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Voice controlled Camera Assisted Pick and Place Robot Using Raspberry Pi

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ABSTRACT

Modern monitoring systems or manufacturing machines have a major drawback as they depend on human operators who can easily get distracted or make mistakes, so a system is needed that can constantly monitor the desired area and make decisions while identifying a pre-trained object. Tracking objects with a camera is critical in any automated monitoring and tracking system. The main goal of this paper is to design and implement a robot that can distinguish objects based on their features, such as color and size, and based on artificial intelligence and image processing algorithms. The robot will analyze the video stream to detect the colored object and specify its location inside the video frame. Using the detected position, the raspberry pi will decide the rotation direction whether it is to the right to the left, or forward until it reaches the object, grabs it and puts it in the robot's pocket. The main controlling unit of the system is the Raspberry Pi, the robot is equipped with a Wi-Fi modem to communicate with the mobile application, which is used to control the robot in two modes: manual mode, where the user can point the robot in any direction either by pressing function button or through voice commands. The second mode is the Automatic mode, where the user can ask the robot to detect an object according to a set of characteristics and grab it without any human intervention and based on a novel digital image processing object-tracking algorithm, the accuracy in voice command mode has reached 95%.

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1. INTRODUCTION

Robotics has long been a prominent feature in the fields of electronics and electrical engineering. This is due to Robots' high potential for reducing human effort and accurately and efficiently performing tasks. Robots are now more than just machines; robots are the solution for many manufacturing industries to replace human labor and at a lower cost. Daily life has many dangerous conditions in which humans cannot deal safely such as disposal of hazardous waste, radioactive materials, and explosive devices [1,2]. This paper aims to design and develop a pick-and-place robot with a Raspberry pi drive controller and an Android app, to select an object according to its properties and position.

Artificial intelligence (AI) is a superb field that purpose to create programs that can solve problems and reason in the same way that intelligent humans do. Robotics, on the other hand, is a field that aims to construct and develop machines that can automate tasks often performed by humans, using ideas from control theory, kinematics, dynamics, artificial intelligence, and other fields.

Artificial intelligence aims to create systems that are as intelligent as possible, which generally entails being able to mimic how animals or humans behave and act in the real world. These systems can be thought of as software systems or as a combination of software and mechanical parts [3,4]. Many researchers and projects in literature have studied the design of AI-based surveillance systems. The widely used sensor in most robotic systems is the camera used to obtain a photo or video. Where the image is processed, features are extracted, and patterns are recognized for object detection.[5]

In Verma et al work, the design of a voice control robot using Arduino UNO R3 is developed. The robotic was designed to control vehicle through Bluetooth module using a set of specific human voice commands (Stop, Backward, Forward, Left, Right and dancing). The commands were given through an Android application called Android Meets Robots Voice (AMR-Voice) to recognize voice commands. This application was installed in the smartphone which acts as a transmitter. In their work, the voice recognition application has an accuracy of 76% for recognizing a voice command but it was also highly sensitive to the noise. [6]. Authors in [7] proposed a vision based voice controlled indoor assistant robot for visually impaired people. The proposed assistant robot consists of several cameras in different location on its body. Cameras are used for motion planning, distance measurement, and object detection. In addition, the robot keeps the user following and analysing the results of his actions, and this increases the accuracy of justifying the performance of the proposed system. Several successful experiments were conducted in different indoor environments. The experimental results show that the proposed assistant robot performs all its work with a high accuracy of 93%, which makes the visually impaired people feel that the indoor environment is safe, convenient, and comfortable.

Authors in [8] provide an analysis of voice control of a collaborative robot. This analysis focuses on different voice commands, their repeatability and reliability in robotic collaboration. The most problematic voice commands and the perfect voice commands for the voice control of the robot were tested, 22 commands were verified, and 100 simulations were performed for each command. 2200 simulations were performed with an average accuracy of 82.7% while testing the voice commands. Authors in [9] developed a Bangla voice controlled robot for rescue operation in noisy environment. The system detects Bengali voice commands to control the robot's movement; the speech detection system includes a Mel-Frequency Cepstrum-based speech feature extraction mechanism and a feature matching technology using vector quantization. The accuracy and distinctiveness of voice recognition reached 93%.

Fuzzy logic microcontroller-based line following robot was developed by Ahmed Radhi, the project used an AVR microcontroller to demonstrate the concept of tracking or following a path specified to a robotic vehicle. Their project used an infrared sensor to detect the user-specified path. The IR Sensors were used to sense line as the variable input for the controller according to these signals, the controller set the turning angle of forward movement thus making robot move forward and turning at the same time. A fuzzy logic control was selected for its robustness and flexibility [10]. In 2013, Kumar and his colleague design an Obstacle Avoiding Robot. It is an autonomous intelligent robot with infrared sensors that detect obstacles in its path and change the robot's direction accordingly. To sense the obstacle, two sensors were placed on the Robot's left and right sides. Depending on the application, the sensors could be infrared or ultrasonic sensors. They detect the object and generate a high or low signal, which is processed by the AT80C2051 microcontroller. The microcontroller was programmed to avoid obstacles, so when it receives a signal from a sensor, it processes it and drives the motor driver, deciding whether the left or right motor should move based on the incoming signal from the sensors [11]. Autonomous Surveillance Robot with Path Tracking Capability was developed by Karthikeyan and his colleague. The goal of their project was to create a Wireless-controlled surveillance robot vehicle that can operate with a range of up to 500 meters. The robot can sense obstacles and live images in its path to guide it using infrared sensors and generate reports of the area being explored for some military applications. Their robot handles a highly secure Linux operating system, and it could destruct by itself if the enemy blocks it [12].

The novelty of this project lies in the mechanism of operating and guiding the robot through a novel combination between the Android application and the Raspberry Pi, where they support the process of controlling the robot automatically by applying an algorithm to discover objects based on their features then track and grab them. The hardware Raspberry Pi, running with UBUNTU (UBUNTU is an open source software operating system that runs from the desktop to the cloud, and to all internet connected things). The operating system flashed into a memory card, and works as a standalone device with the Raspberry Pi camera being used as an image acquisition device to constantly capture image frames of objects of interest .The project provides a manual control to direct the robot, which can perform a specific task through function buttons or commands acoustic.

2. PROJECT IDEA

The main goal of this system is to design and implement a robot that can distinguish objects according to their characteristics, i.e. their color, then using artificial intelligence and image processing techniques, the robot will analyze the video stream to detect the colored ball, and specify the location of the ball inside the video frame and depends on its current position, the raspberry pi will decide to rotate to the right, left or, go forward until it reaches it , and grabs it using the assigned pocket arm. The robot will also be equipped with a Wi-Fi modem to communicate with a mobile application. The innovation in this project is that the application will be used to control the robot in two different modes; Manual mode: the user can control the movement of the robot in all directions through the buttons for the movement and directions or by a voice command. Automatic mode: the user can press one button to let the whole system works automatically. Here the robot starts searching for objects according to their characteristics and works to collect them.

3. METHODOLOGY

The design circuit consists of two main components; Hardware (That describes the system's physical components) and Software (Which instructions are encoded on the computer). The block diagram of the system is shown in Figure 1.

3.1 Hardware

The components required for this project are:

- Raspberry pi 4
- Raspberry pi camera (Camera Module V2)
- DC Motor
- H-bridge(L298n Motor controller)
- Lithium batteries
- Buck converter (LM2596)
- Servo motors
- Pick and Place Arm
- MicroSD card 16GB
- keyboard and a mouse
- A TV or computer screen
- Robot chassis

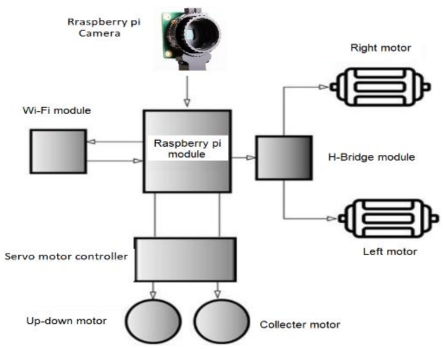

Figure 1. Block diagram of the system.

In this project, the Raspberry Pi considers to be the brain of the robot which implements all the computations like the path of robot movement and the task which needs to perform, with the aid of the Raspberry Pi camera. This camera is used to record HD videos as well as take pictures. The robot is provided with four wheels and the movement is controlled by dc motor which is connected to the Raspberry Pi via L298 motor controller (H-bridge). Figure 2 shows the schematic diagram of the h-bridge connection to the raspberry pi, each two motors are connected to one side of the h-bridge and controlled using three pins where two pins are used for the direction control, where the enable pin is used to control of the motor.

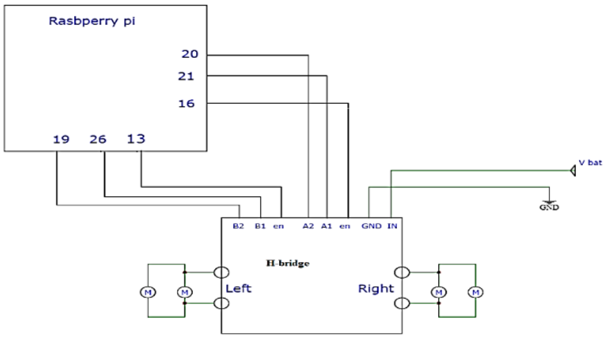

Figure 2. Schematic diagram of the h-bridge connection to the raspberry pi

The robot is equipped with a pick and place arm that is used to pick up the object and place it in the desired location.

A pick and place arm robot consists of two servo motor, controller, pocket, and End Effector. The servo motors are operated with 5 volts, for this reason they are supplied directly from the buck converter (LM2596) output, the control signal for those servos is taken from the servo motor controller. The two control pins of the servo motors are connected to the raspberry pi GPIO2 and GPIO3 where the control signal is logic, zero for open and logic high for close. Figure 3 shows the connection of servo motor to the raspberry pi. The End Effector is connected to last joint of the pocket which is used for the purpose of collecting the objects.

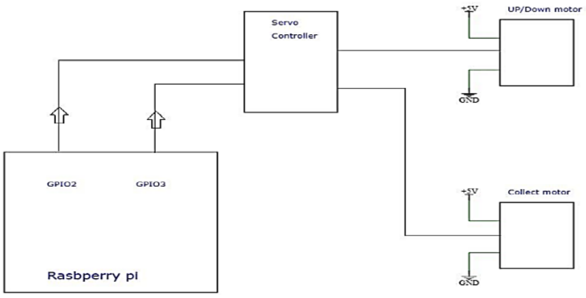

Figure 3. Servo motor connection to the raspberry pi

3.2 Software framework

In this part, the operating system is installed using the Raspberry Pi Imager, which is the fastest and best way to install Raspbian on SD card. Then, the connections are made between the Raspberry Pi and the hardware components. Figure 4 shows Raspberry pi connections [14] and figure 5 is an image taken for the system in the final configuration and it is ready to use, (a) System configuration and (b) robot prototype.

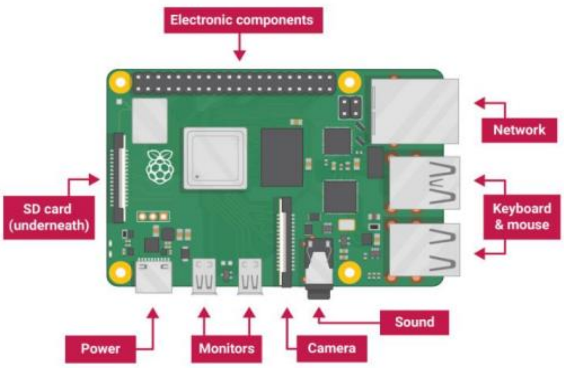

Figure 4. raspberry pi connection [13

(a) (b)

Figure 5. (a) System configuration (b) Robot prototype

3.2.1 System flow chart

The system flow chart in figure 6 describes the robot function, when the Raspberry pi is started, it will connect directly to the Wi-Fi network to receive commands from the mobile application, then the operating mode is selected. If the manual mode is selected, the robot receives commands in one of two ways, either by voice or by pressing the function buttons which is required for the robot to be directed and controlled. If automatic mode is selected, the robot will apply an algorithm to track objects according to their color and size.

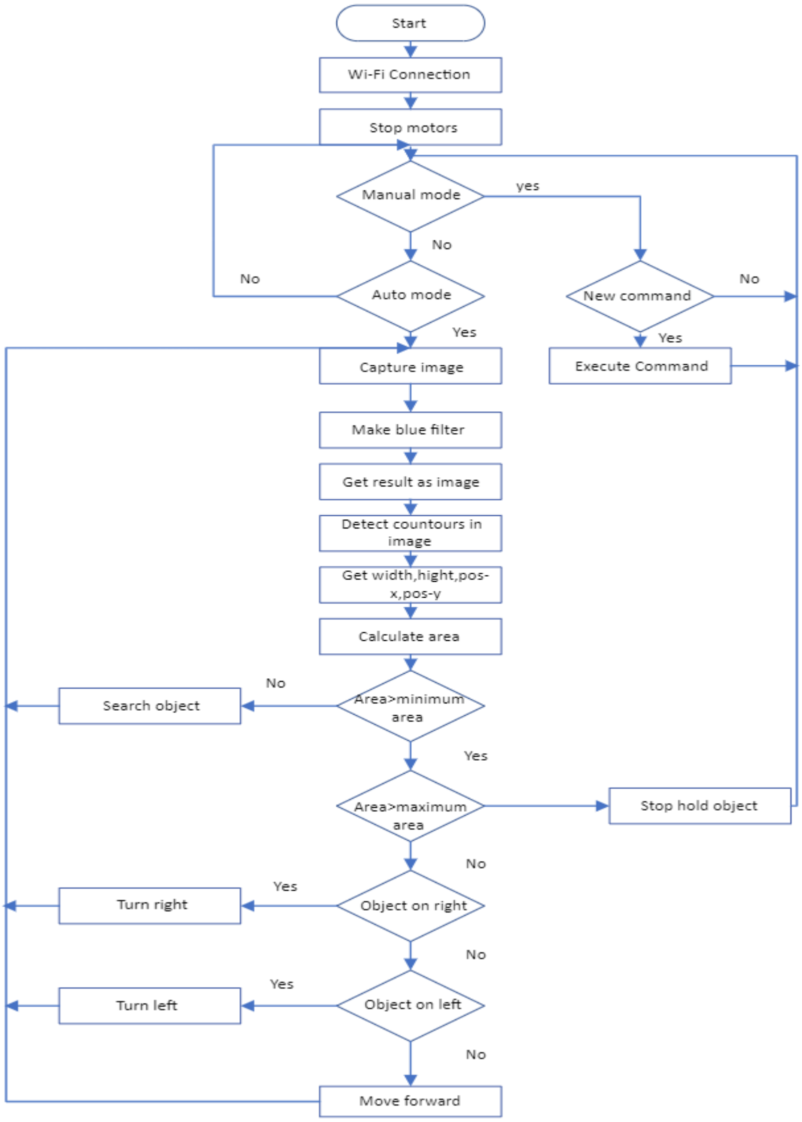

Figure 6. System flow chart

After that, the robot begins to take pictures and process it to search for objects in specific color, by applying color filters supported by the open CV library. There are more than 150 color-space conversion methods available in OpenCV to process the images. In this work, an attempt is made to distinguish a blue object where two of the most common methods are taken into consideration, which are RGB-Grey and RGB-HSV. The Hue (H), Saturation (S) and Value (V) is stands for HSV, where Hue is a term that describes a dimension of color. Saturation defines the intensity and brilliance of the color. On the other hand, Value represents intensity of a color which refers to lightness or darkness. The hue and saturation components are related to the way human eye perception [15-18]. In color conversion process the following steps is carried out:

- Convert image color-space from RGV to HSV
- Set threshold range of blue color for HSV
- Extract the blue color alone

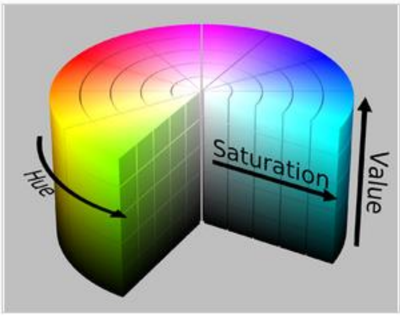

Figure 7. HSV color space

RGB to HSV color conversion equations in python are given by the code below:

```
image = frame.array
hsv = cv2.cvtColor(image, cv2.COLOR_BGR2HSV)
blue = np.uint8([[[200, 100, 60]]])
hsvblue = cv2.cvtColor(blue,cv2.COLOR_BGR2HSV)
Min_blue = np.uint8([hsvblue[0][0][0]-10,100,100])
Max_blue = np.uint8([hsvblue[0][0][0]+10,255,255])
mask = cv2.inRange(hsv, Min_blue, Max_blue)
result = cv2.bitwise_and(image  , image , mask=mask)
```

After that, the object is explored and located according to the x-y coordinates, then the movement is made towards the object and collected it by the robot pocket.

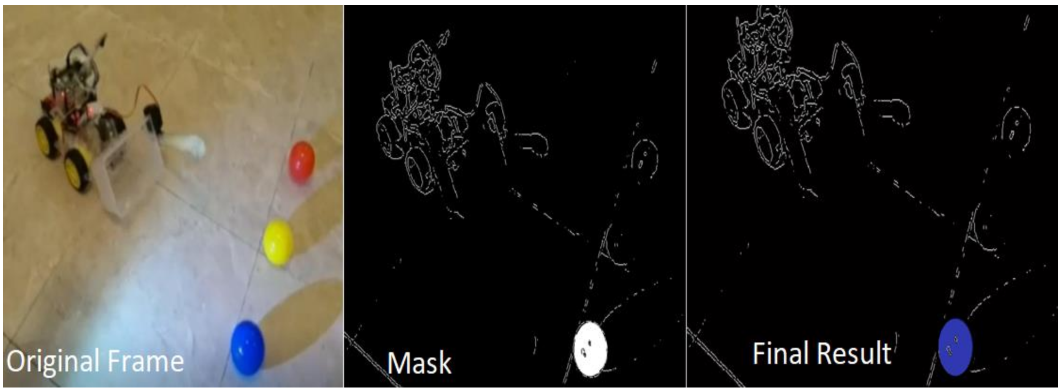

Figure 8. Color detection

3.2.2 System Graphical User Interface

In this section we will explain the graphical user interface built for the users. Before starting, the application user must fill the ip address of the robot, then the user can control the robot as follow:

- Manual operation: The user can press the function buttons to move the robot or press the open/close button for the collector or up/down for the pocket. All the previous commands can be done using the voice commands too. The user can speak and give the desired command and the robot will automatically respond to his orders. The robot recognizes the voice command using the Google Assistant (API) that converts the voice command into text, when the command is given through the smartphone. The API should be ON with internet connection and paired with Wi-Fi module so the commands will be sent to the robot wirelessly. The user can speak and give the desired command while the API uses smartphones internal voice recognition to pass the voice command to the robot as a string (e.g if a person says forward the android phone will return a string forward), then the robot will automatically respond to the order.

- Automatic operation: By pressing the automatic button, the system will start to search for blue ball and automatically track it and put it the pocket. Figure 9 shows the system graphical user interface as seen in mobile application.

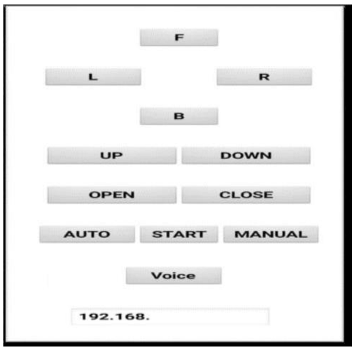

Figure 9. System graphical user interface

4. RESULT AND DISCUSSION

This robot is truly special because it can use artificial intelligence and computer vision to detect the object via a camera and perform tasks depending on the selected mode **(Manual, Automatic).** Figure 10 shows a complete Auto mode process, (a) Switch to auto mode, (b) Searching for the object, (c) Object detection and (d) Pick and place operation. The object color is detected by Raspberry pi open CV library. The image captured by the Raspberry Pi camera is used incolor processing which is done by changing the color space from RGB to HSV and then the object detection process is performed as previously presented in Figure 8.

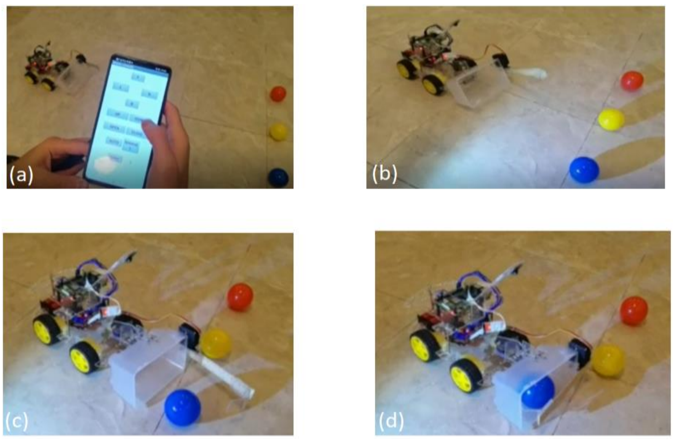

Figure 10. Auto mode process in details: (a) Switch to auto mode, (b) Searching for the object, (c) Object detection, and (d) Pick and place operation.

In voice mode, the voice commands recognition is achieved using Raspberry Pi with the Bluetooth wireless interface of the smartphone. The robot recognizes the voice command using the Google Assistant API that converts the voice command into text, after which the commands are processed. The robot can take multiple voice commands (left, right, forward, backward, open, close, up, or down), the accuracy of the system in the voice mode reached about 95%, as these commands were tested for three different users as shown in Table 1. In the testing experiments of the proposed model, the results show an AC score of 95%. Table 2 demonstrates that the current proposed model is more successful than earlier studies.

Table 1. Accuracy obtained for voice command mode

Voice command	User 1			User 2			User 3			Average Accuracy
	No. of Tests	No. of Correct responses	Ac%	No. of Test	No. of Correct responses	Ac%	No. of Test	No. of Correct responses	Ac%	
Forward	10	9	90%	10	9	80%	10	8	80%	86.7%
Backward	10	10	100%	10	9	90%	10	9	90%	93.3%
Left	10	10	100%	10	10	100%	10	9	90%	96.7%
Right	10	10	100%	10	9	90%	10	9	90%	93.3%
Open	10	10	100%	10	10	100%	10	10	100%	100%
Close	10	10	100%	10	10	100%	10	10	100%	100%
Up	10	10	100%	10	9	90%	10	9	90%	93.3%
Down	10	10	100%	10	10	100%	10	9	90%	96.7%

Table 2. Result comparison of the proposed model and previous studies

Study/year	Number of voice commands	Percentage of accuracy
[9]/2016	100	93%
[6]/2020	not mentioned	76%
[7]/2020	not mentioned	93%
[8]/2021	22	82.7%
Proposed	8	95%

5. CONCLUSION AND FUTURE WORK

This paper presented the process of designing an android mobile application with Raspberry pi to build a robot that is controlled automatically or manually to detect objects with specific features such as color. This robot is fully functional and built from readily available components. It can be used as a self-help to select nearby objects or to discover objects with special characteristics. The system was tested in two environments, in sunlight and under daylight; the performance was about 95%. In the future, this robot can be developed to enable users to work in the night mode, as well as to perform other tasks in wide applications such as military, medical, educational and for those areas where humans can’t reach. In the future work of our system, the robot will be developed to be able to avoid obstacles by adding four groups of infrared obstacle avoidance sensors; each sensor may consists of a LED and a visible photodiode. Where each photodiode can receive blue light waves from the paired LED that is reflected by an obstacle.

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