Accurate Positioning Method of Indoor Plastering Robot Based on Line Laser

Guanqiao Wang, Hongyang Yu

***Abstract*—There is a lot of repetitive work in the traditional construction industry. These repetitive tasks can significantly improve production efficiency by replacing manual tasks with robots. Therefore, robots appear more and more frequently in the construction industry. Navigation and positioning is a very important task for construction robots, and the requirements for accuracy of positioning are very high. Traditional indoor robots mainly use radio frequency or vision methods for positioning. Compared with ordinary robots, the indoor plastering robot needs to be positioned closer to the wall for wall plastering, so the requirements for construction positioning accuracy are higher, and the traditional navigation positioning method has a large error, which will cause the robot to move. Without the exact position, the wall cannot be plastered or the error of plastering the wall is large. A positioning method is proposed, which is assisted by line lasers and uses image processing-based positioning to perform more accurate positioning on the traditional positioning work. In actual work, filter, edge detection, Hough transform and other operations are performed on the images captured by the camera. Each time the position of the laser line is found, it is compared with the standard value, and the position of the robot is moved or rotated to complete the positioning work. The experimental results show that the actual positioning error is reduced to less than 0.5 mm by this accurate positioning method.

***Keywords*—Indoor plastering robot, navigation, precise positioning, line laser, image processing.

I. Introduction

As the population growth rate continues to decrease and the labor force decreases, all walks of life seek to improve productivity through the widespread use of robots, but due to the uncertainty of the construction industry, the complex construction environment, and the degree of danger is second only to the mining industry, the current construction industry is still dominated by traditional worker decoration, which makes it difficult to improve production efficiency.

The interior decoration work is also gradually replaced by robots. The main tasks that can be done by robots in interior decoration are as follows: Article [1] introduces the paste of tiles, and article [2] introduces the use of robots to complete the painting of walls, article [3, 4] introduced the plastering work of the wall. The plastering work of the wall means that for the newly built house, it is often necessary to manually plaster the wall with cement mortar, so that the wall of the whole room becomes flat, which is more conducive to the subsequent fine decoration work.

For indoor plastering, robot positioning and navigation technology is very important. In recent years, many indoor positioning technologies have emerged, such as base station positioning, wi-fi positioning, radio frequency tag positioning, visual positioning and other technologies [5–7]. At present, the commonly used robot positioning and navigation technologies are mostly simultaneous localization and mapping (SLAM), generally divided into lidar-based SLAM technology or computer vision technology-based SLAM technology [8], these two technologies are mostly used in sweeping robots, shopping guide robots in shopping malls and other fields.

Guanqiao Wang and Hongyang Yu are with the University of Electronic Science and Technology of China, China (e-mail: nemaleswang@gmail.com, hyyu@uestc.edu.cn).

In the wall plastering work, the robot needs to achieve autonomous navigation and positioning to the specific position of the wall to be plastered. Traditional positioning methods are generally not used in the field of construction, and SLAM methods based on vision or lidar cannot meet the requirements of building construction scenarios in terms of time and accuracy. The basic technical method of SLAM is: first, the robot scans indoors, and then according to the collected images, the feature points are matched to estimate the motion trajectory, and then the key frames are selected to finally realize the map generation. That is to say, the strategy of mapping first and then positioning is adopted. For the traditional SLAM method, the method of ”mapping first, then positioning” is adopted. Most of the time will be spent on the generation of the map, and the accuracy will also be lost on each key frame selection step.

For fine wall plastering work, the precision of the robot is higher. In the actual construction project, the flatness error of the plastered wall surface is required to be within 0.5 mm. Therefore, it is necessary to propose a method according to the actual engineering needs. New low-cost, high-accuracy, and low-time-consuming methods to implement indoor localization methods.

In order to solve the above problems, this paper proposes an accurate positioning method for indoor plastering robots based on line laser assistance. This method makes more accurate positioning and navigation of the robot by visually recognizing the laser line and adjusting it dynamically until the error is less than the threshold. Calibration ensures that the maximum accuracy of wall plastering can be achieved, so that the final plastered wall is flat.

II. Plastering Robot Structure

The structure of the entire indoor robot accurate positioning system can be simplified as shown in Fig. 1, including a line laser transmitter and the robot itself. In indoor architectural scenes, there are mainly wired laser transmitters and the robot itself. The line laser transmitter emits line lasers parallel to the wall. The robot includes a fuselage, a mechanical pole,

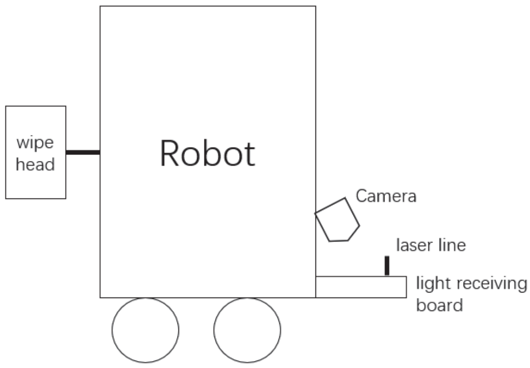

Fig. 1 Plastering Robot Structure

Fig. 2 The relationship between the camera and the light receiving board

a plastering head, a mobile car, two RGB high-definition cameras and the light receiving plate, the body is placed on the mobile trolley, the plastering head is connected to the body through a mechanical rod, the light receiving plate is set at the bottom of the back of the fuselage, and is used to capture the image on the light receiving plate. Fig. 2 shows the light receiving plate and the camera in the the actual position in the robot.

Fig. 3 shows the relationship between the robot and the laser. A line of laser line parallel to the wiper head is drawn, and the position of the line laser in the field of view of the left and right cameras is recorded to obtain the calibration values Y1 and Y2.

III. Accurate Positioning System Process

The accurate positioning of the robot can be achieved by the method based on image processing, which can make the positioning and navigation of the robot more accurate. The overall accurate positioning process can be divided into three parts: the first part is the calibration module, which is used to determine the calibration line; the second part is the image processing module, which is used to identify the laser line in real time during the accurate positioning process; and the third part is the movement parameter calculation module, which is used to control the angle and distance of the robot's movement each time. The three parts coordinate and cooperate to form the accurate positioning system of the entire robot. The entire process is shown in Fig. 4.

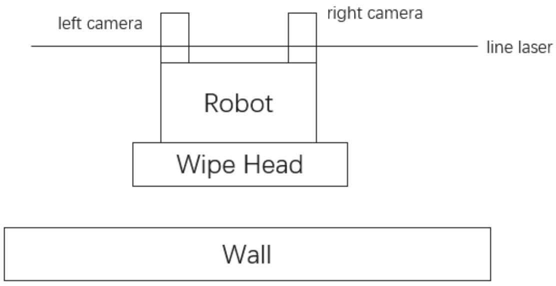

Fig. 3 The relationship between the robot and the laser

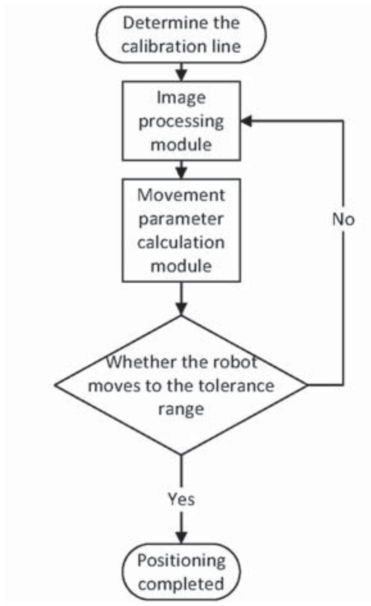

Fig. 4 Accurate positioning system process

IV. Image Processing Module of Robot

In the third chapter, it is mentioned that the camera can identify the laser image to obtain specific calibration values. Taking a high-definition 1080P non-distortion camera as an example, the pixels of the captured picture are 1920*1080. After ordinary positioning and navigation, the robot can be moved to the light receiving board. To obtain the position of the line laser, for the laser line appearing on the light receiving plate, the monocular high-definition camera scans to obtain the image, as shown in Fig. 5, it is hoped that the center of the laser can be extracted as a straight line through image processing.

In order to process the laser line, it is necessary to identify the significant part of the laser, and then convert it into a straight line in the middle band, and operate through a series of image processing methods. The main process is shown in Fig. 6.

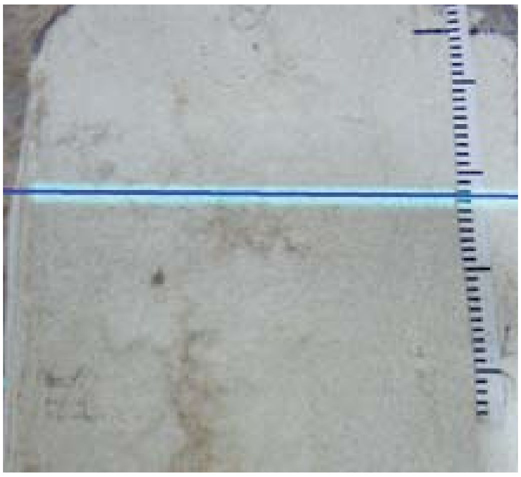

Fig. 5 Converting the laser line to a straight line

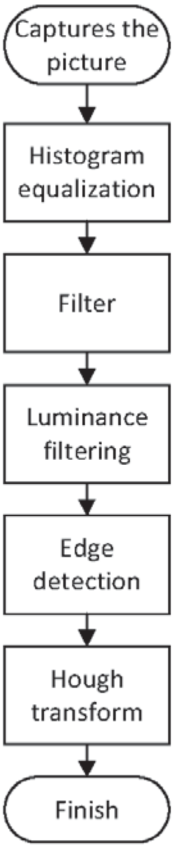

Fig. 6 Image processing flow

A. Histogram Equilibrium

In the actual construction environment, due to the different lighting conditions of the construction room, in the image content to be extracted, the inconsistent brightness of the image will lead to inconsistent brightness of the laser. In order to eliminate this effect, the image is converted to grayscale at the beginning. Then perform histogram equalization, which can reduce the interference caused by too high or too dark brightness, and achieve the effect of image enhancement.

B. Filter

The clearer the image, the more noise it contains. The picture becomes clearer after histogram equalization. Therefore, Gaussian filtering is used to filter out the high-frequency noise in the image, and because the laser line to be identified in the image is in the horizontal direction. According to the filtering method proposed in article [9], a smaller Gaussian kernel can be used in the horizontal direction, and a larger Gaussian kernel can be used in the vertical direction. The size of the Gaussian kernel used here is (2k+1, 4k+1), after filtering, the value F_{ij} of the Gaussian filter at the original image (i, j) can be obtained by the formula (1), and then the median filter is used to eliminate the salt and pepper noise.

$$F_{ij} = \frac{1}{2\pi\sigma^2} exp(-\frac{(i-k)^2 + (j-2k)^2}{2\sigma^2}) \tag{1}$$

C. Brightness Filtering

Since the scene is a construction industry scene, there will inevitably be a lot of dust particles in the image. In this case, in order to filter it, a filtering method based on the brightness feature of the laser line is proposed, which converts the image from RGB to HSV means, and then filter the HSV channel of the pixel to the V channel (brightness) to determine the brightness value of each pixel. If the brightness value exceeds the threshold, it is considered to be a brighter laser spot, otherwise it is a non-laser spot, that is, (2), where α, β, γ are the HSV channel thresholds set in advance through measurement and judgment. For pixels with insufficient brightness, they are directly set to full black, otherwise the pixels are still the original value.

$$P_{hsv(x,y)} \leq \alpha, \beta, \gamma \ , \ P_{hsv(x,y)} = 0 \tag{2}$$

D. Edge Detection

For the filtered pixel, it is still a blurred laser strip. In order to extract the laser into a straight line, the edge of the laser needs to be extracted. The Sobel operator in the Y direction [9] is used to detect the edge of the image. Then two obvious horizontal straight lines can be obtained, which are the upper and lower edge lines of the laser.

E. Hough Transform for Straight Line Fitting

After edge detection, many straight line segments are detected on the edge, but the lengths and slopes of these straight line segments are different, and effective line segments need to be extracted. Here, the Hough transform method with transformable parameters is used, and the threshold value is selected by the voting mechanism. For many short straight line segments with many points, this line segment is represented by the starting point and the end point, and a feedback mechanism is added at the same time. If the number of endpoints is too small at this time, the parameter threshold of the Hough transform should be relaxed, otherwise, the adjustment threshold can be strengthened. After obtaining many straight line segment endpoints, we first use the RANSAC algorithm [10] to filter out the outer points, and then use the least squares method to fit valid points. A large number of points on the upper and lower edges of the laser are fitted as a straight line in the middle of the laser. This method solves the problem of precision loss caused by too thick laser lines.

V. Movement Parameter Calculation Module of Robot

In the second part, a straight line that can represent the laser line is obtained through image processing. Since the distance between the plastering robot and the wall must be a fixed value, the position where the laser line should be can be determined by pre-calibration. This straight line is called the calibration straight line. By comparing the straight line obtained by fitting each time with the calibration straight line, the distance and angle that the robot should move can be calculated.

A straight line reflecting the actual robot position can be obtained by image processing. The intersections of the straight line and the left and right field of view of the camera are represented by Y1 and Y2. We use Y1 and Y2 to represent the actual calibration position. The resolution of the camera used is 1920*1080. Therefore, the left and right endpoints of the calibration line and the fitted line are (0, Y1), (0, Y2), (1080, $Y1\prime$), (1080, $Y2\prime$). To enable the robot to move to the calibrated position, the translation is to move the two lines to coincide, as shown in Fig. 7.

In order to overlap the two straight lines, it is only necessary to calculate the distance and angle that the straight line needs to move. Through the calculation, the distance that the plastering robot needs to move in the Y direction is Y_d. The calculation formula is as (3), where alpha is The amount of pixels represented by one millimeter in practice, the rotation angle that the robot needs to move is theta, and the calculation formula is as (4), where D is the distance between the edges of the two cameras, that is, the distance marked in Fig. 7.

$$Y_d = \frac{(Y1 - Y1' + Y2 - Y2')}{2\alpha} \quad (3)$$

$$\theta = arctan\frac{(Y1 - Y1') - (Y2 - Y2')}{2\alpha D} \quad (4)$$

VI. Experiment

Based on this method, the robot is tested for accurate positioning. Table I represents the accurate positioning results in one experiment. Through five continuous accurate positioning, the distance and angle adjusted each time, it can be seen that with the increase of the number of times, each time Both the distance and the angle of movement are gradually reduced until a set threshold is reached.

Based on this method, within a distance of 2 mm, through ten times of precise positioning, the actual distance measured each time is shown in Table II. It can be seen that through this method, the error of the moving distance is basically controlled within 0.5 mm.

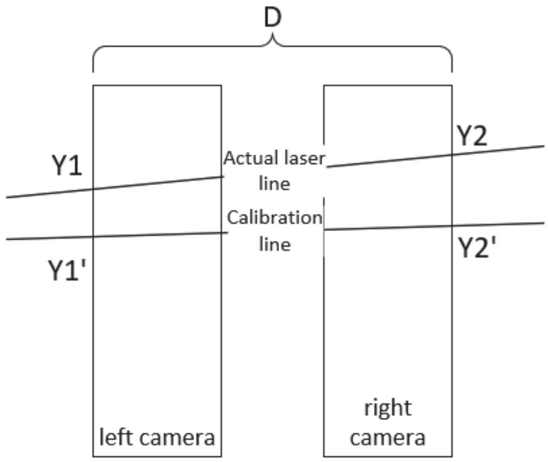

Fig. 7 Calibration line and actual straight line

TABLE I
Adjustment Value Each Time during an Accurate Positioning Process

Number	Distance(mm)	Angle(°)
1	8.5	0.30
2	1.3	0.06
3	0.4	0.00
4	0.1	0.00
5	0.0	0.00

Through this method, the accuracy of indoor positioning is improved to within the range of 0.5 mm. Compared with the traditional indoor positioning technology, the accuracy is shown in Table III. It can be seen that the accuracy of this method is higher than that of the traditional method.

TABLE II
Ten Precise Positioning of the Actual Distance Value

Locating Number	precision(mm)
1	2.1
2	1.5
3	2.3
4	1.8
5	2.4
6	1.6
7	1.8
8	2.1
9	2.6

TABLE III
Indoor Positioning Technology Comparison

Techology	precision
Wifi-based fingerprint method	1–5m
Radio Frequency Identification	0.05–5m
Ultra Wideband Technology	6–10cm
Infrared technology	5–10m
Ultrasonic technology	1–10cm
Visual positioning	0.01–1m
Inertial navigation	2–10m
Lidar SLAM	5–10mm
Accurate positioning based on line laser	0.1–0.5mm

VII. Conclusion

In this paper, an accurate positioning method based on line laser assistance is proposed, which helps the construction plastering robot to perform accurate positioning work by identifying the laser line through image processing, and improves the positioning accuracy to within 0.5 mm, also makes the wall surface smoother. Has huge application value in industry. In the follow-up experiments, it is planned to use a better calculation method to abandon the disadvantage of determining the benchmark in advance, and to perform the positioning work in real time during the work process.

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