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CONTAINER SHIP CELL GUIDE ACCURACY CHECK TECHNOLOGY BASED ON IMPROVED 3D POINT CLOUD INSTANCE SEGMENTATION

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Summary

Generally, cell guides are installed in the cargo hold of container ships, which improve the loading and unloading efficiency of containers and fix containers when the ship is sailing. However, in actual production, due to the low accuracy of ship loading in sections, and the deviation of welding shrinkage and expansion in relevant sections, errors occur in the loading process of containers, resulting in hidden safety risks or significant economic losses. Given the above situation, it is particularly important to find a high-efficiency cell guide accuracy inspection method for construction monitoring. 3D scanner to obtain three-dimensional data is presented in this paper, based on this paper proposes a new method, this method will be used based on improved instances of 3 d point cloud segmentation model to cell guide the segmentation, and fitting container ship cell guide structure, and then realize the function of container simulation test box, cell guide after the segmentation precision inspection at the same time, for the practicality review, we compared the accuracy data gained from inspection simulation and the measured data. As a result, it was confirmed that both values were within about $\pm 1.5\text{mm}$. The validity, and reliability of the method are further verified.

Key words: point cloud; laser scanning; container ship; cell guide; instance segmentation; linear fitting

1. Introduction

Generally, a cell guide with a lattice type structure is installed on the cargo hold of the container ship. cell guide has the function of fixing cargo and improving loading efficiency in the process of navigation. The cell guide starts from the floor of the cargo hold to the flared entry guide at the hatch coaming. They are all connected together. which facilitates the smooth vertical movement of the entire container. However, in the actual operation, the installed cell guide has a deviation from the design drawing due to various reasons, which leads to the container being clamped, or the phenomenon of shaking due to loose spacing. There are many reasons for the deviation, such as the low accuracy of the ship's block loading, or the deviation of the welding shrinkage and expansion of the relevant section during the construction process. Secondly, even if the cell guide in each block meets the

accuracy requirements, after assembly, deviations will eventually occur. Given the above situation, it is particularly important to find a high-efficiency cell guide accuracy inspection method for construction monitoring. This paper proposes a new method, which will use the improved 3D point cloud instance segmentation model to achieve the segmentation of the cell guide point clouds, and fit the container ship cell guide structure, and then realize the function of simulating the movement the container along the cell guides in order to check the accuracy of them. For the practicality review, we compared the accuracy data gained from inspection simulation and the measured data. As a result, it was confirmed that both values were within about $\pm 1.5\text{mm}$.

2. Related works

2.1 Application of photogrammetry and laser scanning in the shipbuilding industry

By using a low-cost amateur digital single-lens reflex camera and affordable photogrammetry software, a close-range photogrammetry model was constructed, and the experimental data and actual manual measurement data were compared, which proved that the model can be applied to the routine metrological measurement in the small and medium-sized shipbuilding industry. However, the accuracy of CRP measurement needs to be further improved [1]. According to actual production, considering the need to collect dynamic information reflecting the assembly process of the shipbuilding industry, [2] proposed a non-contact dedicated monitoring system based on the SFM three-dimensional reconstruction method, which can realize the function of real-time measurement and control during the assembly process. However, because the size of the component in the experimental test case is not large, further research is needed for the measurement accuracy of large components. At the same time, the smaller the component size, the greater the measurement error, so the measurement of local features of the component also needs to be improved.[3] In order to solve the problem that the measurement accuracy of large-size objects decreases when the measurement range of the laser tracker increases, the author proposes a photogrammetric auxiliary laser tracker measurement method, and proposes a coordinate correction based on the Rodriguez rotation formula Method, it is proved through experiments that the measurement accuracy is improved when the laser tracker is used to measure large objects. However, this method has high requirements on the environment and needs to control the environment, including the requirements of stopping the vibrating equipment, shielding the reflectors in the measurement environment, selecting the appropriate lighting conditions and the appropriate temperature, etc. These requirements are for industrial practice. Production causes greater inconvenience. Research [4] Aiming at the point cloud data processing method, a new method of iterating the nearest point algorithm to register the two sets of data after determining the correct registration direction through principal component analysis is proposed. The improved algorithm is used in the experiment of the shipyard. The results show that the method can effectively support the accuracy evaluation of point cloud data processing. Research [5] In response to the high-precision requirements of the shipbuilding industry, the author proposes a three-dimensional point cloud data registration system based on sphere markers. This system has demonstrated its high-performance characteristics in the practical application of shipbuilding blocks. The development of 3D point cloud registration in sphere data. The article describes reverse engineering and 3D point cloud data segmentation technology [6], pointing out that the segmentation technology can generate computer-aided design models from the data, and whether the manufactured products have high precision is closely related to the accuracy of the computer-aided design model. The manufactured products have complex geometric figures, so it is particularly important to design high-precision model algorithms that can maximize the elimination of various types of

errors. The author [7] proposes that the R, G, and B values associated with each scan obtained with the help of an integrated camera are converted to 3D point cloud data in the HSV space, and the color components that are not changed by the illumination are separated from the intensity. Two methods, histogram distribution, and adaptive threshold analyze and quantify the detected corrosion points, and better optimize different repair and maintenance procedures. The use of digital photogrammetry technology to model the hull and propellers of three-dimensional objects to solve the problems in the field of naval architecture [8]. The above research shows that with the rapid development of computer vision and virtual reality technology, measurement methods based on photogrammetry and laser scanning have been paid attention to by more and more scholars and have been widely used in modern shipbuilding industry.



Fig. 1 Scanning the cell guide of container ship

2.2 Inspection methods for the accuracy of container cell guide

Using the container model method [9], this method uses a crane to put a container model of the same size as the real object directly into the cell guide, and check whether it can be loaded in the actual operating environment, but as the container tends to as the size becomes larger, the operability and feasibility of this method are becoming more and more difficult. In general, this method uses sampling inspection in shipyards to determine the accuracy of the cell guide. This method has the advantage of directly determining the accuracy of the container, but it also has the shortcomings of excessive standby time caused by the conflict between the crane and other operations, the safety hazard when working at high places, and the greater impact of environmental factors, which may easily lead to the extension of the construction period. Use the measurement carriage method [9] [10] [11], this method attaches the carriage installed with the distance measuring sensor to the corner of one side of the cell guide for measurement. The container has horizontal, vertical, and diagonal lengths, but this method has the disadvantages of complicated installation of the measuring bracket and handling process, potential safety accidents, and high maintenance and repair costs for measuring equipment. Using the Measurement sensor assembly method [12], this method installs a cable robot system on the upper and lower ends of the four cell guide and uses the sensor integration to measure the distance between the rails to perform the remote measurement, but this method. There are shortcomings of time-consuming and high maintenance costs when installing and dismantling equipment. The 3D laser scanning technology developed in recent years is widely used in the large shipbuilding industry. Safe and efficient berthing is very important to ensure the safety of ships and ports. 3D laser detection and ranging can detect and support ships docking. [13] The principal component analysis method is used to calculate the ship's heading and normal vector to realize the dynamic target recognition of the ship. and safe parking function. [14] proposed a method for

hull modeling and loading cargo compartment identification based on the 3D point cloud collected by the laser measurement system on the loader. The point cloud pairs were incrementally registered to achieve the reconstruction of hull segments and real-time identification of combat targets. Using the method of scanning equipment [15] [16], this method scans the cell guide and uses the scanned three-dimensional data to simulate the container loading process. First, the scanned three-dimensional data is used in the simulation space to make Three-dimensional, and then carry out container loading inspection. Compared with the previous methods, this method has the advantages of being able to consume less time, reduce the risk of accidents, improve conflicts between multiple operations, and improve operational efficiency. However, the accuracy of the scanned data and the method of subsequent processing of data is not yet mature and needs to be improved.

In response to the above problems, this article proposes a new method, which will use the improved 3D point cloud instance segmentation model to achieve the segmentation of the cell guide, and fit the cell guide structure of the container ship, and then realize the function of simulating the container test box. In addition, the accuracy of the cell guide after segmentation is checked, and the effectiveness and reliability of the method are further verified by comparison and analysis with the actual measured data. Figure 2 shows the three-dimensional cell guide data of a container ship obtained by a 3D scanner.



Fig. 2 The three-dimensional cell guide data of a container ship

3. Improved 3D point cloud instance segmentation model

3.1 3D scan data acquisition

The 3D scanner has the advantages of fast scanning speed, simple operation, compact, portable and movable, etc., and is widely used in the acquisition of 3D real sight clouds in various projects. However, the point cloud data obtained by the scanner is discretely distributed, noisy, and uneven in form. Due to a large amount of point cloud data, to efficiently detect whether the cell guide structure is deformed, it is usually necessary to downsample the point cloud [17] [18]. Using a 3D scanner to scan a container ship, there are about 3.7 million point cloud data formed by a set of cell guides. Assuming 10 sets of cell guides, the total amount of point cloud data is about 37 million, which is very large. In actual operation, considering the heavy workload, the container model is generally used to test the box, and the method of random sampling is used to check the accuracy of the guide rail, In this paper, a 3D scanner is used to scan the container ship, and the improved three-dimensional point cloud instance segmentation model is used to segment it. We can realize the inspection of all the cell guides, and the time is low and the efficiency is high.

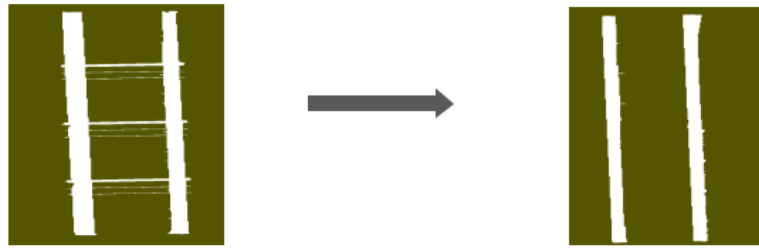


Fig. 3 Processing of a set of 3D cell guide data

Figure 3 shows the processing of a set of three-dimensional cell guide data because the smooth loading of the container depends on whether the distance between the two cell guide meets the specification, so in order to save the calculation cost, a more efficient simulation of the container ship test box Activities, the horizontal fixed box structure that has nothing to do with the calculation of the distance of the cell guide is removed here. The left side of Fig. 3 is a set of scanned cell guide data, and the right side of Fig. 3 is the same set of cell guide data without the lateral fixed box structure.

3.2 Data preprocessing

To more easily verify the segmentation effect of the improved 3D point cloud instance segmentation model on the cell guide, but since there is no public container ship cell guide data set, a container ship cell guide data set needs to be established here, which provides a large number of tags for the deep learning network The training samples, excellent and efficient data sets can make the model more robust, and also help us analyze the subsequent segmentation results. First, the cell guide data is segmented. As shown in Figure 4, it is the segmentation process of cell guide point cloud data. Here we have established a total of 6 container ship cell guide segment data sets. Since the amount of point cloud data of the cell guide of the container ship is extremely large, the processing time and cost are high, and the point cloud data of the cell guide is down-sampled in voxel here.

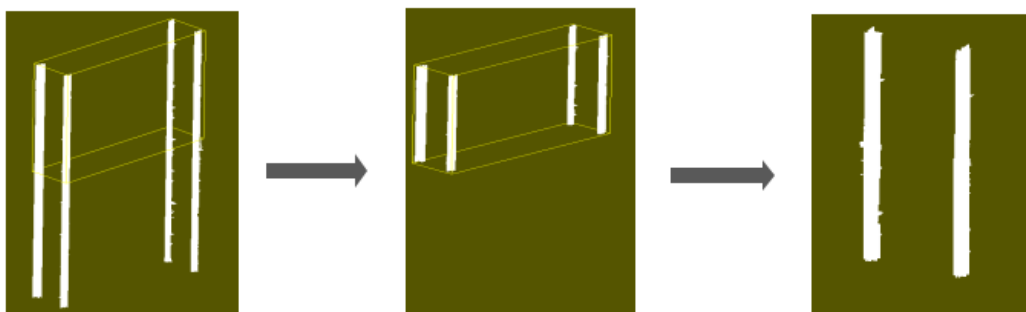


Fig. 4 Segmentation process of cell guide point cloud data

3.3 Voxel downsampling

In voxel downsampling, the three-dimensional space is voxelized first, and then a point is sampled in each voxel. The point here uses the center point as the sampling point. The specific implementation steps are as follows:

(1). Create voxel: Calculate the bounding box of the point cloud, and then discretize the bounding box into small voxels. The length, width, and height of the voxel can be calculated by setting the number of grid points in the three directions of the bounding box.

(2). Each small voxel contains several points, and the center point is taken as the sampling point here.

The voxel downsampling has the advantages of maintaining the shape characteristics of the point cloud, high sampling efficiency, and the ability to control the point spacing through the voxel size. The rail point cloud data after the voxel downsampling processing is shown in Figure 5.

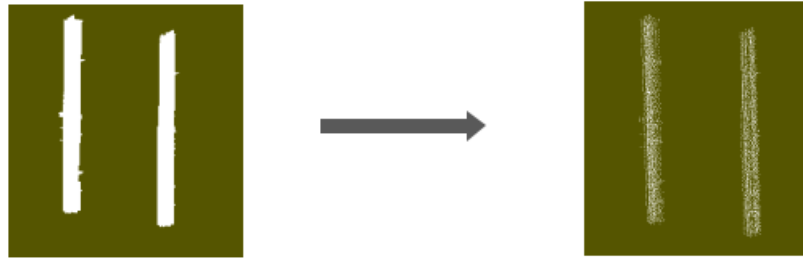


Fig. 5 3D cell guide data after voxel downsampling

3.4 Improved 3D point cloud instance segmentation model

The 3D scanner has the advantages of fast scanning speed, automatic scanning, compact, portable and mobile, and is widely used in 3D real scenic spot cloud acquisition of various projects. 3D data obtained are evenly distributed and noisy in form. With the development of deep learning networks, 3D instance segmentation models are becoming more robust. Among numerous 3D instance segmentation models, 3D-BoNet is a single-stage, end-to-end trainable, efficient and novel 3D instance segmentation framework, and its effectiveness has been proved by the author in multiple point cloud data sets [19]. This paper introduces the multi-scale grouping (MSG) module on the basis of the 3D-BoNet model, and the improved point cloud instance segmentation framework is shown in Figure 6. Experiments have proved that the accuracy of the improved 3D-BoNet instance segmentation is improved, and the calculation efficiency is also greatly improved. The following experimental environments were carried out under the standards of ubuntu18.04, cuda 9.0, python3.6, tensorflow1.6 and RTX 2080ti.

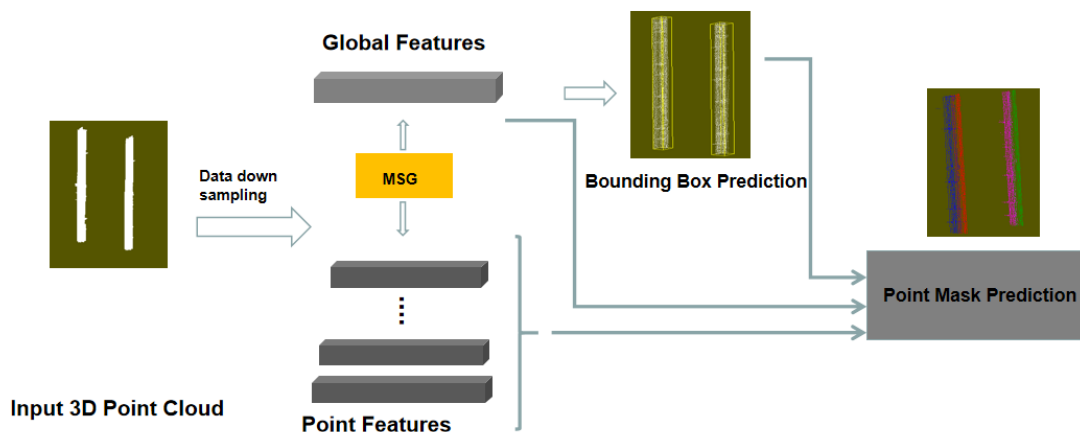


Fig. 6 Improved point cloud instance segmentation framework

The multi-scale grouping (MSG) module, as shown in Figure 7, MSG has grouping layers of different scales. For the same central point, if three different scales are used, three areas are drawn around each central point, and each area The radius of is different from the number of points inside each. The network extracts the features of each scale and connects the

features of different proportions to form multi-scale features, and trains the network to learn an optimization strategy to combine multi-scale features. The learning optimization strategy is achieved by deleting the input points with random probability for each instance. For each training point set, we choose the discard rate θ uniformly sampled from $[0, p]$, where $p \leq 1$. For each point, we randomly discard a point with probability θ to avoid generating an empty point set Here we set p to 0.95. When the input sampling density changes, MSG learns features from different scale regions to achieve the purpose of extracting more feature information.

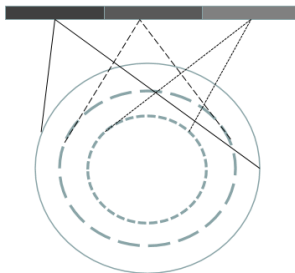


Fig. 7 Multi-scale grouping (MSG)

The idea of transfer learning is to use knowledge in related fields to complete tasks in the target field. It is a new learning paradigm. In practical applications, transfer learning can effectively solve the needs of large-scale training data sets. The current transfer learning is mainly applied to two-dimensional images, and the application in the field of three-dimensional point cloud instance segmentation is relatively scarce [20]. Here we will make full use of the existing data and models to transfer and learn the pre-trained model obtained from the 3D-BoNet with the MSG structure to our container ship cell guide data set. Experiments prove that the improved 3D-BoNet instance segmentation The method used with transfer learning on the container ship cell guide data set not only reduces the training time but also the loss function can converge uniformly, which improves the generalization ability of the instance segmentation model. For evaluation, we compared the following four sets of experimental data. The experimental results show that the 3D-BoNet with the MSG structure and transfer learning is used together with the container ship cell guide data set to achieve the best instance segmentation effect. The mPrec is 89.2 and mRec is 46.4, compared with before improvement, mPrec increased by 9.7% and mRec increased by 1.1%.

Table 1 shows the mPrec and mRec of the classic index with an IoU threshold of 0.5. Table 2 shows the time-consuming comparison of the four methods. It can be seen from the table that the improved 3D-BoNet instance segmentation method takes the shortest time and has the highest efficiency.

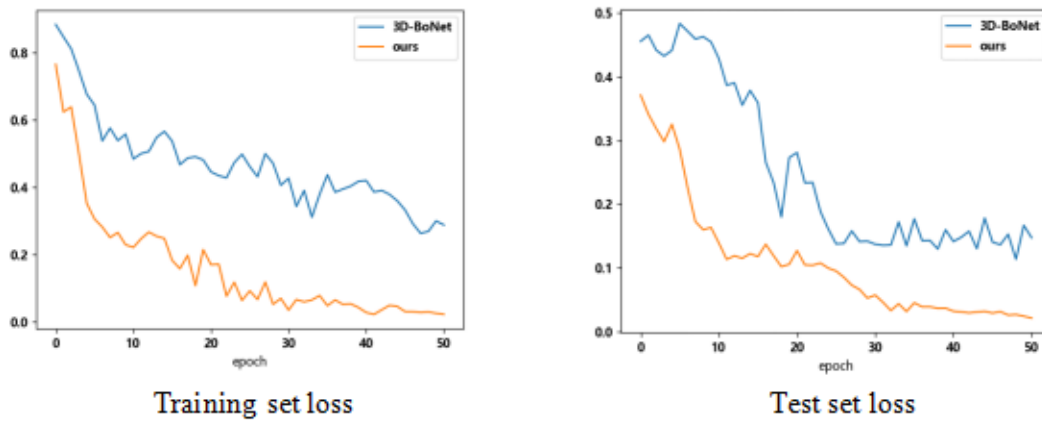
Table 1 Evaluated function mPrec and mRec of comparison experiments

Methods	mPrec	mRec
3D-BoNet	79.5	45.3
Improved 3D-BoNet	86.3	45.8
3D-BoNet+ transfer learning	83.7	45.1
Our Method	89.2	46.4

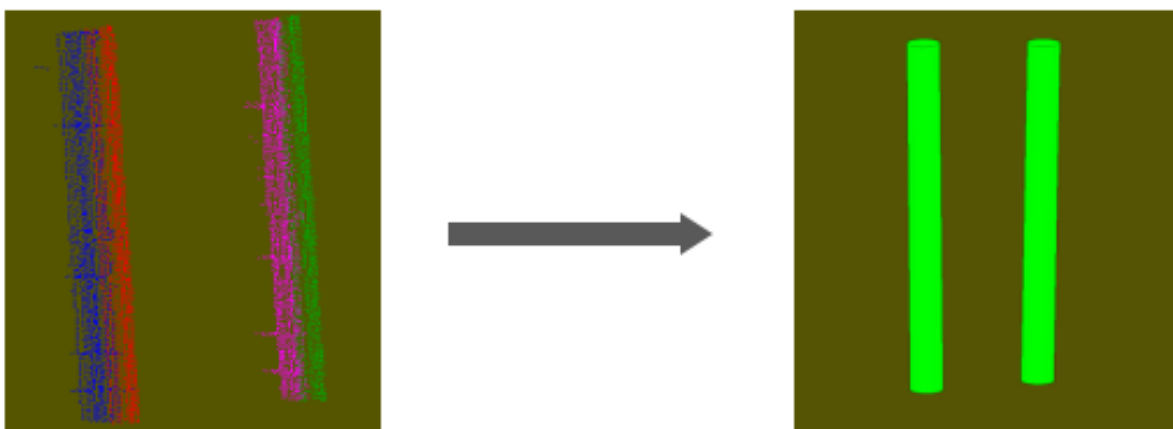
Table 2 Evaluated time-consuming of comparison experiments

Methods	time-consuming
3D-BoNet	52.4s
Improved 3D-BoNet	41.6s
3D-BoNet+ transfer learning	27.2s
Our Method	11.3s

To further verify the effectiveness of our improved method, Figure 8 shows the loss curves of the training set and test set of the 3D-BoNet model and the improved instance segmentation model. From the figure, we can see that it is very difficult to train a robust model on a small data set. The loss curve based on the 3D-BoNet with the MSG structure and the transfer learning method can converge better. Prove its robustness. In summary, the improved 3D-BoNet and the 3D point cloud instance segmentation model of transfer learning can effectively achieve the segmentation of container ship cell guide data.

**Fig. 8** Loss curve of training set and test set

4. Fitting the cell guide structure of the container ship

**Fig. 9** Fitting of the cell guide of a container ship

To calculate the separation distance between the simulated test box and the cell guide, as shown in Figure 9, The random-sample consensus algorithm (RANSAC) is a random

parameter-estimation method. RANSAC randomly selects a subset from a sample, uses the minimum variance estimation algorithm to calculate the model parameters for this subset, and then calculates all samples and the model. When the deviation is smaller than a threshold, the sample point belongs to the inliers of the model, referred to as an inner point; otherwise, it is an outer point. The best model is finally obtained through an iterative process. The RANSAC method is commonly used to fit planes, cylinders, cones, etc., in reverse engineering [21].

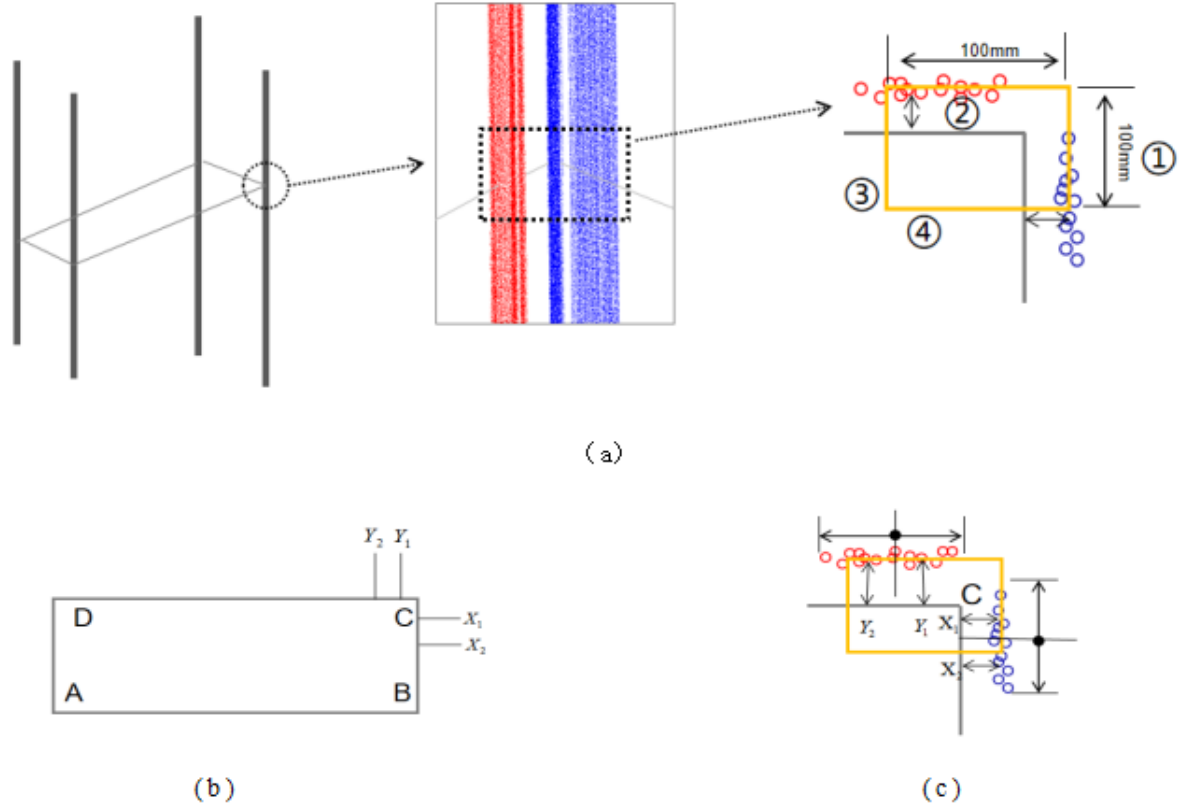


Fig. 10 The distance between the simulated test box and the cell guide

As shown in Figure 10(a), red and blue points represent the three-dimensional point cloud data of the two surfaces of the guide rail. The upward direction of the guide rail is the Z axis, and the plane where the guide rail is located is the X and Y axes. By fitting the cell guide, the distance between simulated test box and cell guide can be calculated. The distance between the linear cell guide at any height position $aX + bY + c = 0$ and the fixed point (X_1, Y_1) on the container can be simply calculated by the following formula:

$$\tilde{d} = \frac{|aX_1 + bY_1 + c|}{\sqrt{a^2 + b^2}} \quad (1)$$

Since the data in formula (1) needs to meet the error range of container ships, here we need to deal with it in two cases.

$$\begin{aligned} d &= \tilde{d}, \text{ if the container is in the allowance area} \\ -d &= \tilde{d}, \text{ if the container is outside the allowance area} \end{aligned} \quad (2)$$

The overall calculation method of the clearance distance between the four corners of the container and the surrounding cell guide is as follows:

$$\delta = \sum_{i=1}^4 \sum_{j=1}^n \tilde{d}_{ij} = \sum_{i=1}^4 \sum_{j=1}^2 \frac{|a_i X_{ij} + b_i Y_{ij} + c_i|}{\sqrt{a_i^2 + b_i^2}} \quad (3)$$

As shown in Fig. 10(b) and (c), a_i, b_i, c_i is the number of linear cell guide located at four fulcrum positions, and (X_{ij}, Y_{ij}) represents two points on the container.



Fig. 11 Measuring the distance between the container and the cell guide

As shown in Table 3, to verify the feasibility and effectiveness of the proposed method, the actual measured distance on-site is compared with the result calculated by the experimental simulation, and the deviation is within the range of $\pm 1.5\text{mm}$, which meets the deviation requirement of less than 10mm in actual operation[22]. Figure 11 shows the on-site measurement of the distance between the container and the cell guide. Here we have selected three points in the height direction of 2.8m , 5.8m , and 8.8m as the measurement positions. At the same time, because of the actual measurement, the lifting of the container is prone to safety accidents. And it is very difficult to control the awakening measurement of the container at the specified height, so a small error is allowed here, and the data has been measured as close as possible.

Table 3 The error between the actual measured distance and the fitted distance (Unit:mm)

Height	Cell guide		Measured value	Calculated value	Error
8,800	A	X	13	12.91	-0.09
		Y	8	8.45	0.45
	B	X	14	14.32	0.32
		Y	12	11.72	-0.28
	C	X	18	17.66	-0.34
		Y	11	11.36	0.36
	D	X	12	12.06	0.06
		Y	14	13.61	-0.39
5,800	A	X	17	17.69	0.69
		Y	11	9.68	-1.32
	B	X	14	15.11	1.11
		Y	11	12.26	1.26
	C	X	16	15.72	-0.28
		Y	12	11.38	-0.62
	D	X	15	15.62	0.62
		Y	14	14.36	0.36
2,800	A	X	21	19.68	-1.32
		Y	11	12.46	1.46
	B	X	21	21.38	0.38
		Y	13	12.55	-0.45
	C	X	15	15.27	0.27
		Y	17.22	16.34	-0.88
	D	X	20	20.67	0.67
		Y	12	11.64	-0.36

5. Results and discussion

The 3D scanning technology, which has been developed in recent years, is used to process the scanned container cell guide data. Compared with the traditional method, it effectively eliminates potential safety hazards. This method realizes the accuracy inspection of the container ship cell guide more accurate and more rapidly. The experimental results prove that the deviation between the actual measurement distance and the point clouds fitting distance is within $\pm 1.5\text{mm}$, which meets the actual production accuracy requirements, and proves that the inspection method based on the improved 3D point cloud instance segmentation model proposed in this paper is effective. This method has a wide range of applications. Accelerating the speed of feature extraction and further finding intelligent solutions to the collision between container ships and cell guide is the direction we will continue to focus on in the future.

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