

MOBILE ROBOT SELF-PLANNING AND NAVIGATION BASED ON ARTIFICIAL LANDMARK LOCALIZATION METHOD AND BINOCULAR STEREO VISION

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Abstract - This paper describes design of artificial landmark based on colour model used for Self-planning in unstructured environment to a robot for its movement. This method provides less error in estimation when compared to existing methods. This project is an investigation into building a system which visually detects artificial landmarks to determine the landmarks within a location, decipher their position within that location and track the landmark throughout the location using Binocular stereo vision.

Keywords— *Artificial landmark, Colour model, Localization method*

I. INTRODUCTION

The motivation for this project is the fact that the extensively used Global Positioning System (GPS) does not work when a receiver unit is unable to obtain a signal from a satellite. In consequence, GPS is impractical, infeasible and, in actuality, impossible for use in tracking a unit's location indoors throughout a building. There are of course many possible ways in which an object can be located and tracked indoors. A 'local' system which mimics GPS isn't totally unfeasible, but does have many downfalls, one of these would definitely be cost another may be issues with timing a signal traveling at the speed of light passing over short distances i.e. 3ns to travel 1 meter. Visually locating and tracking a passive landmark, such as an image, is in comparison relatively simple and inexpensive. A camera could be used to take an image of a location which could then be processed to discover whether the landmark is present in that location. It could then be possible to determine that landmark's position within that location. 'Natural' landmarks are generally static and form part of the surroundings. One obvious example of a natural landmark is a mountain, although an object such as a plug socket could also be seen as a natural landmark and can be used as a reference point if its location is known. 'Artificial' landmarks, also known as fiducially markers, can be sited in static locations and be used as 'signposts' indicating a specific point of interest, for example. This point of interest may change, it may become uninteresting and the marker may be removed or repositioned. Artificial landmarks can also be used to tag objects to give them an identity. A barcode could be an example of such a tag. It is a visual representation of a numerical code that is used represent some information, typically identifying the object to which it is attached.

II. ARTIFICIAL LANDMARK DESIGN

A landmark is localized physical feature that a robot can sense and use to estimate its own position in relation to a known map or a reference frame. Considering the accuracy, real-time, and the scalability of the landmark in complex environment, the artificial landmark is designed as showed in Fig.1. The landmark is composed by four parts: red rectangular border, blue background, scalable pattern, and direction prompt (the triangle in the center). The reason to choose the red color as the rectangular border is that there is little red color in the indoor environment, further more, the red rectangular border is much fewer, and red is high purity, low lightness, and small scattering intensity. The strong contrast between the blue background and the white scalable pattern is helpful to recognize the gap situation of the landmark. In the center of the landmark, a white triangular direction prompt is designed to indicate the direction of the landmark, and avoiding the recognition error caused by error direction of the landmark. The position information can be got by the landmarks with different codes which generate from the gap situation of the inner concentric circles ("1" for gap, "0" for no gap). Owing to the different situation of the 8 gaps, there are 256 situations in maximum. According to the working environment, the numbers of concentric circles can be added or reduced to meet the requirement. (The landmarks in the experiment are square structure of 18cm length, the width of the red border is 1cm, and the width of inside and outside ring is also 1 cm.)



Fig 1. Artificial Landmark

III. LANDMARK DETECTION AND RECOGNITION

A. Landmark detection

According to the feature of the red rectangular border of the artificial landmarks analyzed in section 2, the landmarks can be detected by color segmentation and structure contour. The color segmentation is based on the transformation from RGB color model to HSI.

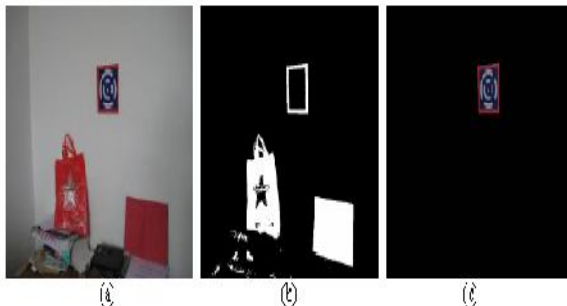


Figure 2. (a) Original image (b) binary image after color segmentation (c) image of landmark detection

B. Landmark recognition

The steps involved in landmark recognition are as follows:

- four vertexes of the landmark in the collected image can be got by linear approximation, as showed in Fig. 3(a), the white “+” represents the four vertexes;
- According to the affine invariant principle, and the four vertexes which are located, the center of the landmark can be located, as showed in Fig. 3(b), the red “+” represents the center of the landmark;
- Based on the invariance of cross-ratio principle, the 8 gap positions of the landmark can be located in the landmark image by the relationship of positions and the actual size of the landmark. As

showed in Fig. 3(c) and 3 (d), the green “+” represents the gap positions of the landmark.

As showed in Fig. 1, the pixel value of the two concentric circles is much higher than the pixel value of the background (the concentric circle is white, and the background is blue), so the gap situation can be detected by comparing the pixel value. However because of the moving of robot, the size of landmark and the illumination of the landmark image would be different.

To guarantee the gap judgment accuracy, a gap recognition method based on self-adaptive window is proposed. As showed in Fig. 3(e), the gap situation can be got by comparing the proportion of the number of low pixels value in the window. Self-adaptive window could adjust its size through the detected landmark region, so it can eliminate the influence of inaccuracy of gap location.

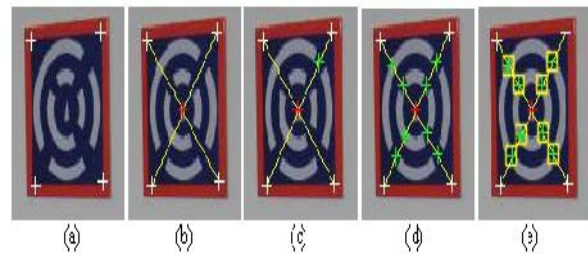


Figure 3. Schematic of landmark recognition

IV. LANDMARK LOCALIZATION METHOD AND BINOCULAR STEREO VISION

A. Landmark Localization Method

Approach: Figure 4 shows the experimental setup. Two poles (used as artificial landmarks) were placed at coordinates of (4000, 2000) and (4000,-1000), respectively, with reference to the robot's global coordinate frame.

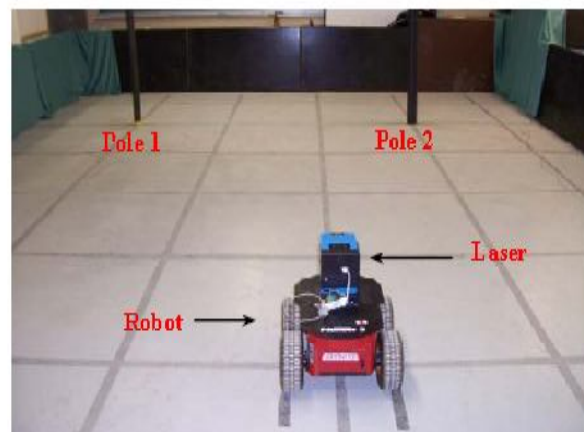


Figure 4. Test Setup for the Landmar Localization Method

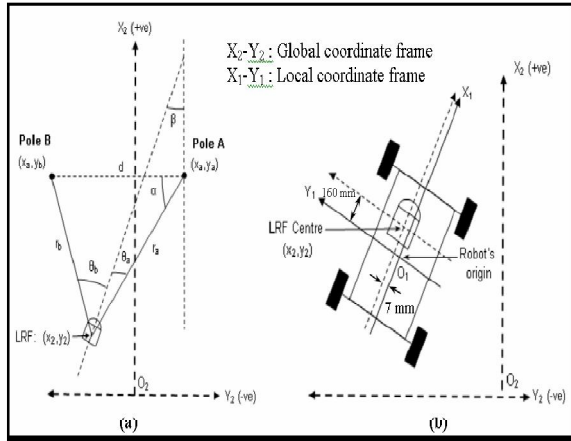


Figure 5. The Artificial Landmark Localization Method

The separation of the landmarks represented as d was set at 3 m in the tests. The distance d could be varied depending on the work space available and the environment in which the robot was working. The distances between the landmarks and the centre of the LRF were defined as r_a and r_b for Pole A and Pole B respectively. θ_a and θ_b were defined as the angles between X_1 axis of the local coordinate frame and the “line of sight” of the poles. In Figure 5 (a), θ_a was defined as a negative angle, and θ_b as a positive angle. Objects detected to the left were assigned a positive value and to the right negative values. The variables r_a , r_b , θ_a and θ_b were all known from the LRF data. In order to compute the position of the LRF (x_2, y_2) with respect to the poles the following equations were derived and used in the landmark localization algorithms.

$$\begin{aligned} (x_2 - x_a)^2 + (y_2 - y_a)^2 &= r_a^2 \\ (x_2 - x_b)^2 + (y_2 - y_b)^2 &= r_b^2 \\ (2y_2 - y_a - y_b) \times (y_b - y_a) &= r_a^2 - r_b^2 \\ y_2 &= \frac{r_a^2 - r_b^2}{2(y_b - y_a)} + \frac{y_a + y_b}{2} \\ x_2 &= x_a \pm \sqrt{r_a^2 - (y_2 - y_a)^2} \end{aligned}$$

The heading angle β was calculated using the following expression

$$\begin{aligned} \frac{\sin \alpha}{r_a} &= \frac{\sin(\theta_b - \theta_a)}{d} \\ \sin \alpha &= r_a \times \frac{\sin(\theta_b - \theta_a)}{d} \\ \beta &= 180 - (90 - \theta_a + \alpha) \\ \beta &= 90 + \theta_c - \alpha \end{aligned}$$

Figure 5(b) shows the position of the LRF relative the robot's local coordinate frame. The centre of the LRF was located at 160 mm, 7 mm with respect to the local coordinate frame of the robot.

The position of the centre of the LRF was subsequently transformed to the robot's origin to

obtain the position of the robot in the global coordinate frame.

B. Binocular Stereo Vision

The binocular stereo vision theory is based on the research of human visual system. When a pair of points in the images captured by the binocular vision sensors is given, the three-dimensional coordinates in real world of this point can be calculated. When the same landmark in the images collected by the stereo vision system is detected, the distance between robot and landmark can be calculated through matching the corresponding points of the same landmark.



Figure 6. (a) Equipment of stereo vision (b) mobile robot with stereo vision

V. RESULTS AND DISCUSSION

The robot was driven to specific locations on landmark localization system readings were all recorded and analyzed.

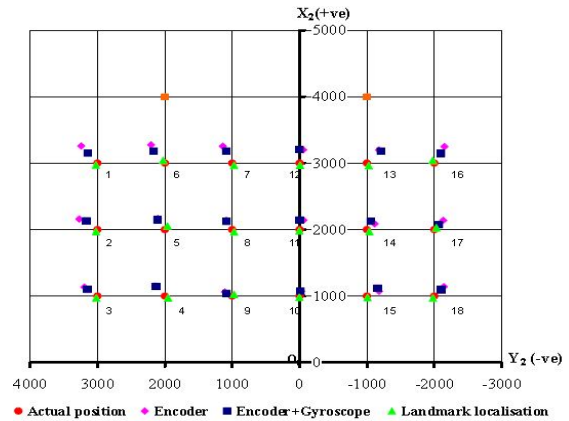


Figure 7. Results from the Artificial Landmark Localization Method (units in mm)

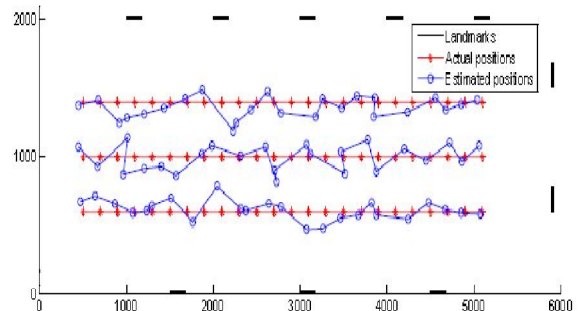


Figure 9. Experiment results of robot self-location

The percentage error between the actual position and measured positions were computed. The measured position refers to the wheel encoder measurement, and the combined wheel encoder and gyroscope measurement. The percentage error was computed as follows:

$$\text{Percentage error} = \left| \frac{\text{Actual distance} - \text{Measured distance}}{\text{Actual distance}} \right| \times 100\%$$

TABLE 1.
SUMMARY OF PERCENTAGE ERRORS

Position estimation method	Percentage error	
	X	Y
Artificial landmark localization	1.95	1.93

TABLE 2.
THE RECOGNITION RESULTS OF THE
ARTIFICIAL LANDMARKS USING
BINOCULAR STEREO VISION

Sum of images	Correct recognized	Recognition accuracy	time/per image
400	331	82.75%	93ms

VI. CONCLUSION

A self-localization method of indoor moving robot based on artificial landmarks and stereo vision is proposed. First, a new artificial landmark model with the features of strong anti-interference and easy-to-recognize is designed, then combining the artificial landmarks and stereo vision to locate the indoor mobile robots. Stereo vision can solve the problem of Omni-directional vision which can not recognize the landmark far from the stereo vision system, and the problem of monocular vision which can not calculate the distance between the landmark and robot. Meanwhile the artificial landmarks can helps to decrease the complexity of stereo matching. The experimental results show that, the method of landmark detection is not only robust to lights and angles, but also to the feature of real-time, and it can meet the requirement of the self-localization of the indoor mobile robots.

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