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IoT-Enabled Voice-Controlled Personal Assistant Robot with Real-Time Audio Feedback and Video Monitoring

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Abstract: The emergence of the Internet of Things (IoT), embedded systems and wireless communication technologies has accelerated the evolution of intelligent robotic systems that assist the user when performing a variety of tasks in the real world. Voice-controlled robots give people a natural and convenient way to control them without using traditional control devices such as switches, joysticks or remote controllers. The paper presents the design and implementation of the voice-controlled personal assistant robot based on Inter-net of Things (IoT) technology. It involves microcontrollers (Arduino Uno) and Bluetooth communication. The robot is controlled by voice commands using a smartphone app. The robot features direction capabilities and audio feedback via a speaker, and real-time video monitoring via Wi-Fi camera. All hardware used to build the robotic platform is commercially available and relatively cheap. It's ideal for educational use, research, and prototype work. Tests were carried out in an indoor environment to assess the stability of communication, response time and command execution accuracy. It showed a highly promising real-time accuracy of approximately 96

Keywords: Voice Controlled Robot, Human–Robot Interaction, Internet of Things, Arduino Uno, Bluetooth Communication, Embedded Systems, Real-Time Monitoring.

I. INTRODUCTION

Embedded systems, wireless communication and Internet of Things (IoT) technologies have been rapidly developed, which has significantly accelerated the development of intelligent robotic systems capable of performing various tasks in the real world [1, 2]. In the medical field, modern robots are being increasingly adopted in the medical field, in industrial automation, in smart homes, in surveillance and in educational fields, in order to enhance efficiency and decrease the human effort required [3]. Voice-based human-robot interaction has gained popularity as a simple, accessible and hands-free method of communication [4, 5]. Switches, joysticks, keyboards or remote controllers are typically used to control traditional robotic systems. These are methods that can control reliably but they need hand-on hand interaction and are not suitable for situations where hands-free operation is required. It has been demonstrated recently that low-cost automation solutions could be achieved using Bluetooth-based robotic platforms and voice control with the help of a smartphone [6, 7]. Many systems, however, pro-vide only motion control, require high-cost hardware or require an internet connection, thus making them less suitable for education and prototype development. To improve the capabilities of robots, several researchers have integrated additional technologies such as computer vision, cloud computing, obstacle detection and Artificial Intelligence [8, 9]. These features enhance the intelligence of the system but also add to the complexity and expense of implementing the system. Thus, a low-cost robotic platform that incorporates voice control, wireless communications, mobility, audio feedback and real-time monitoring in a single embedded system remains desired. To tackle these issues, this paper introduces an IoT-enabled, voice-controlled personal assistant robot developed with an Arduino Uno microcontroller and Bluetooth communication. This system provides a way to control the robot with voice commands via the smartphone, real time robot movement, audio assistance for interaction and wireless camera monitoring with low-cost hardware components. Experimental tests indicate a reliable command execution and stable communication; thus the system is applicable for educational robotics, surveillance, smart home automation and assistive applications.

II. PROBLEM STATEMENT

With the increasing popularity of intelligent robotic systems there is a demand for a platform that is user friendly, economical and capable of natural interaction. Most of the existing robotic systems are manually controlled by using switches, joysticks or remote controls. These need to be touched, can be cumbersome for users. There are several voice-controlled robotic platforms developed, but most require expensive hardware, cloud processing or an inter-net connection always. This reduces their usefulness in prototype development at low cost, research labs, and schools [6–8] (PDE). Moreover, the existing robotic assistants are mainly navigation and surveillance oriented. There isn't any platform that can be operated through voice control, wireless communications, sound recognition and real-time video monitoring. "It is hard to experiment with a smart home application, surveillance, assistive technology or demonstration in such an affordable system doesn't exist." Hence, it is necessary to create an affordable and compact robotic assistant which can navigate by voice commands and provide voice output to the user and real-time perception of the environment as well. To address the above-mentioned problems, an Arduino Uno based voice controlled per-sonal assistance robot system with Bluetooth communication is proposed in this research. The distinguishing feature of this system is that all the elements of the system namely voice control via a smartphone, wireless command transfer, robot movements, voice feedback and video monitoring via Wi-Fi can be integrated in one embedded system

III. RESEARCH OBJECTIVES

The main goal of this research is to create an assistant robot that is controlled by voice and connected to the internet. This robot will be able to perform certain actions timely through wireless communication. The proposed system will be compact, economical and convenient. It will include such functions as voice commands, the ability to move, audio feedback, and live video monitoring. Also, the abilities of the robot will be evaluated in indoor environment. Its effectiveness for education, assistance and surveillance will be judged.

This research aims at the following specific actions:

- We will design an assistant robot which will be controllable via our voice by means of the Arduino Uno microcontroller.

We will ensure that our robot can communicate with the smartphone using HC-05 Blue-tooth module.

- We will design our robot to be able to move after receiving our voice command. It will be going backward, left, right and stopping.

We will enhance the interaction between our robots by adding a feedback module and a camera with Wi-Fi for real-time video monitoring.

- We will test the performance of our robot. Specifically, we'll assess how it meets our requests, how fast it responds, and how stable the link is.

- We want to make a platform that is flexible and does not cost a lot of money.

- We can add features to it later like being able to avoid obstacles moving around on its own connect to the cloud and use Artificial Intelligence.

IV. LITERATURE REVIEW

Voice-controlled robotic systems have received considerable attention in recent years due to their ability to simplify human–robot interaction and improve the accessibility of robotic platforms. Several researchers have developed Arduino-based robotic systems that utilize smart-phone applications and Bluetooth communication to execute voice commands. These studies have demonstrated that speech recognition provides a convenient and cost-effective alternative to conventional control methods while maintaining satisfactory performance for educational and prototype applications [1, 4].

Bluetooth communication has become one of the most widely adopted wireless technologies for embedded robotic systems because of its low power consumption, ease of implementation, and reliable short-range connectivity. Previous research has shown that the HC-05 Bluetooth module enables efficient communication between smartphones and

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Arduino-based controllers, allowing real-time transmission of voice commands with minimal delay [9, 11]. However, many existing systems are primarily limited to robot navigation and basic movement control without incorporating interactive features such as audio feedback or real-time environ-mental monitoring.

Recent advancements in IoT, cloud computing, computer vision, and Artificial Intelligence have significantly enhanced the capabilities of intelligent robotic assistants [12, 14]. Although these technologies improve system intelligence and autonomous operation, they generally require powerful processing hardware, continuous internet connectivity, and higher implementation costs. Such requirements limit their adoption in educational institutions, research laboratories, and low-cost prototype development.

Commercial voice assistants such as Google Assistant, Amazon Alexa, and Apple Siri have demonstrated the effectiveness of natural speech interaction in everyday applications. However, these platforms primarily function as software assistants and are not designed to perform physical robotic operations or environmental interaction. To overcome these limitations, the present work integrates smartphone-based voice control, Bluetooth communication, robotic mobility, audio feedback, and Wi-Fi camera monitoring into a single low-cost embedded platform. The proposed system provides an economical and modular solution suitable for educational robotics, surveillance, smart home automation, and assistive applications while offering flexibility for future enhancements involving autonomous navigation and Artificial Intelligence-based decision-making.

V. PROPOSED SYSTEM

The personal assistant robot, which can be controlled by voice, is a nifty gadget that can assist people with jobs they need to get done. It's a robot that you can talk to, and it will do what you say. With this robot, you can expect a variety of capabilities such as voice recognition, Bluetooth and video monitoring in one device.

The ease of building this robot is facilitated by its use of easily accessible parts, and it can operate in building structures. All it takes with this robot is an app on the mobile phone. In this application, you take the opportunity to turn your words into instructions and send them to the robot via Bluetooth. Once Given the command, the robot will perform the instruction. It can move freely. Goes forward, backward, left, right or stop. The robot is equipped with a speaker that will tell you if he has carried out the instructions you have given him. It comes with a camera which lets you know what is going on around it. With this you can see the robot even if no one is present.

This personal assistant robot with voice control is designed in such a way that it is easily upgradable. This will enable it to do much more in the future such as avoiding obstacles, moving on its own and go online. It may even be able to make decisions using computer vision and artificial intelligence! It's an incredible device for learning, observing, and aiding individuals.

VI. SYSTEM ARCHITECTURE

The personal assistant robot with voice control is comprised of four elements: the one that listens to you, the one that helps it listen to other devices, the one that helps it think and the one that helps it do things. These components need to be put together to ensure the robot functions properly. Follow the directions that it gives. Each component performs an action, and all the components work together to accomplish the robot's task. These components make up the voice-controlled personal assistant robot, which is designed to function effectively and user-friendly.

VI.I Input Layer

The input layer is the place where the user can input instructions to the robot via a voice-controlled app. The app converts the user's speech into text instructions. These instructions are text-based commands which will instruct the robot to do something and to move around how.

VI.II Communication Layer

The communication layer is the communication between the smartphone and the robot. It sends messages between the phone and the robot via a Bluetooth 'thing' called HC-05. The app converts the user's voice into text when the user speaks. Passes it on to the robot via Bluetooth. This is the message that the robot receives. Does what it says.

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VI.III Processing Layer

The brain of the robot is the processing layer. It's an Arduino uno that receives all the commands from Bluetooth and acts accordingly. It compares the user's input to its knowledge. It then provides instructions to the sections of the robot which require motion or action.

VI.IV Output Layer

The output layer is the layer where the robot receives instructions from the user. It is equipped with a motor driver which makes the robot move. The robot can move forward, backward, left, right or stop. It also features a speaker which repeats what the user has said to confirm that it has heard the user. It's outfitted with a camera that allows the user to see what's happening from a distance, around the robot. Together all these parts enable the robot to move around and to do things.

VII. HARDWARE COMPONENTS

The robotics platform we created is made with inexpensive and readily available hardware. These components have been selected to ensure that the platform is affordable, reliable and easy to setup. They are used by devices to perform functions such as sensing the environment, communicating with other devices, processing information, controlling movement, playing audio and monitoring real time events. The hardware used is listed in Table 1.

Table 1: Hardware Components of the Proposed System

Component	Specification	Function
Arduino Uno	ATmega328P	Central controller of the system
HC-05 Bluetooth Module	Bluetooth V2.0	Wireless communication between smartphone and robot
L298N Motor Driver	Dual H-Bridge Driver	Controls the DC motors
DC BO Motors	12 V Geared Motors	Provides robot movement
Speaker Module	Audio Output	Provides audio feedback
Wi-Fi Camera Module	Wireless Camera	Supports real-time video monitoring
Rechargeable Battery	12 V Battery Pack	Supplies power to the robot
Four-Wheel Chassis	Acrylic Platform	Provides mechanical support

The Arduino Uno is like the brain of the robotic platform. It enables all parts to communicate with each other. It gets commands from the smartphone using the HC-05 Bluetooth Module. The L298N Motor Driver controls the motors of the DC BO Motors to move the robot. The Speaker Module is responsible for playing the sounds so the user can know what is going on. The Wi-Fi Camera Module allows us to view the robot at another site. The batteries are powered by the Rechargeable Battery. The Four-Wheel Chassis is the fundamental chassis of the robot. Holds all the components together. This makes the robotic platform easy to move around and conducive to indoor use. The robotic platform is a tool for indoor applications. The robotic platform consists of Arduino Uno, HC-5 Bluetooth Module, L298N Motor Driver, DC BO Motors, Speaker Module, Wi-Fi Camera Module, Rechargeable Battery, and Four-wheel Chassis.

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VIII. SOFTWARE REQUIREMENTS

The software that powers the assistant is a mix of programming code for the robot and a smart-phone application to enable people to communicate with the robot. This software is created with the Arduino system, a simple method to upload and write programs to the robot's brain, the Arduino Uno microcontroller. They selected Embedded C as the language to use because it is well suited to the robot's hardware and has many tools that facilitate communication and robot motion.

A smartphone application is used to convert people's speech into text commands that the robot can understand. These commands are transmitted to the robot via Bluetooth to the app. These are the commands that are always waiting to be received by the Arduino Uno. Control the robot's movements and other parts with them.

The software has significant capabilities such as listening to voice commands, communicating with the robot via Bluetooth (to control its motion), providing audio feedback and working in real-time. The software is also designed to be easily integrated with additional features, such as obstacle detection, navigation, and decision-making capabilities based on Artificial Intelligence (AI). This makes robotic platforms suitable for research and projects that utilize the internet to control robots.

Table 2: Software Requirements

Software	Purpose
Arduino IDE	Used for program development, compilation, and uploading
Embedded C	Used to develop robot control logic
Smartphone Voice Control App	Used to capture voice commands and send them to the robot
Bluetooth Communication	Used for wireless data transfer between smartphone and robot
Wi-Fi Camera Application	Used for live video monitoring and re-mote observation

IX. METHODOLOGY

The voice-controlled personal assistant robot is based on the integration of voice recognition, wireless communication, embedded processing, robotic mobility, audio feedback and real-time video monitoring. We were interested in ensuring reliable communication between the user and the robot while avoiding a complex and costly system. The overall operation of the system is given in the flow chart below (Figure **1**).

First the smartphone and the robot connect using Bluetooth. The robot then waits for the user to say something. The user interacts with the robot through the app that can interpret their voice. The app converts the user's voice into text commands. Send them to the robot using Bluetooth.

The command is received by the robot. Send it to the microcontroller (Arduino Uno) to see what to do. The Arduino looks at the command. Checks whether it is something that the robot can do. If it is the Arduino will send a signal to the motor driver. The robot then moves by turning the DC motors on by the motor driver. The robot can go forward and backward, left, right or stop. When the robot executes the command given by the user, then the robot will speak to let the user know what the robot is doing. Using a Wi-Fi camera that is integrated into the robot, the live feed will be displayed at the same time as the viewing process. Once the robot has performed the command, it waits for the next command and so on until the robot performs any action.

This significantly simplifies adding other functions, such as improved navigation, computer vision, etc., to the system without redesigning it. So, possible future enhancements to the robot to make it smarter are: Adding obstacle avoidance,

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or artificial intelligence to make decisions. It is possible to make the voice-controlled personal assistant robot carry out different tasks.

X. ALGORITHM

The command execution algorithm of the proposed system is given below:

1. Initialize Arduino Uno and all connected modules.
2. Establish Bluetooth communication between smartphone and HC-05 module.
3. Initialize camera and audio module.
4. Wait for voice command from the user.
5. Capture voice input using smartphone applications.
6. Convert speech input into text command.
7. Transmit the command through Bluetooth.
8. Receive the command using HC-05 module.
9. Compare received command with predefined commands.
10. If command is valid, execute the corresponding movement.
11. If command is invalid, ignore it and wait for the next command.
12. Generate audio feedback.
13. Continue video monitoring.
14. Return to standby mode.

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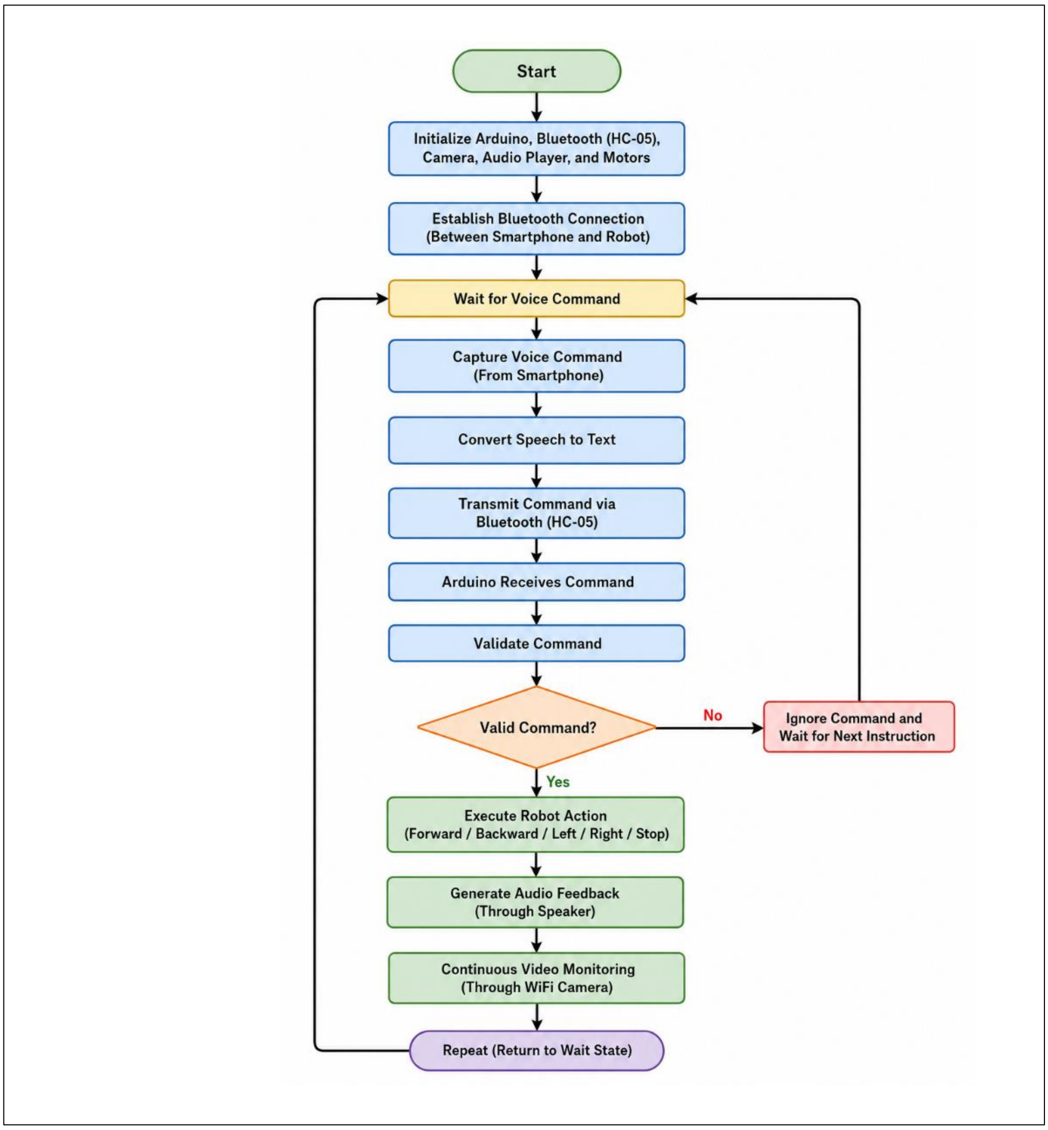

Figure 1: Flowchart of the proposed system

XI. CIRCUIT DESIGN

The circuit design connects all hardware components to the Arduino Uno. The HC-05 Blue-tooth module is connected to the serial communication pins of the Arduino. It receives commands from the smartphone and sends them to the controller. The motor driver is connected to the Arduino output pins and controls the motors based on the signals received from the controller.

The DC motors are connected to the output terminals of the motor driver. The direction of motor rotation changes according to the command given by the Arduino. The speaker module is connected to provide voice feedback. The Wi-Fi camera module is powered separately or through the robot power system, depending on the selected camera module.

A rechargeable battery is used to power the system. The circuit is arranged in a compact manner on the robot chassis to maintain balance and ensure stable movement.

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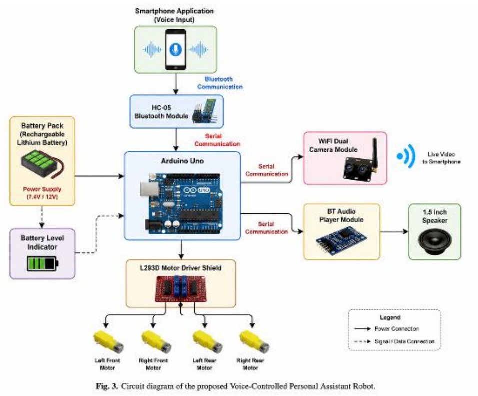

Figure 2: Circuit diagram of the proposed robot

XII. IMPLEMENTATION

The Arduino Uno, HC-05 Bluetooth module, motor driver, DC-motors, speaker module, Wi-Fi camera and Battery pack were used to create the prototype. The chassis consisted of four wheels into which the components were added. Arduino Uno and Motor Driver were positioned close to the center of the platform for a balance.

HC-05 Bluetooth module was programmed and linked to the mobile phone. Movement commands were sent by a voice control application. The code for the Arduino program was developed in Embedded C, using the Arduino IDE program. It is a program that will continuously monitor if any data comes in via Bluetooth and take the necessary action.

The following commands are used in the system:

- Forward movement.
- Backward movement.
- Left turn.
- Right turn.
- Stop movement.

The audio feedback module was programmed with certain responses. This is a Wi-Fi camera that was installed for live monitoring. The entire system was then constructed and tested multiple times indoors.

XIII. EXPERIMENTAL SETUP

The experimental testing was carried out in an indoor environment. The robot was connected to the smartphone via the Bluetooth connection. For each voice command, they have repeated the command several times at various distances within the Bluetooth range. The key parameters tested were accuracy of command execution, stability of the communications, response time and performance of the monitoring.

Five basic commands were used to test the robot – forward, backward, left, right and stop. The test of each command was repeated 20 times. The number of times the execution was successful was noted and used to determine accuracy.

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XIV. RESULTS AND DISCUSSION

The experimental results are shown in Table 3. The robot achieved good command execution accuracy under normal indoor conditions.

Table 3: Command Execution Accuracy

Command	Trials	Successful Execution	Accuracy
Forward	20	19	95%
Backward	20	20	100%
Left	20	19	95%
Right	20	18	90%
Stop	20	20	100%

The backward and stop commands achieved 100% accuracy. The forward and left commands achieved 95% accuracy. The right command achieved 90% accuracy, which may be due to minor delay in command recognition or temporary communication disturbance.

The average accuracy is calculated as:

$$Average\ Accuracy = \frac{95 + 100 + 95 + 90 + 100}{5} \qquad (1)$$

$$Average\ Accuracy = 96\% \qquad (2)$$

The results show that the proposed robot can perform real-time voice-controlled operation with reliable accuracy. The audio feedback improved the **user interaction, while the Wi-Fi camera provided useful monitoring support.**

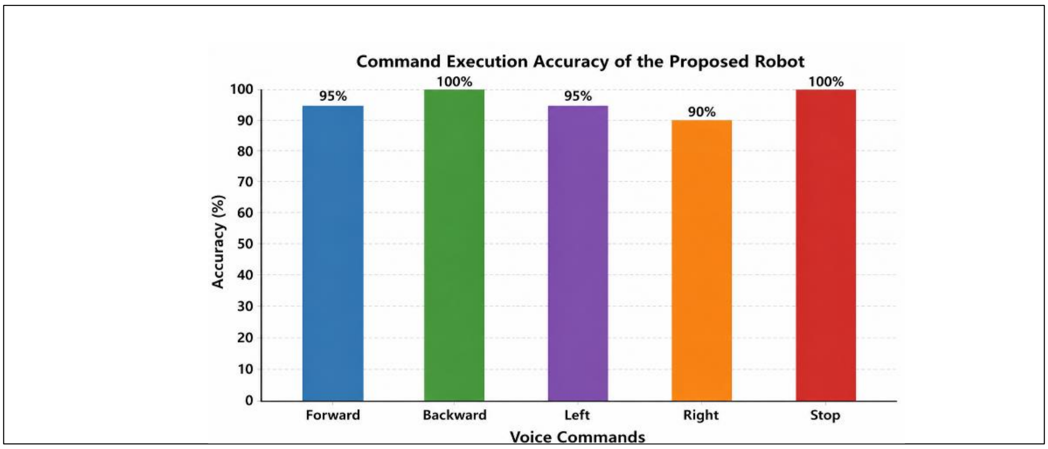

Figure 3: Command Execution accuracy graph

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XV. PERFORMANCE EVALUATION

The effectiveness of the robotic assistant was tested based on the following criteria: command execution accuracy, response time, communication range, and battery performance.

XV.I Command Execution Accuracy

Execution accuracy of commands means the accuracy in executing the commands that are given to the robot by voice. It is calculated using:

$$\text{Success Rate } (\%) = \frac{\text{Successful Executions}}{\text{Total Trials}} \times 100 \tag{3}$$

The experimental results showed that the accuracy of the robot was about 96% on average.

XV.II Response Time

Response time is the time from the activation of a voice command until the robot completes the action. It can be represented as:

$$VoiceProcessingTime + BluetoothTransmissionTime + ActionExecutionTime = Response\ Time \tag{4}$$

During testing, the response delay was found to be acceptable for indoor real-time control.

XV.III Communication Range

The HC-05 Bluetooth module gave stable communication in the indoor range of about 8-10 meters. The range is appropriate for use in the laboratory, classroom demos and indoor monitoring.

XV.IV Battery Performance

The performance of the battery depends on the battery capacity and total current drawn by the motors, Arduino, Bluetooth module, camera and speaker module. The battery life can be calculated by following

one or more of the following:

$$\text{Life of the battery} = \frac{\text{Battery Capacity } (mAh)}{\text{Current Consumption } (mAh)} \tag{5}$$

Short duration testing and demonstration were conducted using sufficient power from the rechargeable battery.

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XVI. ADVANTAGES

The proposed system offers the following advantages:

- Low-cost implementation.
- Simple hardware design.
- Easy wireless operation using a smartphone.
- Hands-free voice-based control.
- Audio feedback for improved interaction.
- Real-time video monitoring.
- Suitable for educational and prototype applications.
- Modular design for future expansion.

XVII. LIMITATIONS

Although the proposed system performed well during testing, it has the following limitations:

- Bluetooth communication is limited to short-distance operations.
- The robot operates only with predefined commands.
- The current prototype does not include automatic obstacle avoidance.
- Voice command accuracy may be affected by background noise.
- Battery life depends on motor load and camera usage.
- The system is mainly suitable for indoor operation.

XVIII. FUTURE WORK

On the proposed design, the detection of obstacles can be added with the use of ultrasonic sensors. The robot can also be programmed to move without the need for constant human input, which is achieved using autonomous navigation. Cloud connectivity for IoT can be implemented for remote management via Internet.

Voice interaction could be enhanced by using Artificial Intelligence and Natural Language Processing. Face recognition, object detection, and person tracking are examples of computer vision features that can be added. The enhancements can enable the robot to become more intelligent and capable of more sophisticated applications.

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XIX. CONCLUSION

The design and implementation of an IoT-based voice-controlled personal assistant robot with voice recognition and Bluetooth communication, embedded processing, audio feedback and real-time video monitoring in a single low-cost robotic platform is presented here. The developed system allows controlling robot movement by speech signals sent to the robot via a smartphone application, and a simple and intuitive interface for human–robot interaction is

provided. The proposed solution is simple, cost-effective and can be used for education, re-search, and prototype development due to the use of readily available hardware components such as Arduino Uno microcontroller and HC-05 Bluetooth module.

The results of experimental tests showed that the robotic platform was stable and reliable in indoor experiments, and the accuracy of the command execution is about 96

In conclusion, the proposed robotic assistant shows that reliable voice-controlled navigation and real-time monitoring are possible by employing simple embedded architecture (no expensive hardware, no complex computing resources). Additionally, the modular architecture allows for flexibility in future enhancements, making the platform an ideal foundation for integration with obstacle avoidance, autonomous navigation, cloud-based IoT connectivity, computer vision and Artificial Intelligence-based decision making.

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