IOP Conf. Series: Materials Science and Engineering **319** (2018) 012056 doi:10.1088/1757-899X/319/1/012056

Smart mobile robot system for rubbish collection

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Abstract. This paper records the research and procedures of developing a smart mobility robot with detection system to collect rubbish. The objective of this paper is to design a mobile robot that can detect and recognize medium-size rubbish such as drinking cans. Besides that, the objective is also to design a mobile robot with the ability to estimate the position of rubbish from the robot. In addition, the mobile robot is also able to approach the rubbish based on position of rubbish. This paper explained about the types of image processing, detection and recognition methods and image filters. This project implements RGB subtraction method as the prior system. Other than that, algorithm for distance measurement based on image plane is implemented in this project. This project is limited to use computer webcam as the sensor. Secondly, the robot is only able to approach the nearest rubbish in the same views of camera vision and any rubbish that contain RGB colour components on its body.

1. Introduction

As the technology keep on growing each and every day, the life of human has become easier and convenient together with the growth of technology. Humans are helped by the technology every day in daily life. Technology today has developed into creating more automatic devices or robots which will help human to save their time to accomplish simple tasks [1]. The growth of technology has been incredibly great that even for simple task like cleaning is included in improvement and development. Cleaning has been a task that requires human energy and time to accomplish. However, people nowadays do not have the interest in cleaning. Hence, the discussion of this paper is about designing a mobile robot with rubbish detection and recognition system and its application [2].

The development of this mobile robot enables human to work at least effort to pick up rubbish. Especially for those people that having problem bending down to the floor to pick up rubbish [1]. There are other types of robotic cleaning machine that have been available in the market, however they did not comes with the application of differentiating the trash into categories. In this project, the smart dustbin is able to differentiate the type of trash it needs to clean by implementing DRI. DRI is the term stands for Detection, Recognition and Identification. Detection is to identify object; recognition is to match the type of object; and identification is specify or categorize the object.

Path planning of robot is one of the most complicated problems that occurs during WMR in outdoor or indoor environments. In path planning approaches, the path trajectory is planned continuously between the start and goal positions with avoiding the obstacles and determine the location of rubbish [3-5]. The controlled of WMR have be done to accomplish WMR rubbish collection task in the right manner [6-8].

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2. Overview of the System Architecture

The system design consists of a camera as the sensor, a computer with MATLAB software as the core channel, two MC30 motor driver, an Arduino Uno to control gear motor through motor driver, and 3 wheel mobile robot prototype for the system as shown in Fig. 1, 2.

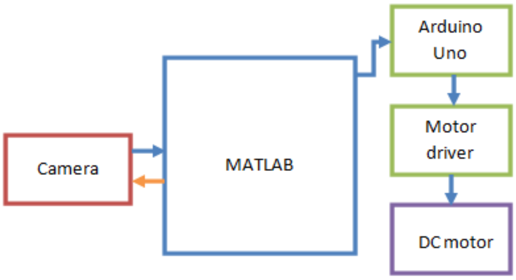


Figure 1. System architecture of Smart Mobile Robot System

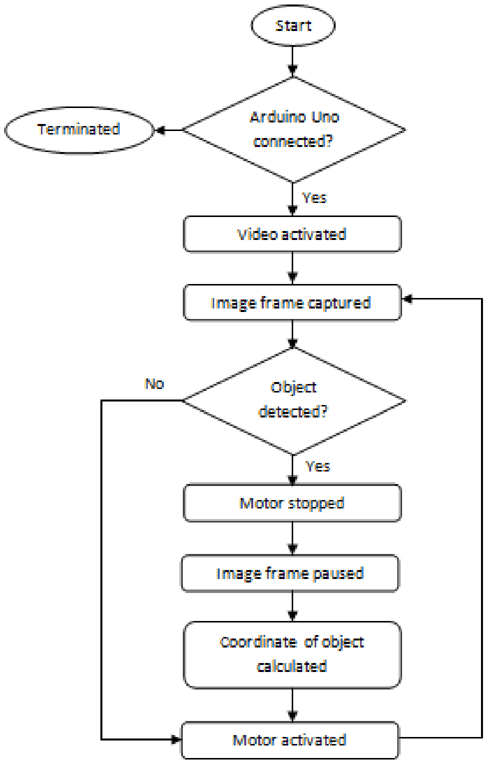


Figure 2. Overall system flow chart

3. Methodology

The methodology activities of this project are as follows:

3.1 Development of Detection and Recognition System

RBG detection is implemented in this project to detect the rubbish around a certain area of view. By retaining the RGB element and adjusting each threshold value, any objects that contain any colour of RGB within the threshold can be recognized and detected.

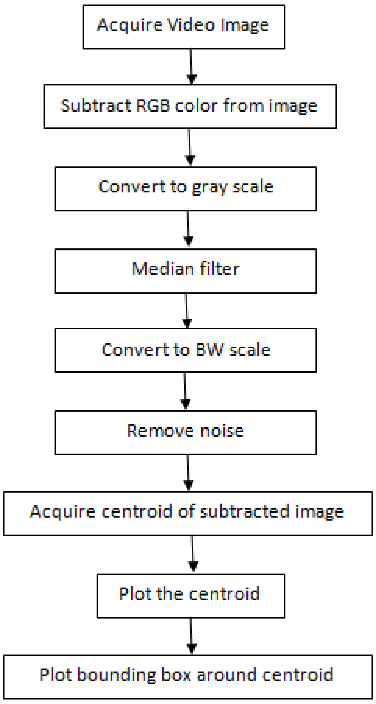


Figure 3. Object detection system process flow

3.2 Image to Reality Coordination System

The relationship between the image plane and the reality coordinate system depends on several parameters of camera. In this case, any coordinate in image plane can be determine by using the image size in pixel (ie. 1280 horizontal pixel * 720 vertical pixel). The coordinate of object from the camera lens that captured in the screen is normally scaled and inverted horizontally and vertically. If the distance of an object in reality which is perpendicular to the lens is *D*, and the distance of image plane from lens is I_{cam}, their relationship is called magnification factor:

$$M = \frac{D}{I_{cam}} \tag{1}$$

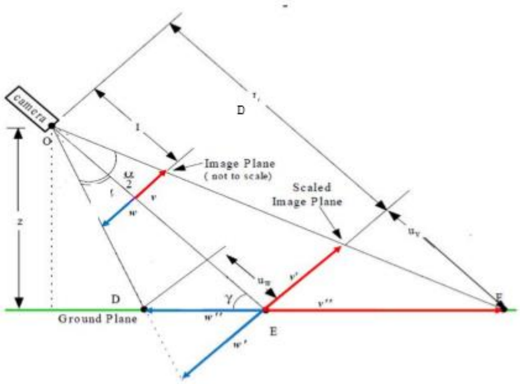


Figure 4. Elevation view of camera

The position of any point on the vertical plane of reality, y_g is as follow:

$$y_g = \frac{z\,y_i}{\sin(\gamma)(I_{cam}\sin(\gamma) - y_i\cos(\gamma))} \tag{2}$$

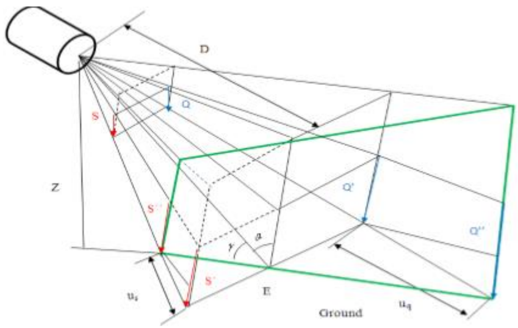


Figure 5. Camera transformations

The position of any point on horizontal plane of reality, x_g is as follow:

$$x_g = \frac{z\cos(\vartheta) - Mx_i\sin(\gamma)}{\sin(\gamma)\,(I_{cam}\cos(\vartheta) - |x_i|)}|x_i| \quad (3)$$

These formulas are base on basic calculations without considering the effect of image distortion. Hence the result is the estimated position based on the image captured.

3.3 Mobile Robot Prototype

The mobile robot is a three wheel robot which has two main wheels with DC gear motor and one free wheel. This mobile robot is fabricated using 40mmx40mm aluminium profile and 10mm thick of aluminium plate. The mobile robot main body has 2 layers, where bottom layer is fixed with two DC gear motor and electrical components while the upper layer is to mount sensors and for other uses purpose.

1) Mobility System

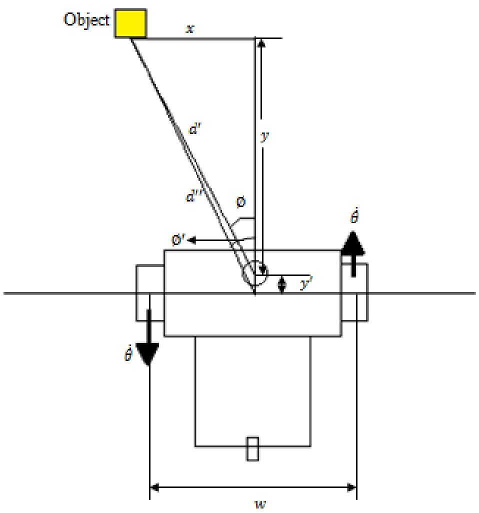


Figure 6. FBD of robot angle to object

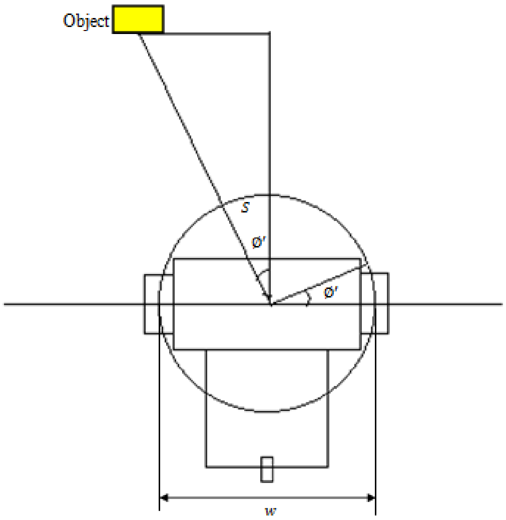


Figure 7. Rotary trajectory of robot

The angle of the object from the center of main body is as follow:

$$\emptyset' = tan(\frac{x}{y+y'}) \tag{4}$$

The distance required to travelled by the wheel to meet the object perpendicularly with the camera at any angle can be simplified as follow:

$$S = \frac{w}{2}\left|tan(\frac{x}{y+y'})\right| \tag{5}$$

2) Error Calculation for Turning Speed of Wheel
For the robot to travel in straight line with least error due to misalignment of the robot body, the angular speed required by both wheel can be acquire by using the following formula:

$$\theta_{error} = r\frac{(\dot{\theta}_L - \dot{\theta}_R)}{w/2} \tag{6}$$

Where $\dot{\theta}_L$ indicates the angular velocity of left wheel and $\dot{\theta}_R$ is the angular velocity of right wheel. The relationship between PWM and speed of wheel can be determined using the following formula:

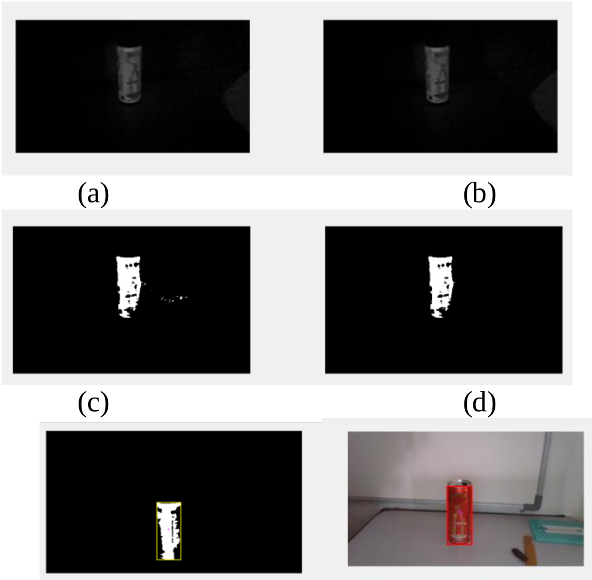
$$\frac{PWM}{PWM_i} = \frac{v}{r\dot{\theta}_i} \tag{7}$$

4. Results and Discussion

The results are illustrated as follows:

4.1 Detection and Recognition System

Fig. 8(a) shows the image of red drinking can is subtracted out from the surrounding and converted to gray scale. Fig. 8 (b) shows the image is filtered by calculating the large pixel with median. Fig. 8 (c) shows the image is converted to binary scale. Fig. 8 (d) is the result from removing noises. Fig. 8(e) is the result after recognizing the drinking can and bounded with rectangle box and centroid. Fig. 8 (f) shows the result of detection and recognition in real image.



(a) (b)

(c) (d)

(e) (f)

Figure 8. Image Filter Process

4.2 Image to Reality Coordination System (Magnification factor calculation)

A paper is placed in parallel with the webcam lens and scaled in centimetre. The distance of paper from camera is 18cm. The length of the paper captured by image is approximately 20cm as in Fig. 9. By applying magnification formula in section 2 eq. 2, the estimated value of *Icam* is calculated which is 1152cm/pixel.

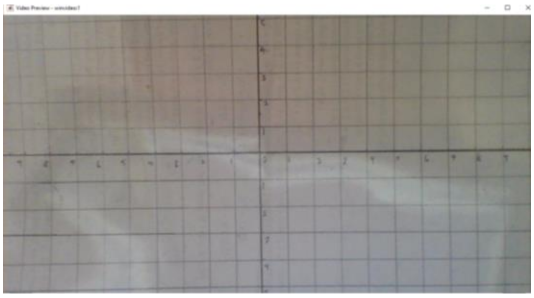


Figure 9. Image captured with reality scale

4.3 Image to reality coordinate comparison

Fig. 10. shows the x and y coordinate calculated by using the image pixel coordinate. The coordinate shows (x,y) distance in cm and the value at bottom is the displacement of the object from camera.

Figure 10. Object coordinate based on image

Table 1. Y-coordinate (vertical) result of reality and result from image

Real Y distance (cm)	**Image Y distance (cm)**	**Difference (cm)**	**Ratio difference (Y_{image} : 1)**
10	8	2	1.250
20	17	3	1.176
30	26	4	1.154
40	35	5	1.143
50	45	5	1.111
60	54	6	1.111

Table 1 shows the result of Y (vertical) distance show in image and also their respective reality distance. The results show that the difference of distance from image and reality distance increases. This shows that as the object is moved away more from the camera, the difference will be larger.

Table 2. X-coordinate (horizontal) result of reality and result from image

Real X distance (cm)	**Image X distance (cm)**	**Difference (cm)**	**Ratio difference (X_{image} : 1)**
10	9	1	1.111
20	18	2	1.111
30	27	3	1.111
40	37	3	1.081
50	45	5	1.111
60	53	7	1.132

Table 2 shows the result of X (horizontal) distance show in image and also their respective reality distance. The results show that the difference of distance from image and reality distance increases. This shows that as the object is moved more to the right or left in the image, the difference will be larger.

4.4 Error of Angle Displaced

The error is tested by giving both DC gear motor the same PWM value and recording the horizontal displacement travelled by the mobile robot. Hence calculate the angle displaced using the equation (6).

Table 3. Result of angle displaced from origin

A (Y travelled /cm)	**B (X travelled /cm)**	**Angle displaced, θ_{error} (°)**
180	7	-2.227
181	-1	-0.317
180	5.5	1.750
178	0.7	0.225
180	9.5	3.021
180	-12	-3.814

180	-3	-0.955
180	-1.7	-0.541
180	-5.1	-1.623
180	-2	-0.637
180	0.7	0.223
Average		-0.445

**Negative sign indicates direction*

Table 3 shows the result of angle displaced by mobile robot when tend to move in straight line. The error of angle displaced is used to calculate the angular velocity of wheel and hence determine the estimated PWM value as input for DC gear motor.

4.5 Wheel Speed
The speed of wheel is determined using the same method as the error of angle displaced. By using the data collected from the experiment, the relationship between PWM and speed of wheel can be related by using formula at Chapter 3 equation (12).

Table 4. Speed of wheel based on time taken and displacement

A (Y travelled /cm)	B (X travelled /cm)	Time taken (s)	Speed, v (cm/s)
180	7	22.47	8.017
181	-1	22.73	7.963
180	5.5	22.91	7.860
178	0.7	22.75	7.824
180	9.5	23.47	7.680
180	-12	24.53	7.354
180	-3	22.85	7.878
180	-1.7	23.22	7.752
180	-5.1	22.90	7.863
180	-2	23.16	7.773
180	0.7	23.54	7.647
Average			7.783

**Negative sign indicates direction*

5. Conclusion
The system is able to detect and recognize rubbish which has RGB (red, green, blue) colour components and approach the rubbish for more action. The system is able to work continuously after approaching one object. It will continue to move forward until the detection and recognition system senses another object. The detection of object is dependent on the brightness of the surroundings. The light reflection will alter the colour captured by the camera and causes failure of detection. the errors occur in this system may due to distortion of image where the image is distorted at the border of four sides of the image. The distortion is normally associated with zoom lenses. The types of distortion occurs is differently according to the focal length of the camera. The mobility error is mainly due to alignment of the robot wheel which causes the mobile robot unable to move according to the calculation. The type of free wheel is also a factor to the angle change. The free wheel must able to withstand the pressure of the weight of mobile robot and able to move freely in the meantime.

Acknowledgment
Authors would like to thank the Ministry of High Education and Universiti Malaysia Pahang for supporting this project under research grant RDU160131.

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