An object-following powerboat using QR Code

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Abstract— One main issue for mobile robotics is the task of localization and navigation. An approach to this problem in an indoor environment is proposed in this paper. This project aims to develop a human-tracking capability for a Powerbot by using a pose reference as the landmark — a QR code on the leader. A Powerbot and a camera are the leading hardware used in this experiment. So, the camera tracks the position and orientation of the leader's QR code at high speed. There are three steps in the human-following process. The first is to recognize a person (or a robot) using QR codes. Second, location detection of the QR Code uses a shape-based pattern matching algorithm to recognize the position of the QR code. The previous experiments estimated the rate of QR Code recognition by about 99.9%. Third, the robot maintains a measured distance from the leader during human tracking. This part is a robot-control experiment to demonstrate the accuracy of the tracking algorithm.

I. INTRODUCTION

A QR (Quick Response) code is a 2D (two-dimensional) matrix barcode, is represented by black and white dots (data pixels or square data dots) and is scanned by a camera. On the contrary to the one-dimensional barcodes, QR code includes up to 3000 characters on a small tag [1].

About the history of the QR Code, QR Code was designed by Denso-Wave Corporation of Japan in 1994. The most crucial goal for inventing QR Code was to track the vehicles which were manufactured. Since then, QR code is used in the automatic identification area, especially in a Human-Tracking Robot, commercial tracking parts in the manufacturing of vehicles and smartphone users [1,2]. High speed and all-directional recognition and a strong capability of error-correcting are the primary purposes of using the QR Code.

Besides these purposes, robots should understand the environment in which they move. This environment is continuously changing with people. So, it is necessary to teach robots the path which they want to move around. The best way is that a human using QR Code shows robot the safe paths. The possible ways show either the human leader or the robot follower. Moreover, the high accuracy of location can affect the accuracy of navigation in mobile robots. So, QR Codes can improve the accuracy of localization methods.

There is previous research to recognize the QR Code, which is challenging under low contrast regions in Non-homogeneous light conditions and the complex conditions. Non-homogeneous lighting is a difficulty in the classification of image regions. An algorithm that includes an inverse perspective and grayscale image transformation, edge detection, and grid-cell generation analyzes a distorted image of the QR Code. This algorithm which uses the gray image processing rather than black and white image processing takes more time to analyze it [3].

In another recent research, there are two classifications for indoor localization as relative and absolute localization. In relative localization, Dead reckoning (DR) methods calculate the whole distance, which is traveled from the starting point [4-6], while the estimation error happens over time. One solution for the problem of localization can be combining the approach with external sensors, such as sonar, beacon, odometry, cameras, GPS, and laser range finders [7]. In this approach, an external sensor or DR methods are needed, which sometimes costs money and extra efforts.

Also, there are two kinds of landmarks that can be used in the localization problem, artificial landmarks, and natural landmarks. With using artificial landmarks, there is no need to change the environment; however, it is a challenging part to distinguish the natural landmarks in a real environment. As a solution to this problem, light fixtures as natural landmarks are proposed by Alves et al. to improve the localization system in an office environment [8]. The problem is that lots of QR codes were used for this research.

Furthermore, some earlier algorithm cannot recognize the specific person, but Katsuki et al. proposed a system which handled multiple heterogeneous objects with 2D barcodes and encoded specific information to the objects [9], [10].

On the other hand, in the previous system on tracking projects, active infrared tags that require heavy batteries are recognized for location detection purposes, but the burden of batteries is the problem of this system [11]. In contrast, the QR Code, which is inexpensive passive tags, can be printed and tracked by powerbot.

However, using the QR Code in human-tracking is in a small frame which depends on the camera performance. The rate of object recognition can decrease, as the distance between the camera and objects increases. One solution of location detection of the tag, a shaped-based pattern matching way is useful. On the contrary, an object between the leader and the powerbot as a follower can cause a problem. Ultrasonic range sensors are useful to avoid obstacles, and QR Codes can be as location references [12]. Unfortunately, the problem is that when the robot is close to the QR Code, the speed of the robot slows down. It is also hard to recognize the QR Code when the robot moves fast around 1 m/s.

Moreover, the usage of the QR Code is to improve the accurate detection of the robot position [13]. However, it is not for real-time absolute localization. Besides, the small size of the QR Code in the camera's view and fast movement of the robot can reduce the rate of detection.

In our experiment, a camera is mounted on a powerbot, and one QR Code tag, which is held by a leader provides the global location data of the leader. Moreover, the recognition and control algorithm will not only improve the rate of recognition but also decrease the rate of computation time with only one QR Code tag. In this algorithm, the current location of the powerbot can be estimated and used as an input for navigation. For reducing the localization error, the calibration of the camera is an effective way to implement it.

The three main steps for the process of tracking can be:

(1) The human recognition using QR Code for a human-following robot application.

(2) The location detection of the human being tracked.

(3) Robot-control which maintains an appropriate distance from the person being followed.

In this proposal, a human-following robot tracks the person using a QR Code tag by a four-wheeled powerbot with a computer vision algorithm.

II. QR Code Vision System

In the vision system, the orientation information and decoded data are obtained from a camera mounted on the powerbot, as shown in figure 1. The camera which is used in the visual system is an Xbox 360 Kinect, which output video at the frame rate of 9 Hz to 30 Hz with a pixel size of 640*480 (Fig. 2).

Figure1. The powerbot which camera is mounted on.

Figure 2. XBox 360 Kinect Camera

III. OBJECT-TRACKING PROCESS ANALYSIS

Three processes can be followed. The first and the primary function is to distinguish between individual people by recognizing the QR Code using a camera. The second is to track QR code using a shaped-based pattern matching. The function of QR Code following which detects the location of the QR Code is used when the distance of the leader is farther than the distance for recognizing the QR Code. The last process is to control the robot and find robot motion. In the control part, a command is sent to the motor. Then the command causes the powerbot to move in an appropriate distance from the leader. The process of tracking can be shown in figure 3.

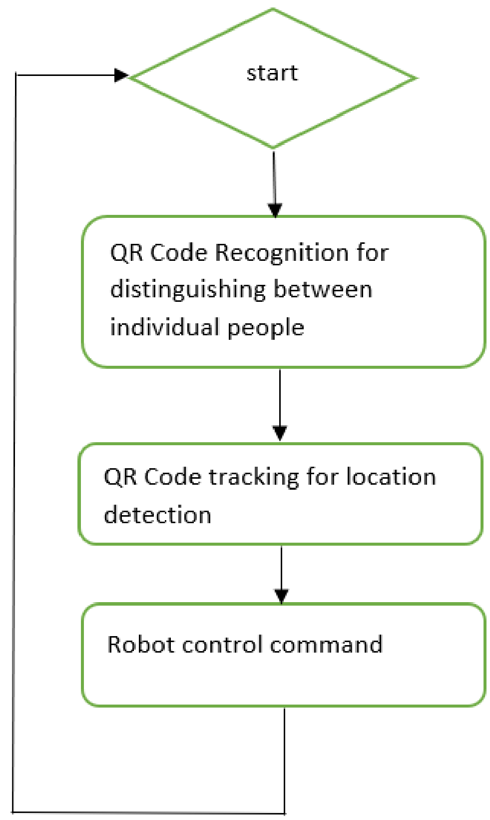

Figure 3. Object-tracking process flow chart

IV. QR CODE DECODING

The QR Code is encoded and captured by a camera in RGB 24-bit format. The symbols of the QR Code defines as a set of black and white pixels in figure 4. There are some steps in the QR Code detection algorithm.

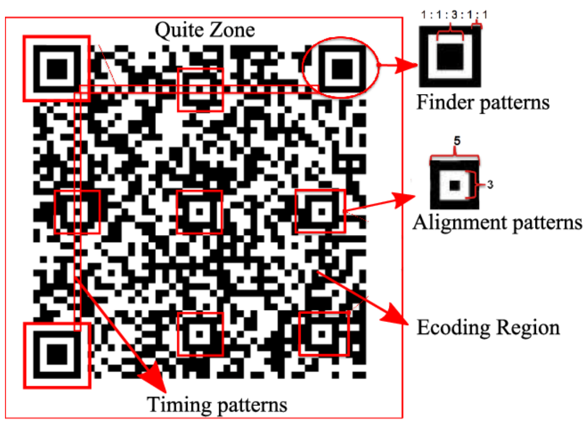

Figure 1. QR Code details [8]

(1) Convert an image of gray to a black and white image that affects the detection speed of the QR Code (Binarization).

(2) Find the region of QR Code based on the finder patterns in the localization part, which provides the fast orientation, improves the speed of QR Code recognition, and decreases the edge detection.

(3) Find an accurate position according to the alignment patterns.

(4) Estimate the angle of inclination and rectify the QR Code for geometric deformation by a linear mapping method (Affine transformation).

(5) Find the version number and build a bitstream.

(6) Scan according to the corrected image and input code stream of the standard 2D matrix.

V. Discussion

A. Benefits of QR Code in powerbot

More information or data are hidden in the QR code that can be stored, recognized, and decoded at high speed and from any direction in mobile Robots. QR code provides resistance against the damages [2]. Besides, a Quick Response Code which is small, less expensive, simple to implement used as a landmark in absolute localization methods in indoor mobile robots, such as the powerbot.

B. Limitations of QR Code in powerbot

As technology makes enormous strikes all over the world, the drawbacks come up with advanced innovations. In displaying the QR Code, the big QR Code is not common to use. There are also some positioning errors in landmarks because of the fast movement of powerbot [14]. To resolve this issue, the speed of the powerbot should adjust within a range that maintains a certain distance from the leader. There is still some limitation of uniformity in barcode encoding applications which is used in the camera on the powerbot. Also, ambient light or sheltering obstacles cause uncertainty for localization and orientation data from the QR Code. In some experiments, the researchers used external sensors for addressing the obstacle and light problem, but in the proposed method, the less costly method is used.

VI. Conclusion

A human tracking powerbot using QR Code detection for mobile robot localization and navigation is proposed. With a camera and a quick recognition algorithm, the vision system which is used in the experiment provides a high-accurate and high-speed recognition method for detecting a leader using the QR Code by a powerbot. The algorithm c detect the location of the leader with the probable recognition of matrix codes in an image. Moreover, a powerbot-control part is proposed to keep an appropriate distance from the leader being tracked. In future work, the development of a Human-following powerbot for robust localization and navigation system is considered. Consequently, the approach which is proposed in this proposal would be adequate for detecting the QR Code and following the leader using the QR Code.

VII. REFERENCE

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