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PATH PLANNING OF MOBILE ROBOTS BASED ON QR CODE

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Abstract

The place and importance of mobile robots in today's industry is increasing day by day. The use of mobile robots for industrial purposes such as sorting, moving and placing is no longer a preference but a necessity. With methods such as line, magnetic field, infrared ray or image tracking, positioning of mobile robots and path planning are possible. The use of these methods depends on the application fields. The industry started with mobile line following robot's application at the beginning, gradually they have been developing day by day, and pursuits for different methods. If the topic examined under the heading of Industry 4.0, it is necessary to equip mobile robots with innovative technologies. The need for mobile robots that can provide fast, effective and practical solutions is being investigated by academics and commercial product developers.

In this study, it is aimed to carry out a QR code based study on path planning of industrial mobile robots with distributed mobility. For this purpose, coordinates of the mobile robot work area are represented by QR labels and prepared in the form of a matrix. This way, developed path planning algorithm can be evaluated as a derivative of existing algorithms.

Key words: Industrial mobile robot, QR code, Path planning, ROS.

1. Introduction

The place and importance of mobile robots in today's industry is increasing day by day. The use of mobile robots for industrial purposes such as sorting, moving and placing is no longer a preference but a necessity. With methods such as line, magnetic field, infrared ray or image tracking, positioning of mobile robots and path planning are possible. The use of these methods depends on the application fields. The industry started with mobile line following robot's application at the beginning, gradually they have been developing day by day, and pursuits for different methods.

This topic is being investigated by the researchers in the literature and studies are being made on an improvement of existing methods and development of new methods. Lee and Jung have worked on mobile robots with image feedback, two-wheeled and self-balancing line follower in their work. Researchers based on mobile robot and operator or humanoid robot arm which they developed in their studies [1]. Li and his colleagues have developed an autonomous mobile robot that uses infrared sensors to detect the direction of the robot and can perform target tracking using real-time

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fuzzy [2]. Skrab'anek and his colleagues combined the information of the encoder and the infrared and magnetic sensors found in the mobile robot that they developed in their work, and the path planning of the robot was realized. The robot, which is placed in a maze, is planned to be able to exit the maze from the shortest path by combining the collected data from the camera and other sensors [3]. Wang and his colleagues have designed a robot capable of welding with vertical climbing motion by following the welding line. The robot they have developed in their work can monitor the welding line with image processing techniques using a real-time dual camera [4]. Marinho and colleagues developed a new method of positioning mobile robots by classification. This method they have developed contains two original versatile image sets and the positioning of the robot references this image set [5].

One of the preferred new methods of locating and path planning mobile robots in workplaces where distributed multiple robots are involved in is the uses of QR code. QR coding technique, mobile service, robots, path planning are taking place in literature. Hao and colleagues have studied the orientation of mobile service robots in a closed environment using artificial labels based on QR code, using a relational method between objects. In their work, they have been able to locate the service robot using a hybrid mapping with QR coding technique [6]. Rostkowska and Topolski have followed the QR code for robots in the workplace using a low cost camera. The researchers take the QR codes placed on the top of the robots in their work and the robot's direction and position information instantaneously [7]. Zhang and his colleagues used the QR code matrix in the upper part of the study area to direct and position the robot. When performing these operations, QR images were obtained from the industrial camera on the robot and the Dijkstra's algorithm was used [8]. Surion and his colleagues formed a matrix consisting of QR codes in the ceiling of the study area, just like in Zhang's work, and they followed the QR codes to guide the robot. They constructed an experimental field consisting of 24 QR labels placed at intervals of 1.2m in their work [9]. Li and his colleagues have developed a vector-based QR code-reading robot that can quickly identify objects in the environment with a CCD camera. By defining the orientation of the QR code above objects in their environment developed robots operate by reference to these labels [10].

These widespread impacts from academic studies have also reflected in the development of commercial products in a short time. Especially in the field of logistics companies have recently moved to mobile robot technology quickly. The path planning and path tracking methods of mobile robots that come along with this widespread effect are among the problems to be investigated. In this study, the direction finding of mobile robots using 3D barcode (QR code) has been studied also, a developed algorithm has been studied on the path planning of the robots that are traveling on the field.

2. QR Code Detection System

2.1. System Configuration

Robot platforms used in today's scientific researches generally prefer ROS (Robot Operating System). This Linux-based operating system that allows a lot of flexible coding techniques is very beneficial to the researcher on the way to the goal. In this study, robot platform named Kobuki which uses ROS operating system is used. In addition, the path planning of the robot is determined by an algorithm developed before the movement of the robot. Operation of the planned path from the starting point to the destination point is provided by the Raspberry Pi single-board computer. Thanks to the QR tags that allow the robot to be guided on the path to the target point. The reading of the QR tags is done via an HD webcam with 720p resolution. With the installed OpenCV library on the Raspberry Pi, QR labels on the ground were detected and analyzed. The relationship between the software and hardware used in the study is given in Figure 1.

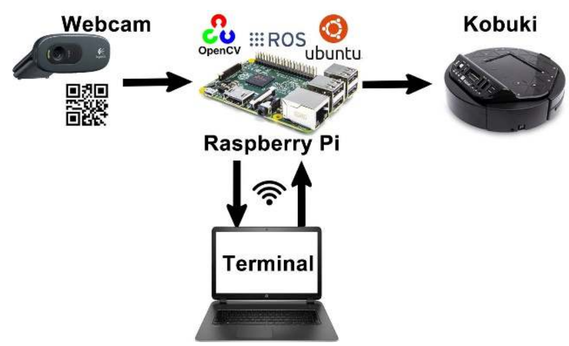

Figure 1: System diagram

2.2. Localization Pattern

When QR codes are structurally examined, each code contains three patterns in separate dimensions, such as detection, alignment, and timing. Position detection patterns located in three of the four corners. This allows 360 degrees high-speed reading of the code. The alignment pattern allows the QR reader to correct for distortion when the code is bent or curved. Timing pattern is the pattern between the detection patterns that are used to correct the center coordinate of the cell when the code is twisted or when errors occur in the cells. Structure of QR code pattern shown in Figure 2.

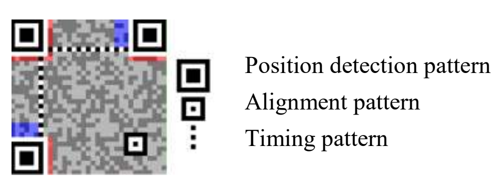

Figure 2: Structure of QR code pattern

QR tags used for locating robots and for finding directions, field of QR tags application in the industry has various methods. In this study, coordinate information of a sample of a mobile robot to be found in the navigation is processed in QR tags and an area is created in the grid structure. The grid structure of the generated sample area is shown in Figure 3. This area contains coordinate information that the mobile robot will use in order to move from a specified starting point to the target point. It contains QR tags that are created with 1m intervals and are easily readable by the camera on the robot. Location information is read by the robot and compared with the path information that had been sent before the robot action. At the same time, this information on the motion path is also sent via a wireless communication protocol to the terminal computer where the algorithm works, and the correctness of the route is evaluated to provide double-sided verification.

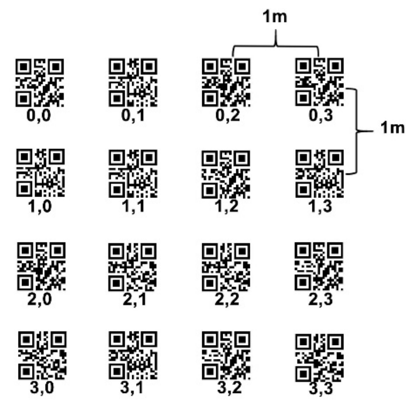

Figure 3: Sample field of QR code pattern.

2.2. QR Code Detection and Slope Account

Path planning from starting point to target point of mobile robot has been provided with an algorithm developed. Thanks to the QR tags the mobile robot follows the planned path on a surface located area at 1m intervals in the form of a square matrix. The coordinate information contained in these tags is generated by the algorithm running on the terminal computer before the movement of the robot and it is transferred to the robot by wireless communication. When the mobile robot is activated, the camera on it is activated too, and every tag containing the coordinate information read and send up to the terminal computer during the movement. The QR code detection has used the OpenCV image processing engine which enables the operation to be performed at a lower cost than other operations.

Essentially the angular differences between the camera angle and the QR labels are very important for correct recognition of the coordinate information. For this reason, the label needs to be analyzed by focusing on a central point by the camera. For this purpose, if the detection pattern belonging to the tag is named as A, B, C, it is necessary to make the tangent slope calculation as shown in Figure 4 and Equation 1.

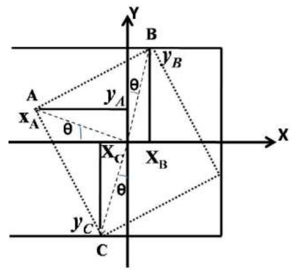

Figure 4: QR tag detection slope calculation [11]

(1) $k = \frac{y_A - y_B}{x_A - x_B}$

If k > -1 and k < 1, the position is defined by the clockwise rotation of the QR code.

It is possible to evaluate the angle of rotation of the QR label to the camera plane when reference is made to the method and geometric transformation principles proposed by Wikipedia. If we consider that the left and right edges are $d_1$and d_2, respectively, as shown in Figure 5;

$d =$ Actual QR label size,

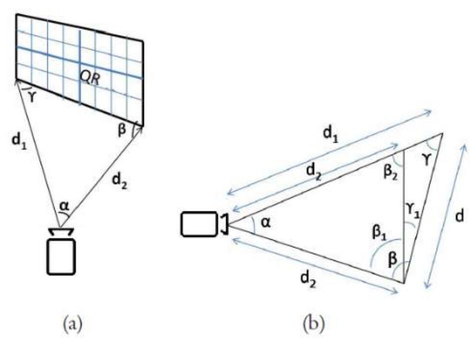

Figure 5: Geometric model for slope calculation of distortion angle

(2) $\alpha = \arccos \frac{{d_1}^2 + {d_2}^2 - d^2}{2.d_1.d_2}$

Similarly β is calculated and according to the triangle formula;

(3) $\gamma = 180^0 - \alpha - \beta$

α, β *and* γ are known and as shown in Figure 4 which $\beta_1 = \beta_2$, Calculated as :

$$\beta_1 = \frac{180^0 - \alpha}{2} \qquad\qquad \gamma_1 = \beta - \beta_1$$

3. Localization Algorithm

Localization plays an important role in the navigation of mobile robots in the field. Localization, which is called positioning the robot to the next target point and contains instant position information, is the most important point in the road planning of mobile robots. In the study, the navigation area of the matrix structure consisting of QR tags, each of which contains coordinate information, constitutes the example localization pattern used. The global road planning covering the coordinates from the starting point of the robot to reaching the target point is done through this pattern. In the localization algorithm, the start and target positions of the robots are firstly taken by a terminal computer with the interface shown in Figure 6. This information is presented to a Cartesian algorithm and then computed for each robotic roaming path. This route information created by the robots can be previewed from this interface again.

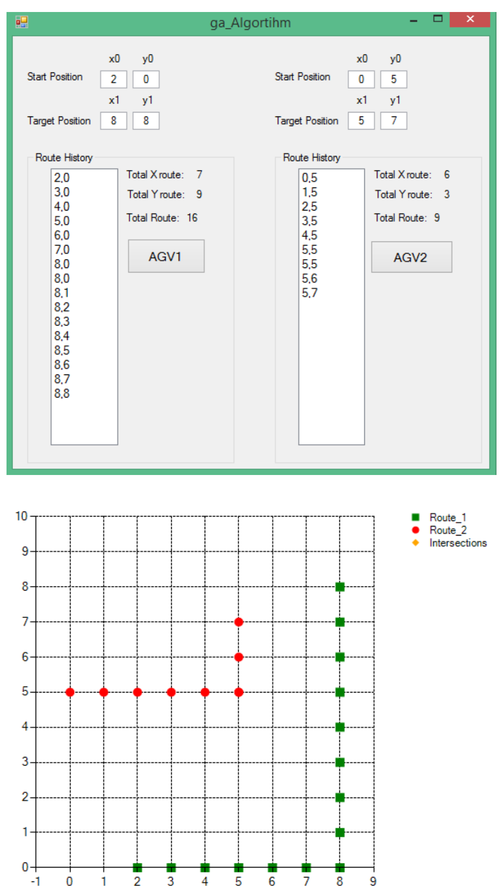

Figure 6: The developed user interface for localization algorithm.

The robot is given the first action immediately after the path information between the start point and the target point is transmitted wirelessly to the robots. By reading the QR tags on the previously created localization pattern, the robots send coordinate information to the terminal computer. At this point, both the robot and the terminal computer able to match the path. An exemplary path from the starting point $(x_0, y_0) = (0{,}0)$ to the target point $(x_1, y_1) = (3{,}3)$ is presented in figure 7.

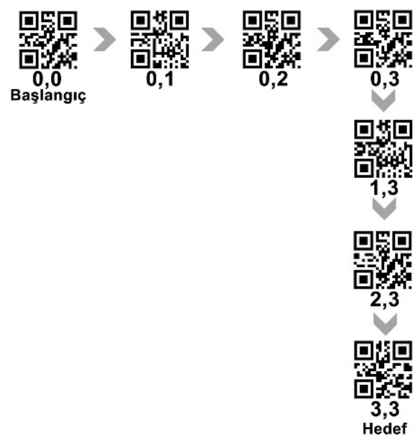

Figure 7: An exemplary path planning of Two-point

Conclusions and Recommendations

Thanks to the algorithm implemented in this study, the progression of the AGVs from the determined start point to the target position is achieved by QR codes. The QR codes used as the positioning method are read by a webcam placed on the robot and are reported to the master station and position verification is performed.

Future work is planned to prevent route overlaps for robots moving in the same environment.

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