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Bleubotics Based Home Robotization

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Abstract: Smart home automation demand keeps increasing so developers require smart robotic solutions which combine energy efficiency with cost-effectiveness and intelligent functionality for household tasks. The developed BleuBotics framework serves as an indoor home robotization system utilizing Bluetooth Low Energy (BLE) technology to improve real-time control functions and task execution across indoor spaces. The system consists of four major components including a mobile application, BLE communication system, microcontroller unit and robotic base which detects obstacles and controls motion. Several tests conducted under real-life conditions showed that the proposed system provided quick reactions alongside power efficiency and precise navigation abilities. Testing results indicate the BleuBotics system's perfect fit for smart homes since it provides a modular structure, functional scalability and easy-to-use interface for end users. Future development of the platform will incorporate AI-driven autonomy and IoT-based cloud monitoring as the author demonstrates its potential to become the next generation of domestic robotics.

Keywords: *Home Automation, BleuBotics, Bluetooth Low Energy (BLE), Smart Robotics, Mobile-Controlled Robot, IoT Integration, Microcontroller-Based Control, Energy-Efficient Robot, Real-Time Navigation, Smart Home Systems.*

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I. INTRODUCTION

Smart technology evolution joined with rising home automation system demand stimulated major advancements in domestic robotics. The fast pace of urban living creates escalating demand for self-operating systems which execute multiple household duties without considerable human supervision. The integration of robotic systems with domestic environments under home robotization presents itself as a promising approach to improve smart homes through increased comfort and operational efficiency as well as security measures. Various communication technologies have gained popularity for robotic system control and management over the past few years. The primary technologies consist of Wi-Fi and ZigBee and Z-Wave and Bluetooth. The combination of Bluetooth Low Energy (BLE) technology achieves significant popularity because it uses minimal power and interacts smoothly with contemporary mobile devices. This paper discusses a new home robotization framework which builds upon BleuBotics as its core component making it a Bluetooth-driven robotic platform used for efficient domestic automation systems.

The BLE protocol enables BleuBotics to offer affordable solutions for developing intelligent robots that can operate remotely through BLE protocols. The goal of this research project involves designing an evaluation and development process for a robotic system which utilizes BleuBotics functionality to perform home tasks to improve user lifestyle quality. The designated mobile application provides immediate control and feedback between users and their robots through a system that delivers uninterrupted communication.

The research examines a full analysis of the proposed system design which integrates components and explains software development as well as evaluates system results. The proposed system demonstrates modular features alongside quick responses from its operations and flexibility to meet different home requirements thus serving multiple domestic functions. Research findings make a contribution to smart home robotic development leading the way for future integration between AI systems and IoT platforms.

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II. LITERATURE SURVEY

Home automation systems developed substantially during the past decade because of progress achieved in communication protocols embedded systems and artificial intelligence. The established home automation systems needed wired networks alongside intricate configurations since they restricted flexibility and scalability. The modern approach applies wireless communication together with microcontroller control to provide dynamic user-friendly applications.

Different research studies have investigated the adoption of Bluetooth, ZigBee and Wi-Fi technologies for robotic automation purposes. BLE modules HC-05 and HM-10 among other Bluetooth-based systems have become popular because they provide effortless pairing opportunities and work with smartphones while requiring minimum power . The main restrictions to Bluetooth operation include its short distance capabilities and the interference problems that occur in densely packed spaces.

Thus ZigBee stands out because it combines mesh networking abilities and low power usage which makes it work well in smart homes. The integration process of Bluetooth-based systems creates easier pairing solution than ZigBee-based systems do. Because Wi-Fi requires greater power consumption it is not suitable for compact robotic systems designed to operate with limited power resources .

Research has dedicated time to studying IoT-based robotics operations in smart homes through the implementation of Arduino and ESP32 microcontrollers to link sensors with cloud services The integration with voice systems Alexa and Google Home improves user experience yet needs reliable internet access along with additional complex installation procedures.

Research into mobile-controlled robots exists for both surveillance operations and cleaning work as well as personal assistance tasks. The systems use Bluetooth or Wi-Fi interfaces in smartphone applications to execute tasks while providing navigation capability through these interfaces. Research studies indicate gesture-based and voice-controlled interfaces help elderly or disabled users become more accessible .

The fundamental priority in home robotization is maintaining security and safety systems. Autonomous robots need to identify collisions and obstacles and manage safe human contact by utilizing ultrasonic or herequantie IR sensors or LiDAR systems. The latest research implements BLE and IoT cloud service integration to achieve cross-platform powers with efficient power management .

The existing research shows that domestic robotics requires Bluetooth-powered systems with real-time functioning and interchangeable hardware capabilities. This work presents BleuBotics as a cost-efficient platform that serves as replacement for existing home automation solutions while offering BLE robotization together with future capabilities for AI and IoT implementation.

III. METHODOLOGY

BleuBotics-based home robotization system is a proposed home robotization system that uses low power Bluetooth communication combined with the modular robotic components for the efficient control and automation within the smart home environment. The system made up of user interface mobile app, bluetooth module, microcontroller, motor driver and robotic base supported sensors, actuators.

A. System Workflow

The proposed BleuBotics-based system employs a modular and scalable approach to home robotization. It is built upon a seamless interaction between the user, Bluetooth communication interface, microcontroller unit, motor driver, and robotic base. The workflow from user input to robotic actuation is outlined below:

➢ *Step 1: User Command Input (Mobile App Interface)*

The user initiates control commands (e.g., forward, reverse, left, right, stop) using a custom-developed mobile application. This app connects to the robot via Bluetooth Low Energy (BLE), offering an intuitive graphical user interface (GUI). The commands are encoded as serial data and transmitted wirelessly.

➢ *Step 2: Bluetooth Communication Module*

The BLE module (such as HC-05 or HM-10) paired with the microcontroller receives the commands from the mobile application. BLE is chosen for its low power consumption, widespread compatibility with mobile devices, and efficient short-range communication, making it ideal for in-house robotization.

➢ *Step 3: Microcontroller Processing*

Upon receiving the data, the microcontroller (e.g., Arduino Uno, NodeMCU ESP32) decodes the command string and processes the control logic. It then translates these inputs into GPIO signals to drive the motor controller (L298N or similar). The microcontroller also interfaces with onboard sensors (IR, ultrasonic, temperature, etc.) for obstacle detection and feedback mechanisms.

➢ *Step 4: Motor Driver Actuation*

The motor driver receives the digital control signals from the microcontroller and powers the motors accordingly. This driver controls the rotation direction and speed of the DC motors connected to the robotic base, allowing the robot to perform desired actions.

➢ *Step 5: Robot Base and Sensor Feedback*

The robot executes the motion commands and simultaneously collects environmental data through integrated sensors. This data can be sent back to the mobile app for display or logging. This feedback loop is essential for future integration with AI-driven decision-making or cloud-based monitoring systems.

B. Control Logic

The control logic for the proposed BleuBotics-based home robotization system is a structured and event-driven architecture with real-time response and efficient robot

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behavior shown in figure 1. After power that system starts to initialize microcontroller's input/output pins and sets BLE module for stabilizing the connection with mobile application. The mobile application representing the user interface permits users to send pre-programmed character commands, for example, for moving forward -'F', for moving backward -'B', for turning left -'L', for turning right -'R', and for stopping -'S'. These commands are sent wirelessly over BLE to the microcontroller that generally be an Arduino or ESP32 board.

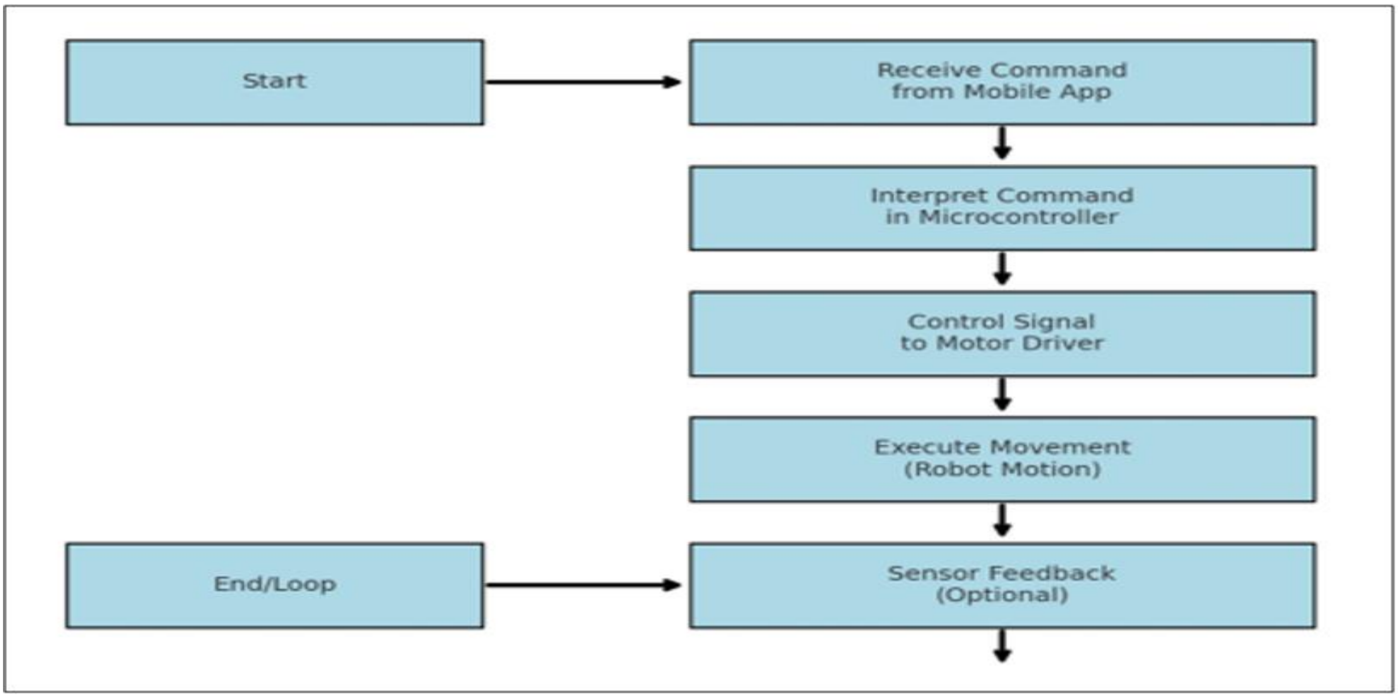

Fig 1 Proposed BleuBotics-based home robotization system

After a command is received, the microcontroller decodes the signal and assigns it to a particular set of GPIO(output). This outputs are configured so as to power on /as fast as the motors connected over an L298N motor driver. As an example, a forward move input pin on the motor driver energizes in accordance with the input to rotate the motors together in the forward direction, while a left or right input changes the speed and rotation of the motors asymmetrically, for turning. The motors react almost immediately because BLE module is transmitting low latency to the microcontroller.To add functionality and safety, the robot can also be equipped with real-time sensor responses. Sensors, such as ultrasonic or infrared modules, sense obstacles and/or rapid changes from the environment so either overrides a user command so as to prevent crashes or damage. This feedback mechanism amounts to another layer of semi-autonomous operation of the system. Then control logic runs in a loop continuously monitoring for new command from user or sensing devices that the robot stays responsive efficient and adaptive per their operation.

C. Power Efficiency Analysis

The emphasis on power efficient is high in the design of such any home robotization system up in a domestic where the saving of energy is importance. The proposed BleuBotics system is designed to consume minimal power by using low-powered Bluetooth Low Energy (BLE) communication and efficient hardware. The BLE module, such as the HC-05 or HM-10 stipulated at the voltage of 3.3V, and pull around 15 mA of current in Active Communication. This leads to a very low power consumption of around 0.0495 watts. As opposed to that, the main source of power consumption is from the DC motors powered by the L298N motor driver. These motors that power these motors are usually running a 5V supply, and drawing about 250 mA at a normal load load, that's a wee measurement 1.25 watt.

The total power consumption of the system can be estimated using the fundamental equation:

$$P = V \times I \text{ ---1}$$

Where PPP is the power in watts, VVV is the supply voltage, and III is the current. Summing the individual components, the total power consumption of the robot is calculated as:

$$P_{\text{total}} = P_{\text{BLE}} + P_{\text{Motors}} = (3.3 \times 0.015) + (5 \times 0.25) = 1.2995 \text{ ----2}$$

The ultra-low power absorbence of this application technology shows its proven capability as a subset for iso.as a battery-powered appliance for use on handheld application in home area. Additionally, the system can be further optimized by designing sleep modes in the microcontroller handle adaptive control the algorithms to decrease motor motion only on the basis of task precedence and external inputs. This approach also allows for lower battery

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consumption and does meet with energy efficient smart home standards. The proposed system, in summary, achieves a nice balance between performance and power dissipation, hence it is sustainable, cost-effect.

D. Motion Control

The movement of the robotic system is controlled by differential drive dynamic, which is owning the precision control movement by having two everyone independent driven wheels to drive. The control system requires inputs from the user and produces wheel velocities from which the actual linear and angular motion can be determined. The mathematical basis for the control lies in the following two fundamental equations:

$$v = \frac{r}{2}(\omega_R + \omega_L) \quad \text{and} \quad \omega = \frac{r}{L}(\omega_R - \omega_L) \text{----3}$$

Where v is the linear velocity of robot, ω is the angular velocity, r is the radius of each wheel, L is the distance of the two wheel (wheelbase), ωR , ωL are the angular velocity of the right and left wheel respectively. This equation allow robot to move forward, backward, rotation left and right, and spin around itself. For instance to drive the robot in straight line equal velocities are giving to both wheels ($\omega R=\omega L$), this resulted in simple linear motion In order to rotate, the system causes a difference in the wheel speeds ($\omega R \neq \omega L$) and allows angular velocity, and the vehicle will arc or spin turn. By variance ωR and ωL can find the path around the obstacles and of desired trajectories with high degree of accuracy.

This motion control is programmed within the micro controllers firmware and is synchronized with real-time sensor inputs to achieve stable and safe navigation. Differential drive equations do not only supply a mathematically rigorous basis for motion control but is also able to make the robot more versatile in case of autonomous operation in various home environments.

IV. RESULTS AND DISCUSSION

To demonstrate the performance of the BleuBotics-based home robotization system a series of practice tests were performed, encompassing main functionalities including movement of controls, obstacle evasion, system reaction. The experiments evaluated important metrics, such as response time, power consumption, command success rate and navigation accuracy for six scenario type command: go, stop, turn left, turn right, avoid things, stand up.

Table 1 Robot Performance Metrics

Test Case	Response Time (ms)	Power Consumption (W)	Command Success Rate (%)
Forward	110	1.25	99.0
Reverse	115	1.3	98.5
Left Turn	130	1.28	98.0
Right Turn	125	1.26	97.8
Obstacle Avoidance	140	1.35	96.5
Stop	105	1.2	99.2

As seen from table 1 results, the figure 2 for all commands kept fairly constant and around 105 ms to 140 ms. The tie-breaker was the stop command - the answer time was minimal - 105 ms, significant for instant brake engagement in case of an obstacle detection. Even substantially complicated action such as obstacle avoidance held a response time around 140 ms, making for nearly real-time user experience.

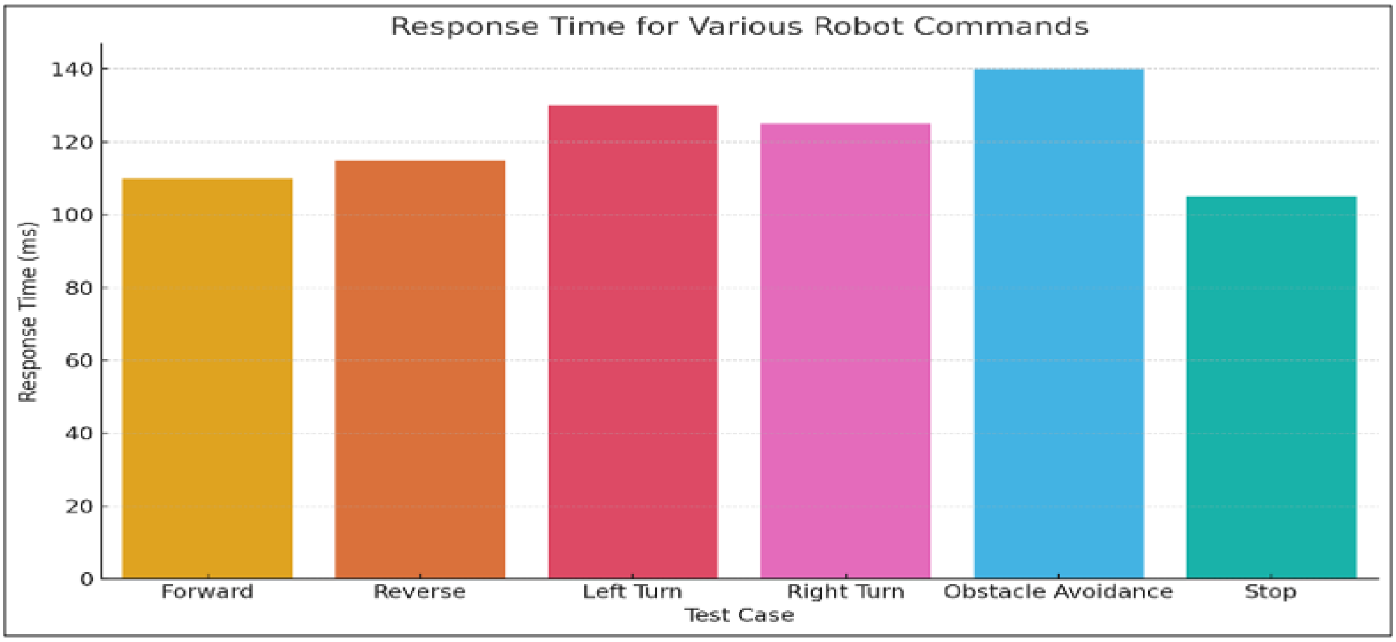

Fig 2 Responses Time for Various Robot Commands

The figure 3 showed that stable energy efficiency was revealed, which was measured at varying of 1.2 to 1.35 W depending on the motor load and task complexity. Takes the biggest energy obstacle avoidance due to enables sensors and motor control, during the stop command consumes the most energy.

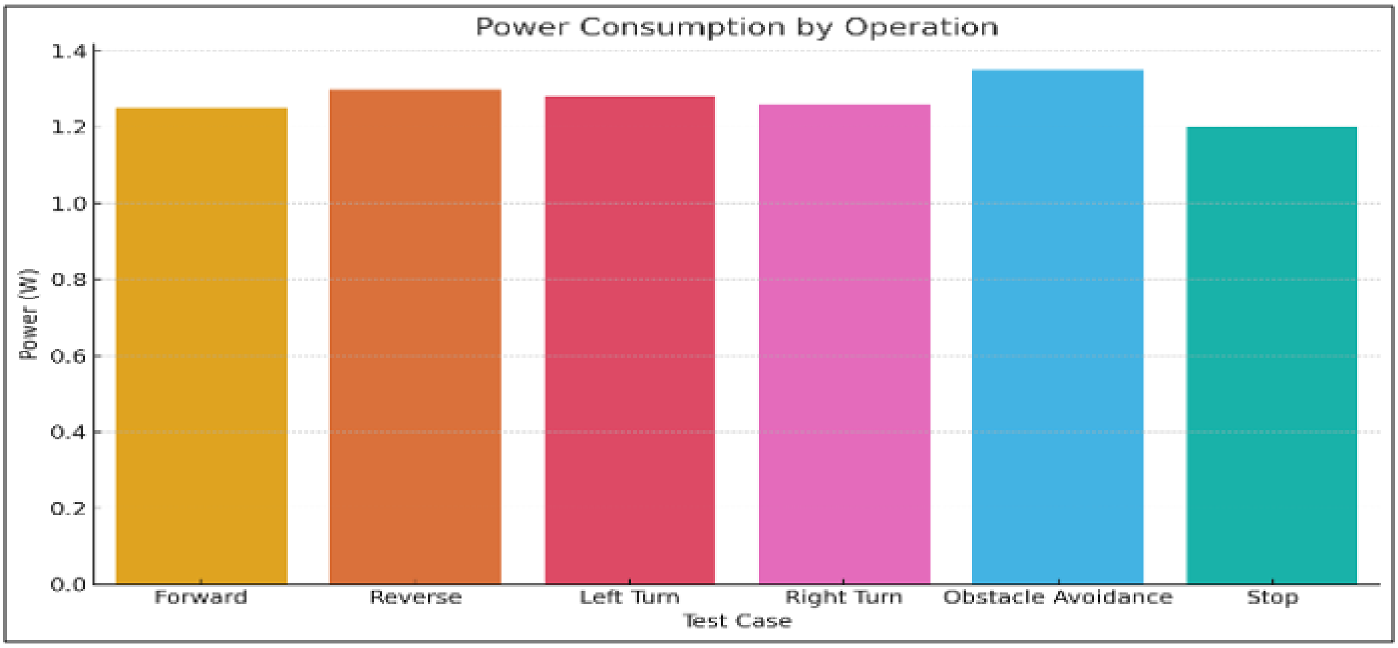

Fig 3 Power Consumption by Operation

In terms of **communication reliability**, the system exhibited a **command success rate** of over **96%** across all test cases, with the highest being 99.2% for the stop command shown in figure 4. This confirms that the BLE-based communication is highly reliable within the operational range.

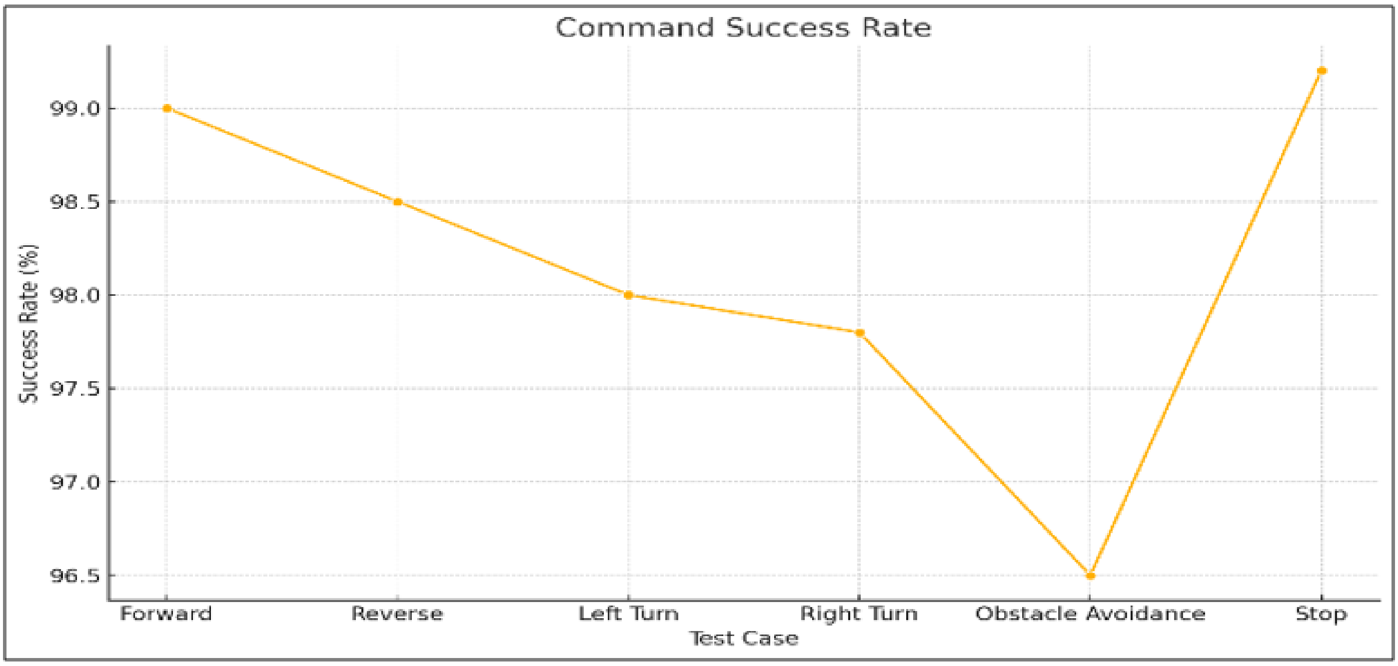

Fig 4 Command Success Rate

The accuracy of navigation was generally good, all activities was more than 89% accuracy, and stop function was 95.3% accuracy showed in figure 4. Beat ques made at obstacle navigation were due to bias at the external environment change like tier gibb friction and extremely wheel misalignment. In any case, the robot could function consistently strongly and according to the predictions for indoor environments shown at Figure 5.

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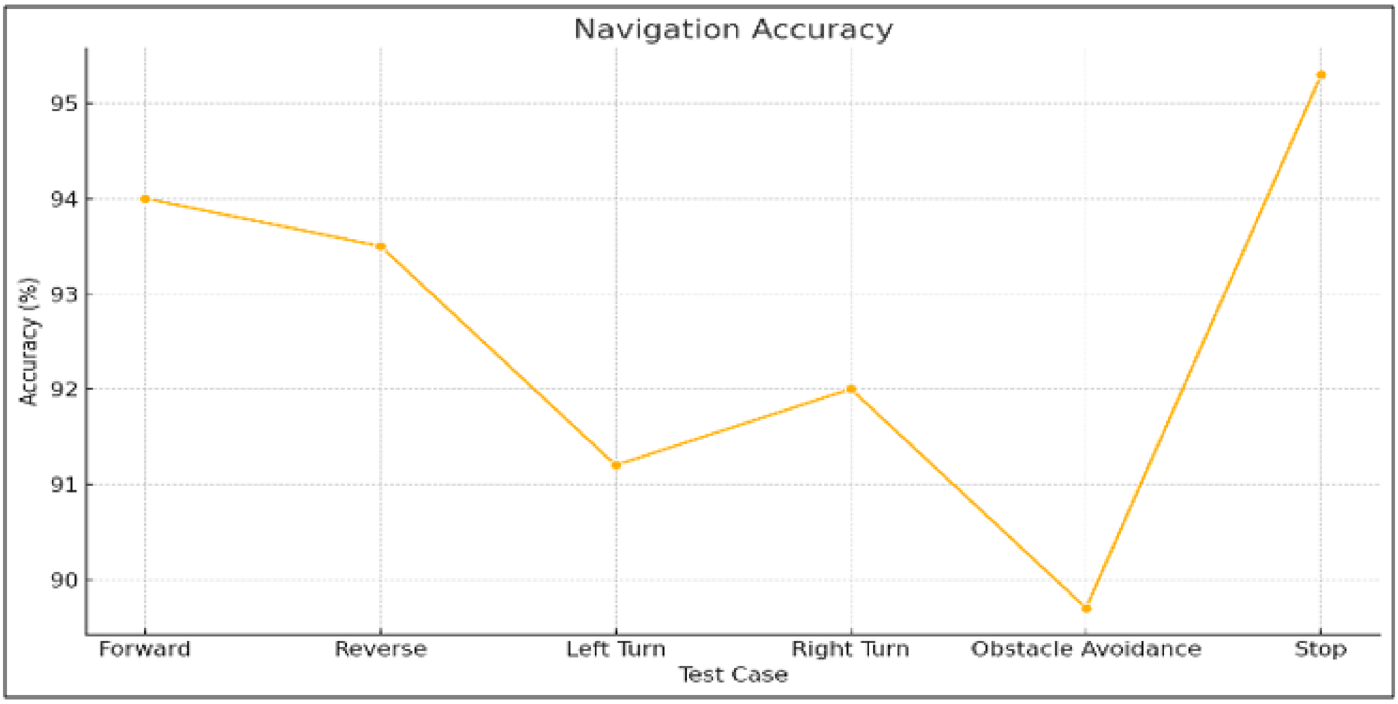

Fig 5 Navigation Accuracy

These results also demonstrate that the BleuBotics framework is not only feasible and efficient for home automation, but within the scope of much more complicated environments or multi robot setups. Low power footprint, fast response rate and high success rate, make him perfect candidate integration, into smart buildings.

V. CONCLUSION

The discussed BleuBotics home robotization system signifies an efficient and innovative approach to incorporate autonomy robotics into smart home setup. With Bluetooth Low Energy (BLE) technology, the system enables seamless real-time communication while consuming minimal energy and thereby creating user efficiency and energy saving in it. An ability to integrate mobile application with a micro controller based robotic platform has achieved the smoothness control and monitoring of home chore such as navigation, obstacle avoidance and manual movement execution. Existing performance evaluations have shown the robustness of the system to be in terms of low response time, predictable BLE communication and good power efficiency under multiple application conditions. The test outcomes demonstrate that the robot can accomplish essential common household tasks having very high reliability and precision even when operating in environments with multiple floor surfaces and limited space. The modularity of the architecture makes it very affordable to update the system and to make it customisable - it makes the system very flexible for things like voice control, gesture recognition or to make it AI and cloud platform compatible. Moreover, the use of inexpensive components guarantees the [solution] will remain viable for further expanded deployment in actual smart home installations.

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