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Dist: Vijaypura

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DEPARTMENT OF MATHEMATICS

PROJECT WORK

This is to certify that students of B. Sc I SEM participated in Mathematics Project work on Mathematics Day 2022-23. Model on <u>Mathematics used in QR code Scanner</u> satisfactorily completed their work under my supervision at our college under Rani Chennamma University Belagavi.

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Abstract:

Providing position and orientation estimations from a two-dimensional (2D) image is challenging, as such images lack depth information between the target and the automation system. This paper proposes a numerical-based monocular positioning method to determine the position and orientation of a single quick response (QR) code object marker. The three-dimensional (3D) position information can be extracted from the undetermined system using the QR code's four vertices as positioning points. This method uses the fundamental principles of the pinhole imaging theory and similar triangular rules to correspond the QR code's corner points in a 3D environment to the 2D image. The numerical-based model developed with suitable guessing parameters and correct updating rules successfully determines the QR-code marker's orientation. Then the MATLAB platform simulates the proposed positioning model to identify the maximum rotation angles detectable at various locations using a single QR-code image with the known QR code's size and the camera's focal length. The simulation results show that the proposed numerical model can measure the position and,

orientation of the tilted QR-code marker within 30 iterations with great accuracy. Additionally, it can achieve no more than a two-degree angle calculation error and less than a five milimeter distance difference. Overall, more than 77.28% of the co-ordinate plane simulated shows a converged result. The simulation results are varified using the input value, and the method is also capable of experiemental verification using a monocular camera system and QR-code as the land mark.

★ The 2D QR Code Marker:

The QR code has been extensively adopted for product identification recently. It will become a standard marker on every product packaging in the near future. The four corners of the QR code on the packaging can be utilized to identify the position and orientation, together with the packaging's dimension information, can then be used by the robot to compute the gripper trajectory and grasp

- the product. In time with the current trend, QR codes are used as markers for a product position and orientation identification system in the project.

shows the QR code samples with labelled corner points and lines. These points can be used to indicate the QR code's orientation. By mounting a camera on the robot end-effector, the QR-code image can be acquired. The corners of the QR code can be identified later using an image processing algorithm. The details of algorithm The details of the algorithm can be found in [16, 21, 22]. In this project, the corners are labelled and denoted as,

$P_1 = (x_1, y_1, z_1)$, $P_2 = (x_2, y_2, z_2)$,

$P_3 = (x_3, y_3, z_3)$, and $P_4 = (x_4, y_4, z_4)$,

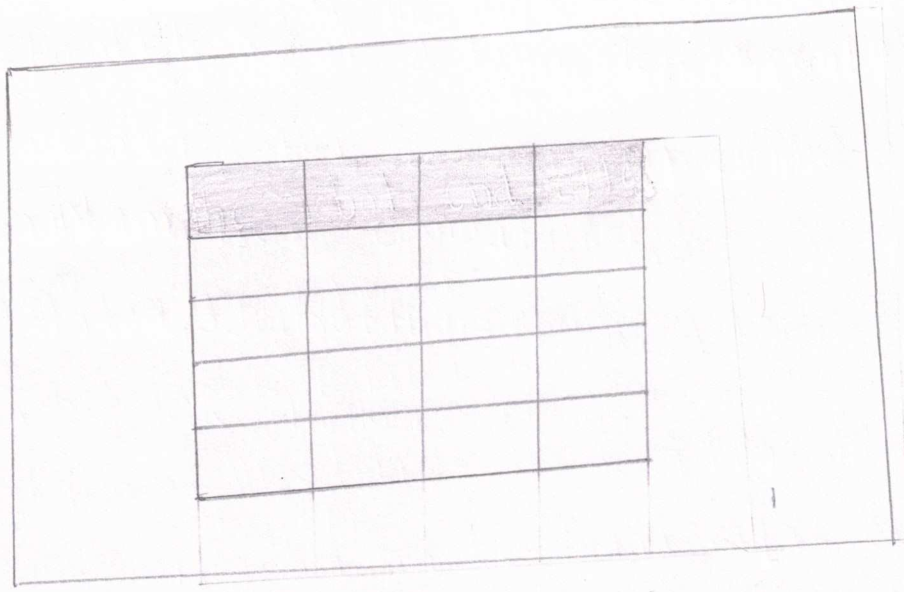
respectively, as shown in * Meanwhile, Table 1 lists the details of the length, l_1 to l_6, between the corresponding points.

Figure 1. Sample QR code: (a) length l_1, l_2, l_5; (b) length l_3, l_4, l_6.

(a) (b)

* Sample QR Code: (a) length l_1, l_2, l_3; (b) length l_3, l_4, l_6.

* The length of the QR code marker between corresponding points.



3. The positioning Model of the QR code

* Shows the main workflow used to develop the mathematical model for the proposed positioning system.

* The main workflow for the mathematical model.

Pinhole Imaging Theory / Similar Triangle Rule
Guessing parameters of QR's vertices

↓

Point-to-Point Distance Measurement
conditions for Guessing parameters

↓

Numerical computation
updating rules for guessing parameters

↓

3D Rotation Matrix
QR Marker's orientation.

* The system extracts the QR code's 2D image co-ordinates and maps them to their corresponding 3D geometrical characteristics.

* The estimated distance between two corner points scales the estimated conditions of the z coordinates.

* The z-coordinate values for the next iteration are computed using the updating rules

* The result converges when the absolute convergence error fulfils the requirement.

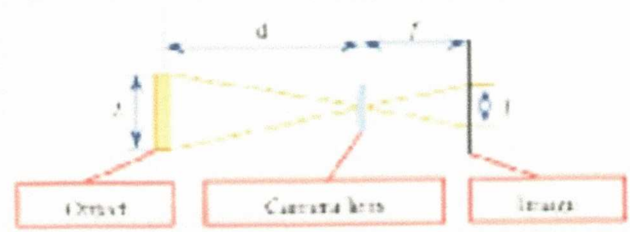
* The orientation information is calculated using the inverse rotation matrix.

* Decoding the information stored in the QR code is not the main aim of this research

→ The pinhole imaging theory and similar triangles rule are adopted to determine the objects location from an image.
This relates the object to the corresponding 2D image, as illustrated

where, L denotes the actual side length of the object. l is the side length. d is the working distance btw the object & camera lens & f is focal length.

Figure 3. The basic principle of pinhole imaging.



Referring to pinhole imaging theory, the ratio of the focal length to the object distance can be defined as:

$$\frac{f}{d} = \frac{l}{L} \quad \text{------------ (1)}$$

Thus, the actual side length of the object is:

$$L = \frac{l}{f} d \quad \text{------------ (2)}$$

4. Point-to-point Distance Model as Z-coordinate Conditioning Rules

The guessed conditions for the z-coordinates require a known value to gauge the estimated value. Since the distance between the corner points p_i and p_j on the QR code is known and fixed, it can be used to formulate the updating rules.

The distance between the corner points, l_{ij}, is defined as:

$$l_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}, \quad \text{for}$$

* The QR code is square-shaped; thus, it's horizontal and vertical length are the same.

$$l_1 = l_2 = l_3 = l_4 = l$$

• Conclusion:-

The proposed lightweight numerical method positioning model succesfully simplifies the extraction of positional information from one single 2D image. The proposed model applies the pinhole imaging theory and similar triangles rule to find the geometric relationship btw the QR code and the captured image, Then, a positioning model is developed using the numerical method. to estimate QR code's depth information. and to perform computations toward convergence using the updating rule. The four coner points of the QR code are the positioning points for the model.

Q.R CODE

Coordinator IQAC