 1.

![Figure 1. The algorithm processing flow and the software block diagram.](image)

5. Conclusion

On the developed measuring equipment, the workpieces of different specifications, types and sizes are measured. The experimental results show that the overall recognition accuracy is 99%, and the false alarm probability is less than 1%. Meet the design requirements.

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