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An IoT-Based Colour Sensing and Detection Robot with Voice Command Input

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Abstract

This paper presents a robot that accepts a colour name as a spoken command, locates an object of that colour, and drives towards it. The user speaks a colour into a microphone; speech recognition interprets the command and validates it against the set of colours the system handles. The robot then scans its surroundings using an ESP32-CAM together with a TCS3200 colour sensor to identify a matching object. Once one is found, an Arduino Uno computes the direction to it and drives the wheels through an L298N motor driver, while an ultrasonic sensor measures the remaining distance and an LCD displays it. If the spoken command is not one of the recognized colours, or if no matching object is found, the system announces "Please give the correct colour" through the speaker and shows the same message on the LCD rather than failing silently. Two sensing methods are used together deliberately: the camera gives a wide field of view for locating a candidate object at a distance, while the TCS3200 gives a reliable colour reading at close range where the camera is affected by ambient lighting. The system is powered by a 12 V lead-acid battery through a 7805 regulator. Applications include colour-based sorting, assistive robotics and interactive automation.

Index Terms: *Arduino, colour detection, ESP32-CAM, human-robot interaction, Internet of Things, robot navigation, speech recognition, TCS3200***.**

I. Introduction

Automation and intelligent systems have changed many industries, and as demand grows for machines that can act autonomously, the integration of artificial intelligence, the Internet of Things, computer vision and speech processing has become increasingly significant. Together these let a robot perform complex tasks, respond to a changing environment and interact with a user in a natural way.

This work builds a robot that accepts colour instructions by voice, identifies the specified colour using vision-based sensing, and navigates autonomously towards the coloured object. It bridges human instruction and machine execution, translating a spoken command directly into robotic action. The approach is relevant to warehouse management, colour-based sorting lines, assistive robotics and automated monitoring, and it shows how cameras, sensors and microcontrollers can be combined with voice recognition software to produce an interactive system.

A. Existing System

Existing colour-detection robots are limited in scope. Most use a basic sensor arrangement with a TCS3200 placed directly in front of the robot, detecting surface colours as the robot passes over them. These setups operate in controlled environments with objects positioned in a predefined way, and are typically used in line-following robots or small-scale colour sorting machines.

Interaction in these systems is manual. They are pre-programmed or driven through a remote control or mobile app, with little or no use of speech recognition. They also adapt poorly, since they cannot respond to changes in the environment or to user input in real time. Feedback is another gap: a user typically has no way of knowing the robot's status without watching it, and there is little error handling when incorrect input is given.

B. Proposed System

The proposed system integrates voice recognition, camera-based vision and autonomous movement. The user speaks a colour name into the microphone, and speech recognition interprets the command. The robot then scans its surroundings with the ESP32-CAM, which gives a wide view for object detection. Using the camera feed together with the TCS3200 sensor, it identifies objects matching the specified colour, calculates the relative position and distance, and drives towards the target through the L298N motor driver. The LCD displays the distance as the robot closes on the object.

The error-handling routine is what makes the system usable rather than merely functional. If the command is not recognized, or the colour is outside the predefined set, the robot responds with an audible message and an LCD notification asking for a correct colour. Without this, an unrecognized command would leave the robot motionless with no indication of why.

II. Literature Survey

A. Colour Detection in Robotics

Colour detection is widely used in sorting systems, automated inspection and object tracking, and the TCS3200 is a common choice for detecting basic colours. A study on colour-based object sorting using Arduino demonstrated a conveyor-based robot that sorts objects by surface colour with the TCS3200. Detection was limited to objects placed directly in front of the sensor, and the system had no autonomous movement or interactive feedback.

B. Vision-Based Detection

Camera modules such as the ESP32-CAM have been increasingly adopted for real-time image processing. A project on ESP32-CAM-based surveillance and object tracking showed the potential of low-cost camera modules for video analysis and remote monitoring. It integrated wireless image streaming successfully but lacked colour recognition algorithms and any autonomous response.

C. Speech Recognition in Robotics

Voice commands have become more common in robotic systems as speech models have improved. Work on a voice-controlled smart wheelchair implemented navigation through predefined voice commands using a speech API. Such systems handle motion control but include no visual perception or colour detection, so the voice channel controls movement directly rather than specifying a goal for the robot to find on its own.

D. IoT in Robotics and Identified Gaps

IoT in robotics typically provides remote access, real-time data sharing and cloud integration. A study on an IoT-based smart surveillance robot with live streaming explored remote surveillance with data transmission to a mobile app, showing the value of IoT in robot control but without interactive input methods such as voice or colour recognition.

Each of these lines of work advanced one technology, but none combined them. The gap is an integrated approach with voice-controlled colour selection, colour detection using both a sensor and a camera, autonomous navigation and real-time feedback with error handling. That combination is what the present system addresses.

III. Hardware

A. ESP32-CAM

The ESP32-CAM is a small development board combining a microcontroller with a camera module and built-in Wi-Fi. It provides the wide visual field used to locate a candidate object before the robot moves towards it.

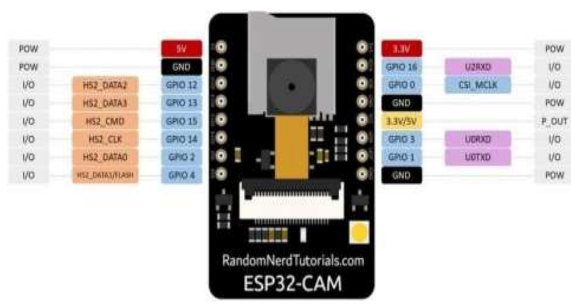

Fig. 1. ESP32-CAM module.

B. TCS3200 Colour Sensor

The TCS3200 detects colour by filtering incident light through red, green and blue filters and producing a frequency output proportional to the intensity in each channel. It gives a more reliable colour reading than the camera at close range, where lighting is controlled by proximity to the object. This is why both are used: the camera locates, the sensor confirms.

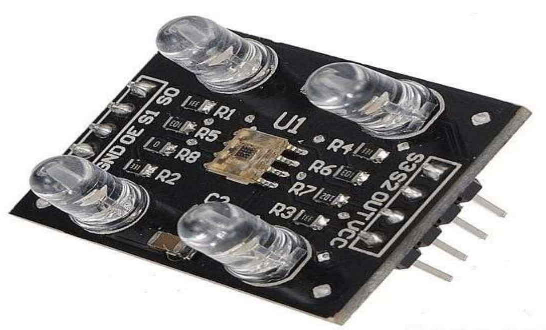

Fig. 2. TCS3200 colour sensor.

C. Arduino Uno

The Arduino Uno is the central controller, reading the colour sensor and ultrasonic sensor, driving the LCD, and issuing motor commands through the motor driver based on where the target has been located.

Fig. 3. Arduino Uno.

D. L298N Motor Driver

The L298N is a dual H-bridge driver that gives independent bidirectional control of two DC motors with PWM speed control, allowing the robot to move forward, reverse and turn by driving its two sides at different speeds.

Fig. 4. L298N motor driver.

E. Power and Supporting Components

A 12 V lead-acid battery supplies the robot, with a 7805 regulator providing the 5 V logic rail. Relays switch the higher-current loads, diodes protect against reverse polarity and inductive kickback from the motors, and resistors and transistors handle current limiting and signal-level switching. The robot moves on small wheels driven by 30 RPM centre-shaft gear motors, with jumper wires connecting the modules.

Fig. 5. Lead-acid battery and 30 RPM gear motor.

IV. System Design

A. Input Design

The primary input is the spoken colour name captured by the microphone. Sensor inputs follow: the camera feed from the ESP32-CAM, the frequency output of the TCS3200, and the echo timing from the ultrasonic sensor. The recognized command is validated against the set of permitted colours before any motion begins, so that an unrecognized word produces a prompt rather than an arbitrary movement.

B. Output Design

Output takes three forms: motion, through the motor driver towards the located object; display, with the measured distance shown on the LCD as the robot approaches; and audio, with the speaker announcing the error message when a command cannot be handled. Presenting the same message on both the LCD and the speaker means the feedback reaches the user whether they are watching the robot or not.

C. Block and Circuit Diagram

The overall structure is shown in Fig. 6 and the circuit detail in Fig. 7.

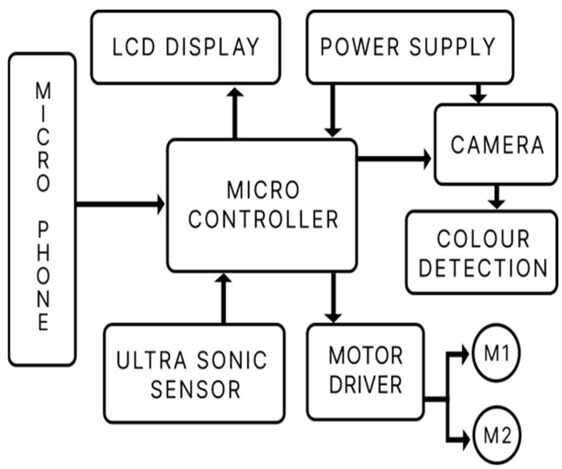

Fig. 6. Block diagram of the system.

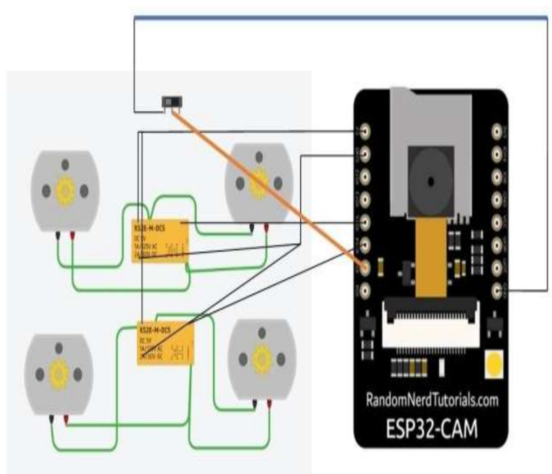

Fig. 7. Circuit diagram.

V. Results

The assembled robot is shown in Figs. 8 to 10. On receiving a valid colour command the robot scanned its surroundings, identified an object of that colour, and drove towards it while displaying the closing distance on the LCD. On receiving an invalid command it produced the error prompt on both the speaker and the display.

Fig. 8. Assembled robot.

Fig. 9. Front view and side view.

Fig. 10. Robot under working conditions.

The two-sensor arrangement performed as intended. The camera located candidate objects across the room, and the TCS3200 confirmed the colour once the robot was close enough for the reading to be stable. Relying on the camera alone gave less consistent results under changing room lighting, which is the reason for keeping the dedicated sensor in the design despite the camera already being present.

The main constraint is the colour set. The system distinguishes a small number of well-separated colours reliably; colours closer together in hue, or objects whose surface is glossy enough to reflect the ambient light rather than their own colour, are harder to classify correctly. Ambient lighting affects the camera stage more than the sensor stage, so performance is better in consistent indoor light than near a window.

VI. Conclusion

The system integrates speech recognition, colour sensing and autonomous movement into a robot that identifies and reacts to specific colours in its environment. It combines the ESP32-CAM for visual detection, the TCS3200 for colour recognition and the Arduino Uno for control, responding to valid voice commands, displaying feedback on the LCD and navigating autonomously through the motor driver. The error handling gives clear prompts when input cannot be interpreted, which is what makes the robot usable by someone who is not familiar with its internals.

The design can be extended to automated colour sorting, assistive robotics for visually impaired users, and manufacturing lines. It shows that commodity embedded hardware is sufficient to combine voice input, vision and navigation in one system.

VII. Future Scope

Wider colour range. Calibrating against a reference chart and compensating for ambient light would let the system handle colours closer together in hue than the present set.

Obstacle avoidance. The ultrasonic sensor currently measures distance to the target; using it also to detect obstacles on the path would let the robot route around them rather than stopping.

Cloud integration. Transmitting operational data to a cloud platform would support remote control and analysis, and would let the robot be integrated into a larger automated environment.

Object recognition. Adding shape or object classification to the colour detection would let the robot distinguish between two objects of the same colour.

Multiple targets. Handling a sequence of colour commands, or several objects of the same colour, would extend the system from single-target retrieval towards sorting.

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