Design and Implementation of a Touchless Hand Sanitizer Dispenser Mobile Robot

Hind Z. Khaleel[1*], *Firas A.* Raheem[1], *and Mahdi* Azzam[1]

[1] Control and Systems Engineering Department, University of Technology – Iraq

Abstract. Two years ago, coronavirus COVID-19 spread all over the world. This virus causes the death of many people. The main problem is the way to maintain healthy hand wash in the circumstance of physical touch to the bottle that causes infection. The purpose of this paper is to design and implement a movable touchless hand sanitizer dispenser mobile robot that identifies the human body by processing the images taken from the camera to estimate the distance between the mobile robot and the human. A microcontroller board which is used to control four DC motors. The all design shows better activity than the usual and manual fixed touchless hand sanitizer design because the movable one can move with an acceptable error to the patient or a healthy person anywhere, he found. People can be protected from any virus or germs by using this proposed design. The main contribution of this work that our design system is useful in Anti-Covid-19 application and the total method has been collected the use of image processing, mobile robot, sensor hardware design, and the overall algorithm that control the application work.

1 Introduction

In récent years, technologies have been developed in all sectors of life. Humans developed robots to use in numerous applications of our life. One of the most important applications of the robot is the medical application. Hospitals use robots to make surgeries, besides, to carry medical equipment and for sterilization purposes, etc. [1]. A mobile robot design is useful in hand sanitizer operation, there are many studies presented in this field. The most priority has been given to hygiene as a prevention measure to avoid the transmission of the disease, as proposed by the World Health Organization (WHO), owing to the global severe dangerous respiratory syndrome coronavirus 2 (SARS COVID 2) epidemics Although the use of soap and water is the preferred way to clean one's hand, another option has recently become common. In their work, the researchers designed the AROGYAKAVACHAM device as an automatic sanitizer dispenser with a touchless temperature reader to protect people from SARS-Cov-2. Ultrasonic sensor, ordinal, L298 motor driver, IR sensor are attached to the device. Some drawbacks of their device:1) the system requires to write temperature down of persons that entering the building even he or she sits six feet far from the device.

* Corresponding author: hind.z.khaleel@uotechnology.edu.iq

2) Through the lower solar insolation circumstances cause the solar panel of a system cannot to operate. 3) Temperature sensor did not give a correct reading while the human hands are not within the range and unsteady [2]. Hand sanitizers are represented as the products that are applied and cleaned over the surface of the hands to deactivate pathogenic microorganisms.These sanitizer products are made to dry quickly after the application are removing the need for soap, water, and drying helps for example the towels [3]. There is a severe assessment everywhere to control the COVID-19 disease and spread it to the world. All hospitals and the nurses have suffered from treatment the affected persons and stopping the virus from spreading to the neighbor persons. The sanitizer and the mask are providing to all over the place to protect the persons from spreading disease or virus and to kill the COVID-19 virus from the human hand. People's hands and mouth saliva are caused spreading of the virus in the world. The mouth spread is controlled by the usage of a mask and the hand wash sanitizer controls the human hand. The virus is also spread from one person to another, when each person's hands touch, use, and compress the same dispenser. It should be an automatic hand wash sanitizer dispenser, to control and maintain the spread from human to human. The researchers designed a fixed hand wash sanitizer. The motor has pumped the sanitizer liquid to the human by sensing the IR Sensor [4]. Robotics has appeared as one of the speedily industrialized engineering zones in the current-day invention and in numerous parts used in the industrial area to play out a varied task, which combines the industrial machines and parts like painting, and spot welding. Robots are predictable to remove an individual’s association in a labor-serious and not used workplace. The authors design and develop a smart contactless hand sanitizer-dispensing with a mobile robot [5]. The main aim of this research can be briefly described as 1) In the previous papers [1 - 4], the authors designed the fixed hand sanitizer. The fixed system cannot reach the patient but the movable hand sanitizer reaches humans or patients at any location. 2) In this paper, a touchless hand sanitizer dispenser mobile robot has been designed and implemented using a Wi-Fi camera. The hardware camera is used to detect the human using image processing. Besides that, an ultrasonic sensor is linked to the mobile robot. It was useful for measuring the distance between mobile robots and humans. 3) In this work, the proposed hand sanitizer mobile robot is better than the hand sanitizer mobile robot as compared with [5]. In our system, the ultrasonic sensor with a camera computes the distance between the mobile robot and the human. In [5] the mobile robot moves randomly.

2 Modeling of a 4-wheel mobile robot

The kinematic model of the 4-wheel mobile robot consists of the following:

2.1 The kinematics of 4-wheel mobile robot

Kinematics can be defined as the mathematical study of the motion (position and velocity) without the forces consider [6]. The 2-DOF of differential drive 4-wheel mobile robot is shown in Figure 1. The velocity vector of the mass robot center V_G is perpendicular to the mass center axis as shown in Figure1.

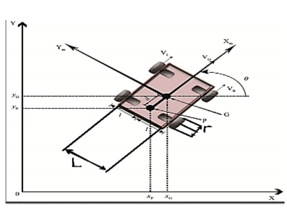

Fig. 1. Four-wheel mobile differential drive robot posture [6].

The x_G, y_G components and evaluated as [6]:

$$\dot{x}_G = V_G \cos(\theta) \quad (1)$$

$$\dot{y}_G = V_G \sin(\theta) \quad (2)$$

Where (x_G, y_G) are the coordinates of point G in the local frame, and θ is the heading angle of the mobile stand that is measured from the X-axis. By dividing (1) and (2), it became [6]:

$$\frac{\dot{y}_G}{\dot{x}_G} = \frac{V_G \sin(\theta)}{V_G \cos(\theta)} \quad (3)$$

$$\theta = \tan^{-1} \frac{\dot{y}_G}{\dot{x}_G} \quad (4)$$

The linear velocity of the wheel can be symbolized as (V), that having an angular velocity (φ), is stated as [6]; $\mathrm{V} = \dot{\varphi}\, \mathrm{r}$ (5)

The r letter is the radius of the mobile robot wheel. The velocity vector of the robot mass center is obtained by [6]: $V_G = \frac{\mathrm{V_L} + \mathrm{V_R}}{2}$ (6)

Due to (8) the linear velocity of the left and the right wheels are [6]:

$$V_L = \dot{\varphi}_L \mathrm{r} \quad (7)$$

$$V_R = \dot{\varphi}_R \mathrm{r} \quad (8)$$

r is the rotation of the mobile robot in the final humongous transformation. In addition, we substitute (7) and (8) in (6), we get [6]:

$$\mathrm{V_G} = \frac{\dot{\varphi}_R \mathrm{r} + \dot{\varphi}_L \mathrm{r}}{2} = \frac{\mathrm{r}}{2}(\dot{\varphi}_R + \dot{\varphi}_L) \quad (9)$$

$$\dot{\theta} = \omega = \frac{V_R - V_L}{L} = \frac{\mathrm{r}}{L}(\dot{\varphi}_R - \dot{\varphi}_L) \quad (10)$$

Where $(\dot{\theta})$ represent the rotational velocity of mobile robot body.

With rewriting (6) and (10) the angular velocities for the left $(\dot{\varphi}_L)$ and right $\dot{\varphi}_R$ wheels are

$$\dot{\varphi}_R = \mathrm{V_G}\frac{1}{\mathrm{r}} + \frac{\mathrm{L}}{2\mathrm{r}}\dot{\theta} \quad (11)$$

$$\dot{\varphi}_L = \mathrm{V_G}\frac{1}{\mathrm{r}} - \frac{\mathrm{L}}{2\mathrm{r}}\dot{\theta} \quad (12)$$

L is the distance between the two wheels of a mobile robot. The kinematic matrix for the mobile robot is computed as [6]:

$$\dot{\mathbf{q}} = \begin{bmatrix} \dot{x}_G \\ \dot{y}_G \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos(\theta) & 0 \\ \sin(\theta) & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \mathrm{V_G} \\ \omega \end{bmatrix} \quad (13)$$

$$\begin{bmatrix} V_G \\ \omega \end{bmatrix} = \begin{bmatrix} \frac{\mathrm{r}}{2} & \frac{\mathrm{r}}{2} \\ \frac{\mathrm{r}}{\mathrm{L}} & -\frac{\mathrm{r}}{\mathrm{L}} \end{bmatrix} \begin{bmatrix} \dot{\varphi}_R \\ \dot{\varphi}_L \end{bmatrix} \quad (14)$$

By combining (13) and (14), the equation is [6]:

$$\begin{bmatrix} \dot{x}_G \\ \dot{y}_G \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{\mathrm{r}}{2}\cos(\theta) & \frac{\mathrm{r}}{2}\cos(\theta) \\ \frac{\mathrm{r}}{2}\sin(\theta) & \frac{\mathrm{r}}{2}\sin(\theta) \\ \frac{\mathrm{r}}{\mathrm{L}} & -\frac{\mathrm{r}}{\mathrm{L}} \end{bmatrix} \begin{bmatrix} \dot{\varphi}_R \\ \dot{\varphi}_L \end{bmatrix} \quad (15)$$

3 Proposed touchless hand sanitizer dispenser of movable robot

The proposed flowchart of this work starts with the initialization of the values of the variables x, y, θ of a mobile robot as shown in Figure 2.

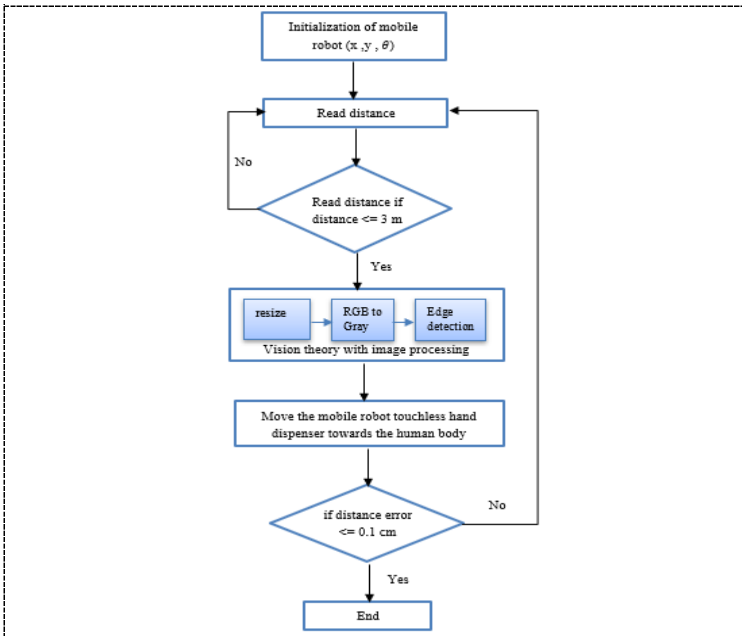

Fig. 2. Proposed touchless hand sanitizer dispenser mobile robot flowchart.

The calculation method was mentioned in the previous section. The mobile robot moves from the start point to the end (goal point). The ultrasonic sensor that is linked to the mobile robot is useful for measuring the distance between the mobile robot and the object (sensor) using sound waves. If the distance is ≤ 50 cm the movable robot stop and the vision (camera) captures the person's image. The personal image is processed using image processing methods in order to get the edge detection of the image as described below: The vision theory is based on image processing techniques. Image processing can be defined as a method to make many processes on the image. These processes are useful for enhancing and extracting useful information from an image [7]. In this work, the Wi-Fi vision device of the mobile robot is used for recording videos. Each video consists of multiple frames (images) of objects. The multiple images of the video are processed with three image-processing methods:

1) Resize image

In this method, an image resizes into (200 X 200) with the Bicubic interpolation approach. An interpolation method reduces the number of image pixels. The pixel B (r', c') is designed by interpolating the nearest 4 x 4 pixels where it starts with A (r, c) and finishes to A (r+2, c+2). Figure 3 shows the original image shape that has the two-scale factors symbolized as Sr and Sc of A. Sr: rows scale factor and Sc: column scale factor [8].

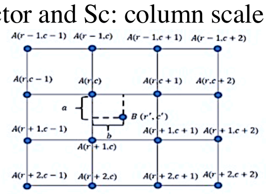

Fig. 3. Resize image with Bicubic interpolation method [8].

The new scale factors for image B are evaluated as (16) and (17) [8].

$$Sr = (R/R') \qquad (16)$$

$$Sc = (C/C') \qquad (17)$$

$B\ (r', c')$ calculated as

$$B(R',C') = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} A_{ij} \quad (18)$$

Where, A_{ij} illustrated as sixteen nearest of pixel values of B (R',C'). The factor a_{ij} is calculated by Lagrange (19) [2].

$$a_{ij} = a_i \text{ X } a_j \quad (19)$$

The two factors a_i and b_i are evaluated as (20) and (21) [2].

$$a_i = \prod_{k=0\ k\neq i}^{3} \frac{(r'-[Sr\times(x+k)])}{[Sr\times(x+i)]-[Sr\times(x+k)]} \quad (20)$$

$$b_i = \prod_{k=1\ k\neq j}^{3} \frac{(c'-[Sc\times(y+k)])}{[Sc\times(y+i)]-[Sc\times(y+k)]} \quad (21)$$

Where, a_i is the ith rows of A and b_i is the jth columns of A, and k is not equal to i. The x and y values for each row and column are divided with two scale factors Sr and Sc [8].

2) RGB to Gray image

In this section, the RGB (color) image is transformed to the gray image through the constant weights as in (22) [3].

$$Gray_{image} = 0.299 * R + 0.587 * G + 0.114 * B \quad (22)$$

The red, green, and blue are named as R,G, and B respectively. While 0.299, 0.587, and 0.114 represented the constant-coefficient weights. The summation of all constant weights is equal to one value [9].

3) Robert Edge Detection of image

Robert edge detection includes the extraction boundaries of the image. The image edges are extracted and converted from the grayscale image to the binary image [10]. The person image edges are extracted using the Robert Edge Detection method.

Using C++ and MATLAB programming languages, the main program is written in the Arduino Uno microcontroller that is attached to the mobile robot in order to move the mobile robot towards the human body with the all-hardware components described below. Then the position errors of e_x and e_y demonstrated as:

$$e_x = X_g - X_c \quad (23)$$

$$e_y = Y_g - Y_c \quad (24)$$

Where, $(X_g, Y_g)$is the goal point of the center body in the x-axis and y-axis of the mobile robot. (X_c, Y_c) is the current point of the center body in the x-axis and y-axis of the mobile robot. If position errors <= 0.1 cm the flowchart end and the mobile robot stop then the person can sanitize his hand with contactless. In this work, the hardware circuit of the mobile robot consists of an Arduino UNO Interfacing with the motor driver, ultrasonic sensor hc-sro4, two batteries 9 volt battery and ion lithium battery 3.7 volt supplied to the circuit. L298N motor drive is useful for controlling the 4 DC motors. An ultrasonic sensor measures the distance between the mobile robot and the person. The circuit of touchless hand sanitizer dispenser consists of an Arduino Uno linked with relay, IR sensor type tcrt5000, water pump type ultra-quiet submarine with 9 volt battery. The proposed design of the touchless hand sanitizer dispenser mobile robot is shown in the Figure 4 below.

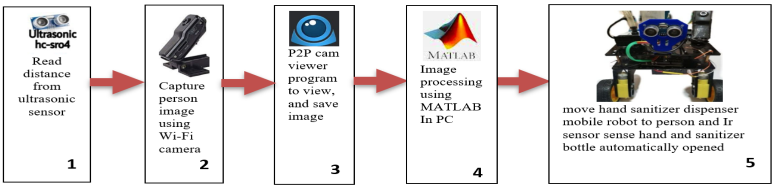

Fig. 4. The proposed block diagram of a touchless hand sanitizer dispenser mobile robot.

Figure 6 shows the proposed block diagram of this work. The first block includes the use of an ultrasonic sensor as mentioned in section 3 which is mechanically fixed on the mobile robot and can read the distance within 180 degrees in front of the mobile robot. The second block contains a Wi-Fi camera that takes one picture of the person. The third block includes a P2P cam viewer software installed on the PC and is used for connecting the Wi-Fi camera of the mobile robot with the PC. This software can view and save images on the PC. The fourth block contains the MATLAB program in order to process the image using image processing theory. In the last block, the mobile robot moves toward the person. The microcontroller card-based Arduino technique with H-bridge controls the four DC motors' direction of motion. When the mobile robot reaches the person, the IR sensor senses the human's hand, the microcontroller Arduino UNO sends a command to the relay, but it closes, and when the relay is closed, the water pump starts working and continues to work as long as the sensor senses an object. The water pump automatically raises the fluid from the bottom of the up using a relay. The fluid flows out and the human's hand can be sterilized without touching anything. The proposed system is enough to clean both human hands.

4 Experimental result

The human images captured from the Wifi-camera of the mobile robot are processed using image processing approaches. These methods are resizing, RGB to gray, and edge detection are mentioned in the above section according to equations (16), (17), (18), (19), (20), (21), and (22). Figure 5 shows image processing of four images captured for one person taken by the from Wifi-camera that fixed on the mobile robot during its motion towards the person and measured with three different distances (150, 53, and 10) cm as a case study for a test.

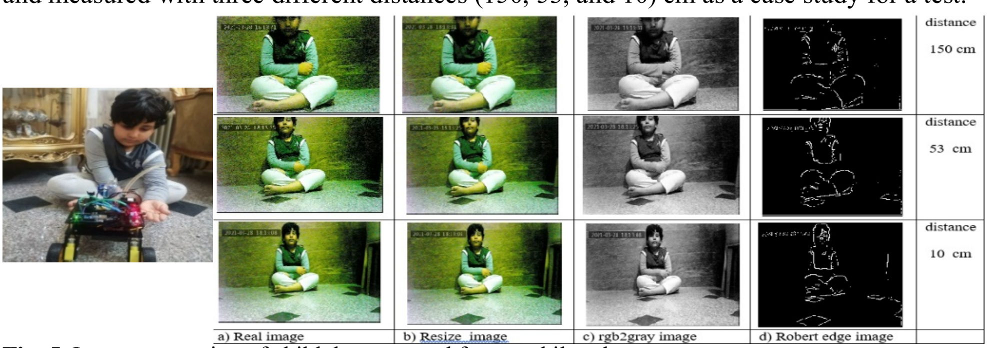

Fig. 5. Image processing of child that captured from mobile robot camera.

The movable robot moves from the start point (0,0) cm to the goal point (150,0) cm according to the ultrasonic sensor reading. The position errors of e_x and e_y demonstrated as in (23) and (24). The MATLAB results after 5 iterations are shown in Figure 6.

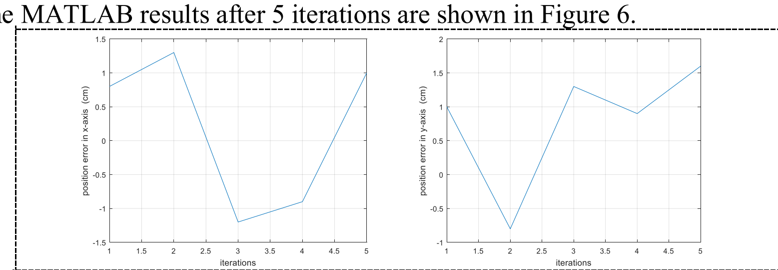

Fig. 6. The result of position error in x-axis and y-axis with iterations.

5 Conclusions

Touching dirty devices or tools can spread a lot of germs and viruses, as people with dirty hands also use them. A touchless hand sanitizer dispenser mobile robot has been designed to solve this problem because it offers a quick sanitizer way. With the proposed design of the touchless hand sanitizer dispenser mobile robot, there is no common contact point, which means less or no germs and viruses will be transferred from one person to another. The image processing technique is used to identify the person's body before moving the robot, and until reaching him by measuring the distance at each sample of motion. The approximate position error results are (1.3, -1.2) cm on the x-axis and (1.6, -0.8) cm on the y-axis. The experimental results of verifies the effectiveness of using the proposed design and the proposed technique of solution where the images are taken with less noise that enables the mobile robot to recognize the person's image. The main contribution of this work besides to be an extremely new Anti-Covid-19 application which is now in real need, is the total approach that include and collect the use of image processing, mobile robot, sensor hardware design, and the overall algorithm that control the application work.

References

1. Jeon S, Lee J. The simulator for performance analysis of multiple robots for hospital delivery. 2016 13th Int Conf Ubiquitous Robot Ambient Intell URAI 2016. Published online 2016:746-748. doi:10.1109/URAI.2016.7734105
2. Joshi HSV. AROGYAKAVACHAM—Automatic Hand Sanitizer Dispenser with Temperature Measurement. In: Proceedings of the International E-Conference on Intelligent Systems and Signal Processing. ; 2022:785-796. doi:10.1007/978-981-16-2123-9_61
3. Abuga K, Nyamweya N. Alcohol-Based Hand Sanitizers in COVID-19 Prevention: A Multidimensional Perspective. Pharmacy. 2021;9(1):64. doi:10.3390/pharmacy9010064
4. Srihari MM. Self-Activating Sanitizer with Battery Imposed System for Cleansing Hands. Proc 2nd Int Conf Inven Res Comput Appl ICIRCA 2020. Published online 2020:1102-1105. doi:10.1109/ICIRCA48905.2020.9183347
5. Eddy Mohammed, M. N. Y, Daoodd II, Siti Humairah Kamarul Al-Zubaidi, S. B, Omar Ismael Sairah, A. K. A-S. 2019 Novel Coronavirus Disease (Covid-19): Smart Contactless Hand Sanitizer-Dispensing System Using IoT Based Robotics Technology. Rev Argentina Clínica Psicológica. 2020;29(5):215. doi:10.24205/03276716.2020.1022
6. Said WK, Ahmed S, Kassim AB. Nonlinear Controller Design for a Mobile Manipulator Trajectory Tracking. IJCCCE. 2014;14(January):30-41.
7. Gonzalez RC, Woods RE. Digital Image Processing Third Edition Pearson. Pearson International Edition; 2008.
8. Hisham MB, Yaakob SN, Raof RAA, Nazren ABA, Wafi NM. An analysis of performance for commonly used interpolation method. Adv Sci Lett. 2017;23(6):5147-5150. doi:10.1166/asl.2017.7329
9. Hantoush Alrubaie SA, Hameed AH. Dynamic Weights Equations for Converting Grayscale Image to RGB Image. J Univ BABYLON Pure Appl Sci. 2018;26(8):122-129. doi:10.29196/jubpas.v26i8.1677
10. Selvakumar P, Hariganesh S. The performance analysis of edge detection algorithms for image processing. 2016 Int Conf Comput Technol Intell Data Eng ICCTIDE 2016. Published online 2016. doi:10.1109/ICCTIDE.2016.7725371