Bulletin of the *Transilvania* University of Braşov • Vol. 11 (60) Special Issue No. 1 - 2018
Series I: Engineering Sciences

REVIEW OF AUTOMATIC LIFTING OBSTACLE DETECTION TECHNOLOGY FOR PREFABRICATED BUILDING PREFABRICATED COMPONENTS

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Abstract: *According to the different types of sensors used, the automatic lifting obstacle detection technology of prefabricated building prefabricated components was reviewed, and various obstacle detection techniques were analyzed. These technologies mainly include prefabricated obstacle detection technology based on laser radar, prefabricated obstacle detection technology based on millimeter wave radar, precautionary obstacle detection technology based on computer vision, and obstacle detection technology based on optical flow prefabricated components. At the same time, the author points out that any effective obstacle detection system can't rely on a single sensor for environmental perception. Therefore, it is a research focus and difficulty in the field to detect the automatic lifting obstacles of prefabricated building prefabricated components by using various sensor information fusion technologies. In addition, in the context of the 13th Five-Year National Key R&D Program, the efforts in the "2018 Green Building and Construction Industrialization" project were introduced.*

Key words: *obstacle detection, automatic lifting, prefabricated building and components.*

1. Introduction

Prefabricated buildings are buildings that are assembled on site using prefabricated parts [5, 29]. In the traditional prefabricated building construction site, most of the construction teams of 5-6 people cooperate with the tower crane to take the building unit as the working unit, and the interior wall panels, exterior wall panels, laminated slabs, beams and columns produced by the prefabricated component factory, prefabricated components such as stairs, bay windows, and air-conditioning panels are hoisted and installed according to certain construction methods [30]. This type of prefabricated building construction method has problems such as difficulty in seating the prefabricated components, poor assembly precision, low construction efficiency, and high labor intensity [4, 28].

At present, the United States, Germany, Japan, Canada and other developed countries

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have invested a lot of research work in the research and development of prefabricated building automation hoisting equipment and have made some progress [13]. China has carried out research on the 13th Five-Year National Key R&D Plan “2018 Green Building and Construction Industrialization”. During the hoisting operation of prefabricated building prefabricated components from the loading field to the positioning node in the three-dimensional space running movement path and the positioning node falling in place, it may encounter the following types of obstacles affecting the smooth implementation of the prefabricated component automatic lifting installation. For example, construction site machinery and equipment, completed buildings, construction workers, temporary tools, long-term standing objects, etc. Therefore, the automatic lifting obstacle detection technology for prefabricated building prefabricated components is an important part of the key technology of industrial platform construction and integration of construction engineering.

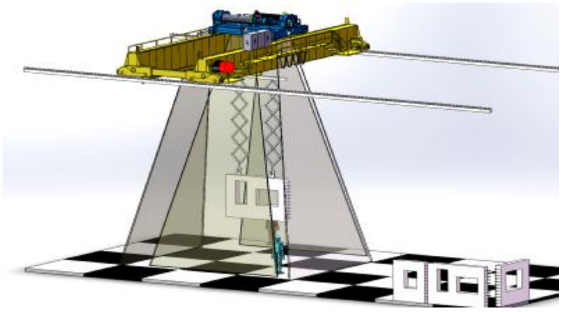

Fig.1 *Obstacle detection effect diagram during the process of transportation*

Obstacle detection and recognition technology involves cross-disciplinary research fields such as radar technology, computer vision, sensors, pattern recognition, information fusion, information communication, high performance computing, and artificial intelligence [23, 25]. The main research institutions at home and abroad have proposed many implementation methods in the research of this field with the help of various new sensors and algorithms. For example, obstacle detection technology based on laser radar, obstacle detection technology based on millimeter wave radar, obstacle detection technology based on computer vision, obstacle detection technology based on optical flow, obstacle detection technology based on multi-sensor information fusion, and the like [15].

This paper will combine the practical application of the China's 13th Five-Year National Key Research and Development Program and the research literature published by relevant research institutions at home and abroad as the background to describe the automatic lifting obstacle detection technology of the prefabricated building prefabricated components.

2. Lidar-Based Obstacle Detection Technology

Lidar obstacle detection technology is mainly used for the detection and identification of dynamic obstacles, such as the detection of dynamic obstacles such as operating workers and engineering machinery that may exist in the process of hoisting the prefabricated components. The obstacle detection technology based on laser radar is mainly divided into three parts: feature extraction, dynamic obstacle modeling and dynamic obstacle recognition [6, 16, 24, 26]. The specific process is shown in the Figure 2 below.

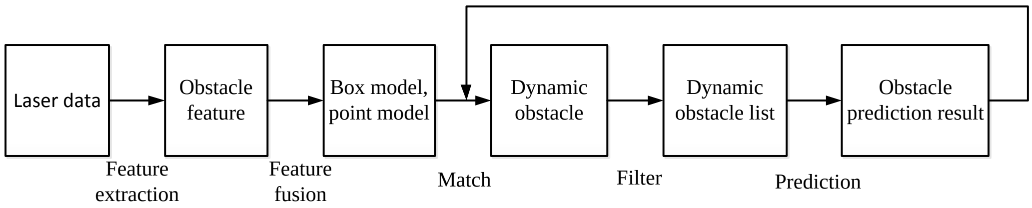

Fig.2 *Dynamic obstacle detection tracking flowchart*

2.1. Feature extraction

The lidar data contains laser point data arranged in a clockwise direction, each point containing its angle, distance, and reflected pulse width information. The laser points can be clustered and segmented by distance [2, 7, 10]. Obstacle edge features and corner features better describe the contour of the obstacle. The following algorithm can be used to extract obstacle features.

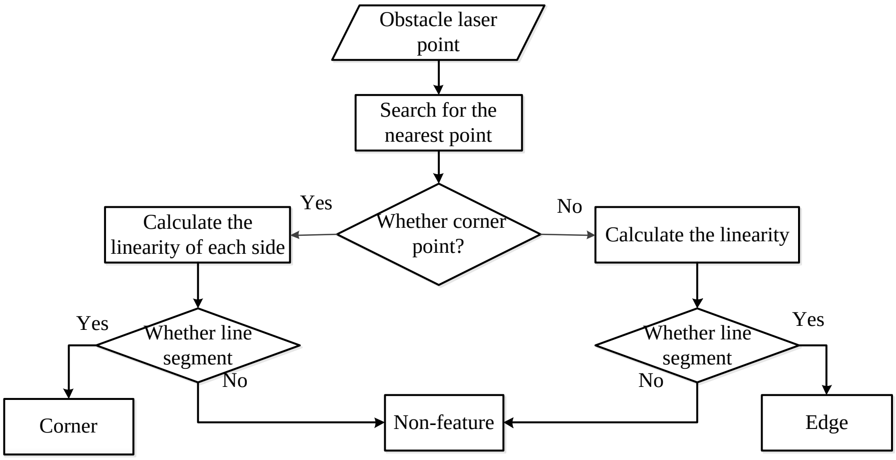

Fig.3 *Flow chart of feature extraction algorithm*

2.2. Dynamic obstacle modeling

In order to accurately estimate the motion state of the obstacle, the characteristics of the linear scanning radar are utilized, and the frame model and the point model are used to represent the obstacle and the corresponding kinematic model is established. As shown below.

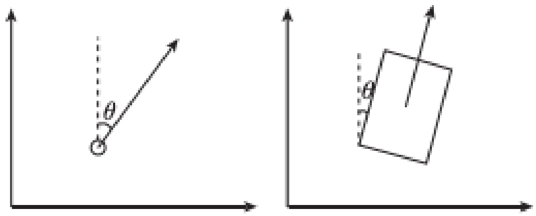

Fig.4 *Point model and box model*

2.3. Dynamic obstacle recognition

Dynamic obstacles that may occur during the installation and installation of prefabricated building prefabricated components can have a great impact on the hoisting route planning, safety distance warning, and effective avoidance strategies adopted by automatic lifting [27]. In order to improve the recognition accuracy and time efficiency of dynamic obstacles, the lidar recognition method based on laser radar uses geometric contour features and motion state features such as length, width, linearity, circularity and speed of obstacles. The main process is shown below.

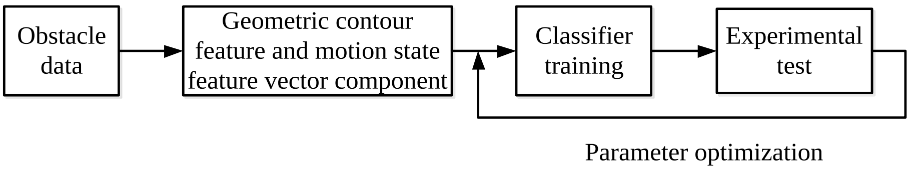

Fig.5 *Flow chart of lidar identification method*

3. Obstacle Detection Technology Based on Millimeter Wave Radar

Millimeter wave radar is sensitive to the longitudinal motion of dynamic obstacles and has a large detection distance [22]. It is one of the key research techniques in the field of obstacle detection research. The obstacle detection technology based on millimeter wave radar can be divided into three steps: 1) data acquisition, 2) data processing, 3) target maintenance. The data acquisition part is the preliminary work, which aims to obtain the raw data collected by the millimeter wave radar and organize it into a data structure for post processing [3, 19].

The purpose of the data processing part is to extract the target description sequence from the targets acquired by each frame of radar and associate the same target [11, 18]. The target maintenance part maintains a detected stable existence target sequence, which is the final detection result [9].

4. Obstacle Detection Technology Based on Computer Vision

With the development of vision sensors and computer vision technology, the automatic lifting obstacle detection system for prefabricated building prefabricated components adopts computer vision-based detection technology to become a research hotspot in the field of obstacle detection and recognition.

The RGB_D image (depth image) has the advantage of simultaneously acquiring obstacle RGB image information and D depth information, and has attracted extensive attention from major research institutions at home and abroad. Currently, depth camera sensors that collect RGB_D images are based on the principle of testing depth information, and are mainly divided into binocular vision technology, structured light technology, and time of flight (TOF) technology.

Obstacle detection technology based on computer vision mainly includes obstacle image acquisition and camera calibration, image preprocessing, and extraction of obstacle information [1, 14, 20, 21].

4.1. Image acquisition and camera calibration

The depth camera is placed at the prefabricated member spreader, and the depth camera lens is adjusted toward the horizontal plane of the hoisting operation of the prefabricated member to take appropriate depth image information.

The camera calibration is to realize the conversion of the corresponding relationship between a certain point of space and its projection point on the camera image plane, and the corresponding relationship is determined by the camera model. The parameters of the model are called camera parameters, and are divided into internal parameters and external parameters. The external parameters are the relationship between the camera coordinate system and the world coordinate system, and the internal parameters are related to the optical characteristics of the camera and the internal structure. The calibration process of the camera is the process of solving the inner and outer parameters. Domestic and foreign traditional camera calibration methods include Zhang Zhengyou calibration method, Abdal-Aziz and Karara's DLT direct linear transformation calibration method and Tasi method.

4.2. Image preprocessing

Image preprocessing is mainly for the case where there is more noise and interference for the acquired image. In order to ensure the subsequent steps of feature detection and recognition, the non-target information in the image is diluted, the target feature information is enhanced to eliminate interference, and the original image is subjected to grayscale, filtering, geometric transformation, binarization and the like. The automatic lifting obstacle detection system for prefabricated building prefabricated components is based on real-time considerations. The preprocessing only uses graying, median filtering and binarization [12, 17].

4.3. Obstacle detection

A depth camera using the binocular vision principle calculates the plane equation of the ground in the left camera coordinate system after the camera is calibrated. The detection flow chart is as follows:

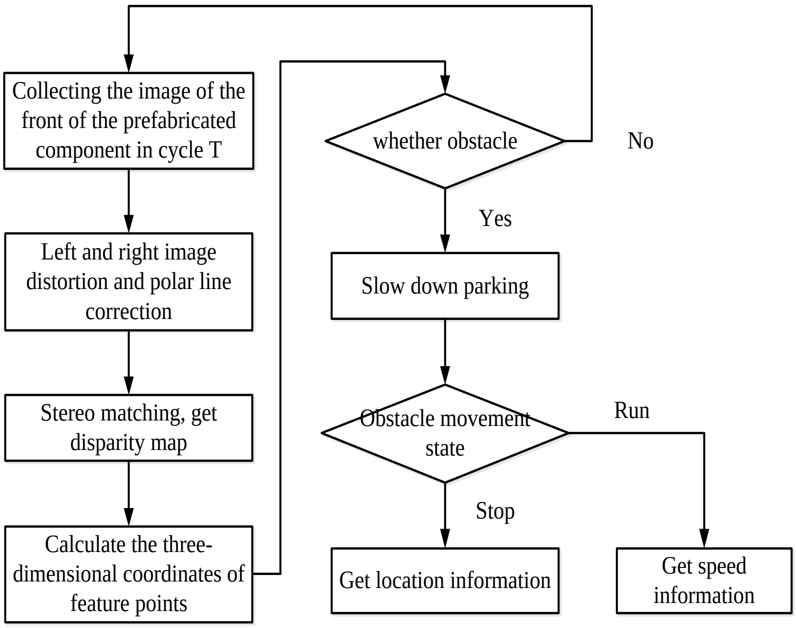

Fig.6 *Detection flow chart*

5. Optical Flow Based Obstacle Detection Technology

The method uses multiple images obtained by the same camera at different times to estimate the optical flow. Since the obstacle is often a sudden change in the optical flow field, the obstacles can be detected according to the optical flow field segmentation, and their distances are estimated [8]. However, the calculation amount and complexity of the method are very large, and the error of the baseline estimation also causes the obstacle distance estimation error.

6. Conclusion

In short, the method based on any obstacle detection has its advantages and disadvantages. The automatic lifting obstacle detection technology for prefabricated building prefabricated components does not currently have a satisfactory solution for researchers. Improving the accuracy and real-time performance of obstacle detection is the main goal of various research teams in the field. Any obstacle detection scheme can not rely on a single sensor to sense the external environment. Multi-sensor information fusion has many advantages such as rich information, strong robustness and wide application range, which will be the focus and difficulty of future obstacle detection research. Although China's research in this field still has a certain gap with the developed countries in the world, as long as we use it for innovation and meticulous research, we can certainly achieve fruitful results.

7. Acknowledgments

The article is supported by National Key R&D Program of China: 2017YFC0703903, National Science Foundation of China 51705341, Liaoning Natural Science Foundation 2016010623 and Shenyang Science and Technology Plan Project 17-231-1-28.

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