Raspberry Pi Pico Bluetooth Home Automation System using Voice Recognition

Project Report

For

Internet of Things Projects using Python (CSE 4110)

Submitted by

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DECLARATION

We certify that

a. The work contained in this report is original and has been done by us under the guidance of our supervisor(s).

b. The work has not been submitted to any other Institute for any degree or diploma.

c. We have followed the guidelines provided by the Department in preparing the report.

d. Whenever we have used materials (data, theoretical analysis, figures, and text) from other sources, we have given due credit to them by citing them in the text of the report and giving their details in the reference.

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REPORT APPROVAL

The report entitled

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is approved for

Internet of Things Projects using Python (CSE 4110)

in

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Place: ____________________

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I extend my heartfelt gratitude to all those who contributed to the successful completion of the "Raspberry Pi Pico Bluetooth Home Automation System using Voice Recognition" project.

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ABSTRACT

The Voice Controlled Home Automation project leverages the Raspberry Pi Pico board, HC05 Bluetooth module, and a 4-channel relay driver to create an innovative home automation system. Moving beyond traditional mechanical switches, the project introduces wireless control with an Android application and integrates voice commands for device manipulation.

The hardware setup includes the Raspberry Pi Pico, Micro USB Cable, 4-Channel Relay Driver, HC05 Bluetooth Module, connecting wires, a breadboard, an AC bulb holder, and an AC bulb. Thonny IDE serves as the software platform for the MicroPython code that facilitates communication and control.

The HC05 Bluetooth module enables wireless communication between the Android application and the Raspberry Pi Pico, establishing a versatile interface for controlling connected appliances. A 5V relay driver allows for the seamless ON and OFF switching of devices through the relay.

The circuit diagram illustrates the connections between the HC05 Bluetooth module, relay driver, and AC components, providing a clear understanding of the physical setup. The source code (main.py) written in MicroPython governs the reception of voice commands through the Bluetooth module, enabling the comparison and execution of predefined actions.

This project not only extends the capabilities of the previously developed Bluetooth Controlled Home Automation system but also showcases the integration of voice commands for enhanced user convenience. The abstract encapsulates the key components, functionalities, and contributions of the Voice Controlled Home Automation project, providing a succinct overview for project documentation.

Chapter 1: Introduction

1.1. Motivation

The motivation behind embarking on the Voice Controlled Home Automation project stems from a desire to elevate the conventional home automation experience. Traditional mechanical switches, though functional, lack the modern flair and convenience offered by wireless and voice-controlled systems. In the current phase of automation and smart living, the project seeks to address this limitation by integrating cutting-edge technologies.

The motivation further extends to explore the capabilities of the Raspberry Pi Pico board and HC05 Bluetooth module in conjunction with an Android application. By introducing wireless communication and voice commands, the project aims to redefine user interactions with home appliances. The intention is to move beyond the manual operation of switches and buttons, offering a more intuitive and hands-free approach to controlling devices within a home environment.

Additionally, the project serves as an educational endeavor, providing enthusiasts and developers with a practical application of MicroPython on low-memory devices. The use of the HC05 Bluetooth module demonstrates the potential for affordable and widely available technology to enable seamless communication between electronic devices.

In summary, the motivation for this project lies in enhancing home automation by embracing wireless solutions and integrating voice commands. The goal is to create a more user-friendly, efficient, and futuristic home automation system that aligns with the evolving landscape of smart living and IoT technologies.

1.2. Design Goals

i. **Seamless Wireless Communication:** The primary design goal is to establish seamless wireless communication between an Android device and the Raspberry Pi Pico board using the HC05 Bluetooth module. This eliminates the need for physical connections, providing a more flexible and user-friendly interface for home automation.

ii. **Voice-Activated Control:** The project aims to integrate voice commands for controlling home appliances. The design goal is to enable users to effortlessly interact with the automation system, issuing commands to turn devices on or off using natural language.

iii. **Expandability and Scalability:** The system is designed to be expandable and scalable, accommodating the control of multiple devices. The 4-channel relay driver allows for the simultaneous control of different appliances, providing versatility for users with diverse home automation needs.

iv. **User-Friendly Android Application:** The development of a user-friendly Android application is a key design goal. The application should serve as an intuitive interface, allowing users to easily connect to the Raspberry Pi Pico, configure settings, and issue voice commands for device control.

v. **Compatibility and Integration:** The design emphasizes compatibility with commonly available components, ensuring accessibility for hobbyists and enthusiasts. The integration of the Raspberry Pi Pico and HC05 Bluetooth module showcases a harmonious synergy, enabling efficient communication and control.

vi. **Efficient Power Management:** Energy efficiency and power management are essential design considerations. The system should be designed to minimize power consumption during idle periods, contributing to sustainability and long-term usability.

vii. **Robust Circuit Design:** The circuit design should be robust and resilient, ensuring reliable performance in real-world conditions. The project emphasizes clarity in the circuit diagram to facilitate easy replication and modification by other enthusiasts.

viii. **Educational Value:** The project aims to have educational value by utilizing MicroPython for programming the Raspberry Pi Pico. The design encourages learning and exploration, making it accessible for individuals interested in both home automation and programming on low-memory devices.

ix. **Security Considerations:** While focusing on user convenience, the design also incorporates security considerations to safeguard the wireless communication between the Android application and the Raspberry Pi Pico. Encryption and secure authentication measures are explored to protect against unauthorized access.

x. **Documentation and Accessibility:** Comprehensive documentation is a key design goal, ensuring that other enthusiasts can easily replicate and understand the project. Accessibility considerations are taken into account, providing clear instructions for hardware connections, software setup, and code implementation.

By addressing these design goals, the Voice Controlled Home Automation project aims to deliver a robust, user-friendly, and educational solution that enhances the home automation experience through wireless communication and voice-activated controls.

1.2.1 Purpose

The purpose of the design goals is to create a holistic, user-centric, and sustainable solution for voice-controlled home automation. By addressing various aspects, from user experience to educational exploration, the design goals aim to enrich the overall impact and accessibility of the project.

i. **Seamless User Experience:** The design goals aim to create a seamless and enjoyable user experience by eliminating the need for physical connections and introducing wireless communication. Users can effortlessly control their home appliances using an Android device and voice commands, enhancing convenience and accessibility.

ii. **Intuitive Interaction:** The integration of voice-activated control aligns with the purpose of simplifying interaction with the home automation system. By allowing users to communicate naturally with the system, the design goals focus on making the technology more intuitive and user-friendly.

iii. **Flexibility and Adaptability:** Designing for expandability and scalability ensures that the system can adapt to users' evolving needs. The ability to control multiple devices simultaneously provides flexibility, allowing users to customize their home automation setup based on individual preferences.

iv. **User Empowerment:** The user-friendly Android application empowers users to effortlessly connect to the Raspberry Pi Pico, configure settings, and control devices. The purpose is to democratize home automation, making it accessible and understandable to a broader audience.

v. **Harmonious Integration:** The design goals emphasize the harmonious integration of commonly available components like the Raspberry Pi Pico and HC05 Bluetooth module. This purpose facilitates widespread adoption by enthusiasts, fostering a collaborative community around the project.

vi. **Efficient Resource Utilization:** The consideration of efficient power management aligns with the purpose of sustainability. By minimizing power consumption during idle periods, the design goals aim to contribute to energy efficiency and promote responsible resource utilization.

vii. **Reliability and Replicability:** A robust circuit design enhances the reliability of the system. Clear documentation and a well-structured circuit diagram fulfill the purpose of enabling enthusiasts to replicate the project easily, fostering a community of learners and creators.

viii. **Educational Exploration:** The design goals promote educational exploration by utilizing MicroPython for programming the Raspberry Pi Pico. This purpose encourages individuals to delve into programming on low-memory devices, fostering a learning environment for both beginners and experienced enthusiasts.

ix. **Security and Privacy:** Prioritizing security considerations serves the purpose of ensuring the confidentiality and privacy of user data. By implementing encryption and secure authentication measures, the design goals aim to protect against unauthorized access and potential security threats.

x. **Knowledge Sharing and Accessibility:** Comprehensive documentation and accessibility considerations fulfill the purpose of knowledge sharing. By providing clear instructions and insights into the project, the design goals contribute to the accessibility of the technology, encouraging a broader community to engage with and benefit from the project.

1.2.2 Scope

The scope of the Voice Controlled Home Automation project encompasses various aspects, ranging from the technical functionalities to the potential applications and educational opportunities:

i. **Technical Functionality:**
   a. The project's primary scope is to enable wireless communication between an Android device and the Raspberry Pi Pico using the HC05 Bluetooth module.
   b. Voice-controlled commands will be implemented to facilitate the seamless ON and OFF switching of home appliances connected through a 4-channel relay driver.
   c. The system will support multiple devices simultaneously, allowing users to control diverse appliances within their home environment.

ii. **User Interaction and Convenience:**
   a. The project aims to enhance user interaction by providing an intuitive Android application for configuring settings and issuing voice commands.
   b. Voice recognition capabilities will be integrated to interpret natural language commands, increasing the convenience and accessibility of the home automation system.

iii. **Scalability and Expandability:**
   a. The project's scope includes the ability to scale and expand the system to accommodate additional devices or functionalities in response to user requirements.
   b. The 4-channel relay driver design allows for the simultaneous control of multiple appliances, providing flexibility for users with diverse needs.

iv. **Educational Value:**

a. The project serves as an educational tool for individuals interested in exploring MicroPython on low-memory devices like the Raspberry Pi Pico.

b. Documentation and clear instructions aim to facilitate learning, making the project accessible to both beginners and experienced enthusiasts interested in home automation and programming.

v. **Compatibility and Integration:**

a. The project's scope extends to compatibility with commonly available components, ensuring accessibility for hobbyists and enthusiasts.

b. Integration with the HC05 Bluetooth module showcases the potential for affordable and widely available technology to enable seamless communication between electronic devices.

vi. **Security Measures:**

a. The scope includes the implementation of security measures to safeguard the wireless communication between the Android application and the Raspberry Pi Pico.

b. Encryption and secure authentication will be explored to protect against unauthorized access and enhance the privacy of user data.

vii. **Community Engagement:**

a. The project's scope encourages community engagement by providing a well-documented and replicable solution.

b. Enthusiasts and developers are invited to contribute, share insights, and explore the potential for customization and improvement of the home automation system.

viii. **Real-World Applicability:**

a. The home automation system's scope extends to real-world applicability, allowing users to implement voice-controlled automation in their homes for practical and daily use.

In conclusion, the scope of the Voice Controlled Home Automation project is comprehensive, encompassing technical functionalities, user interaction, scalability, educational value, compatibility, security measures, community engagement, and real-world applicability. This broad scope aims to address the diverse needs and interests of users while fostering a collaborative and educational environment within the enthusiast community.

1.2.3 Applicability

The Voice Controlled Home Automation project holds significant applicability across various domains, offering innovative solutions for modern living and technological exploration:

i. **Smart Homes:** The project finds immediate applicability in smart homes, where residents seek intuitive and hands-free control over their home appliances. Voice commands enable users to effortlessly manage lighting, heating, and other devices for enhanced comfort and convenience.

ii. **Accessibility Solutions:** The voice-controlled interface caters to individuals with mobility challenges, providing an accessible means of managing home devices. This applicability supports inclusivity by offering a user-friendly solution that transcends physical limitations.

iii. **Educational Platforms:** The project serves as a valuable educational tool for enthusiasts, hobbyists, and students interested in exploring MicroPython, Raspberry Pi Pico, and Bluetooth communication. It offers hands-on experience in hardware integration, coding, and home automation concepts.

iv. **DIY Home Automation Enthusiasts:** DIY enthusiasts in the home automation community benefit from the project's applicability by providing a customizable and extensible solution. The 4-channel relay driver design allows users to control multiple devices simultaneously, catering to diverse home automation setups.

v. **Technology Exploration:** The project's applicability extends to technology exploration, allowing users to delve into the world of wireless communication, voice recognition, and low-memory device programming. This hands-on experience fosters a deeper understanding of IoT (Internet of Things) concepts.

vi. **Energy Efficiency Initiatives:** By incorporating voice-controlled automation, the project contributes to energy efficiency initiatives. Users can easily manage the ON and OFF states of devices, promoting responsible energy consumption and environmental sustainability.

vii. **Prototyping and Prototyping Enthusiasts:** The project serves as a practical prototyping platform for those interested in experimenting with home automation concepts. Prototyping enthusiasts can use the provided circuit diagram and source code as a foundation for creating their customized solutions.

viii. **Community Collaboration:** The applicability of the project lies in its potential to foster community collaboration. Enthusiasts can share insights, improvements, and modifications, creating a collaborative ecosystem where individuals contribute to the advancement of voice-controlled home automation.

ix. **Real-World Home Integration:** Beyond experimentation, the project is applicable for real-world integration into homes. Users can implement the voice-controlled automation system as a functional and convenient solution for managing their daily activities.

In summary, the Voice Controlled Home Automation project's applicability spans smart homes, accessibility solutions, educational platforms, DIY home automation communities, technology exploration, energy efficiency initiatives, prototyping endeavours, community collaboration, and real-world home integration. Its versatility makes it a valuable asset across a spectrum of interests and applications.

1.3. Problem Statement

In contemporary living, home automation has become an integral aspect of enhancing comfort and efficiency. While various solutions exist, the conventional methods of control, such as mechanical switches, lack the sophistication and hands-free convenience that modern users seek. Additionally, the complexity and cost associated with implementing voice-controlled systems often present barriers to widespread adoption.

The absence of a cost-effective, accessible, and educational voice-controlled home automation solution hinders enthusiasts, DIY communities, and individuals with mobility challenges from embracing this transformative technology. Existing systems often lack documentation, making it challenging for beginners to understand and replicate the setup. Moreover, the integration of wireless communication and voice commands demands a comprehensive yet straightforward solution that aligns with the capabilities of low-memory devices like the Raspberry Pi Pico.

The Voice Controlled Home Automation project aims to address these challenges by providing a user-friendly, scalable, and educational solution. It seeks to democratize voice-controlled home automation, making it accessible to a broader audience while fostering a collaborative community around the technology. The project aims to bridge the gap between sophisticated but expensive solutions and limited but cost-effective alternatives, bringing voice-controlled home automation within reach for enthusiasts and individuals seeking an innovative and hands-free approach to managing their living spaces.

1.4. Organization of the Report

The organization of the report for the "Voice Controlled Home Automation using Raspberry Pi Pico and HC05 Bluetooth Module" project is thoughtfully structured to provide a comprehensive understanding of the entire endeavor. The introduction sets the stage by introducing the context and purpose of the project, followed by a clear articulation of the identified problem statement. The literature survey section provides a thorough review of existing research and technologies relevant to home automation, voice control, and the specific components employed, such as the Raspberry Pi Pico and HC05 Bluetooth module.

Moving forward, the report delineates the project's objectives and scope, outlining the goals and limitations. The design and methodology section elaborates on the technical aspects, presenting the system architecture and detailing hardware and software requirements. The implementation section takes a hands-on approach, explaining the circuit design, source code, and testing procedures. Results and discussion provide an analysis of the project's performance and potential improvements. The conclusion wraps up the report by summarizing key findings and proposing avenues for future exploration. With this well-organized structure, the report ensures clarity, coherence, and a logical flow of information for readers to grasp the entirety of the voice-controlled home automation project.

Chapter 2: Literature Survey

2.1. Background work done so far

The literature survey delves into existing studies and research related to home automation technologies, voice control systems, and the application of Raspberry Pi Pico and HC05 Bluetooth modules in similar projects. The background work highlights the current state of the field and identifies gaps and opportunities for the Voice Controlled Home Automation project.

i. **Home Automation Technologies:** Previous research has extensively explored various home automation technologies, ranging from Wi-Fi-enabled systems to Zigbee and Z-Wave protocols. The literature emphasizes the need for user-friendly interfaces and efficient communication between devices for a seamless automation experience.

ii. **Voice Control in Home Automation:** Studies on voice-controlled home automation systems showcase the evolution of natural language processing and voice recognition technologies. Voice interfaces like Amazon Alexa and Google Assistant have become prevalent, offering hands-free control of smart home devices.

iii. **Raspberry Pi Pico and HC05 Bluetooth Module:** The Raspberry Pi Pico's emergence as a low-cost, high-performance microcontroller is a significant development in the literature. Research highlights its capabilities for embedded systems and its compatibility with MicroPython, making it an attractive choice for IoT projects. The HC05 Bluetooth module has been widely studied for wireless communication in various applications. Research emphasizes its simplicity, cost-effectiveness, and compatibility with microcontrollers, making it a popular choice for establishing Bluetooth connections.

iv. **Voice-Controlled Home Automation Projects:** Existing voice-controlled home automation projects often involve the integration of microcontrollers, sensors, and voice recognition modules. These projects vary in complexity, but they collectively showcase the feasibility and potential of voice-activated systems.

v. **Educational Applications of Raspberry Pi Pico:** The educational value of the Raspberry Pi Pico is emphasized in literature, with studies highlighting its use in teaching programming and embedded systems. Research indicates that its affordability and flexibility make it an ideal platform for hands-on learning.

vi. **Challenges and Opportunities:** Literature identifies challenges in voice-controlled home automation, such as addressing security concerns, refining voice recognition accuracy, and ensuring compatibility across devices. Opportunities lie in the continuous improvement of natural language processing algorithms and the exploration of cost-effective solutions.

vii. **Open-Source Community Contributions:** The active participation of the open-source community in developing projects similar to Voice Controlled Home Automation underscores the collaborative nature of such initiatives. Open-source documentation, forums, and repositories contribute to shared knowledge and accelerated innovation.

While significant progress has been made in voice-controlled home automation, the literature survey reveals opportunities for further exploration. The integration of Raspberry Pi Pico and HC05 Bluetooth modules in this project aligns with the current trends and research in the field, offering a unique contribution to the evolving landscape of smart home technologies.

By building upon the existing body of knowledge, the Voice Controlled Home Automation project aims to address specific challenges and contribute to the growing repository of accessible and educational home automation solutions.

Chapter 3: Design Scheme

3.1. System Design

The system design for the Voice Controlled Home Automation project involves a cohesive integration of hardware components, communication modules, and software elements to enable seamless control of home appliances via voice commands. The design is structured around the Raspberry Pi Pico microcontroller, HC05 Bluetooth module, and a 4-channel relay driver.

3.2. Architecture

The core of the system architecture revolves around the Raspberry Pi Pico microcontroller as the central processing unit. The HC05 Bluetooth module serves as the wireless communication bridge between an Android device and the Raspberry Pi Pico. The 4-channel relay driver facilitates the control of multiple home appliances.

3.2..1 Hardware Components

i. **Raspberry Pi Pico:** The Raspberry Pi Pico serves as the brain of the system, executing the MicroPython code responsible for interpreting voice commands and controlling devices.
ii. **HC05 Bluetooth Module:** The HC05 module establishes a Bluetooth connection with an Android device, enabling wireless communication for sending voice commands to the Raspberry Pi Pico.
iii. **4-Channel Relay Driver:** The relay driver interfaces between the Raspberry Pi Pico and home appliances, allowing for the ON and OFF control of multiple devices simultaneously.

3.3. Component Design

i. **Raspberry Pi Pico:** Raspberry Pi Pico is a low-cost, high-performance microcontroller board with flexible digital interfaces.
   a. **Functionality:** Serves as the central processing unit for the system, executing MicroPython code to interpret and respond to voice commands.

b. **Connections:** Power supplied through VBUS, GND for ground, and individual GPIO pins for relay control.

c. **Programming:** Programmed using MicroPython to establish Bluetooth communication, interpret voice commands, and control connected devices.

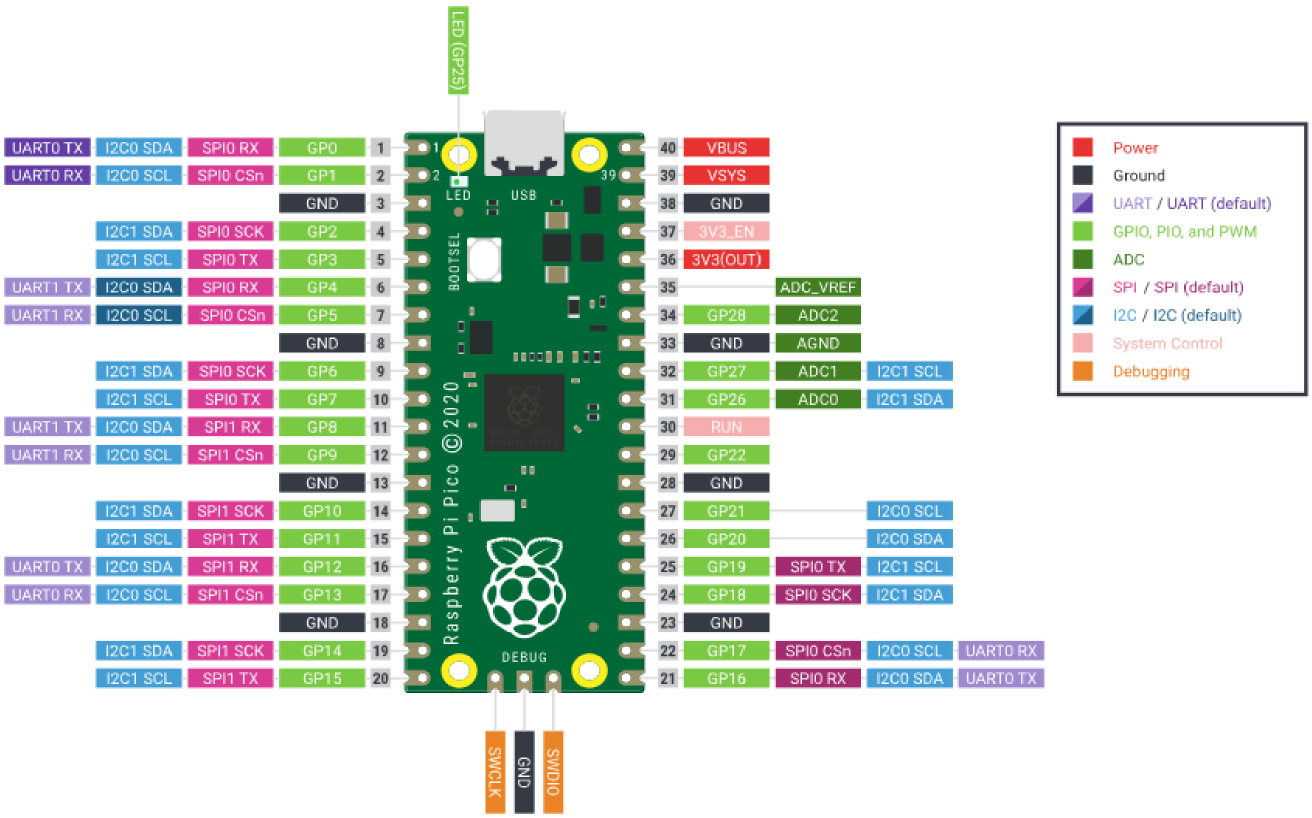

Fig. 3.1 : Raspberry Pi Pico

ii. HC05 Bluetooth Module:

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup.

a. **Functionality:** Facilitates wireless communication between an Android device and the Raspberry Pi Pico, enabling the transmission of voice commands.

b. **Connections:** VCC and GND for power, TX and RX for serial communication with the Raspberry Pi Pico.

c. **Communication Protocol:** Utilizes a serial communication protocol to receive voice commands from the Android application.

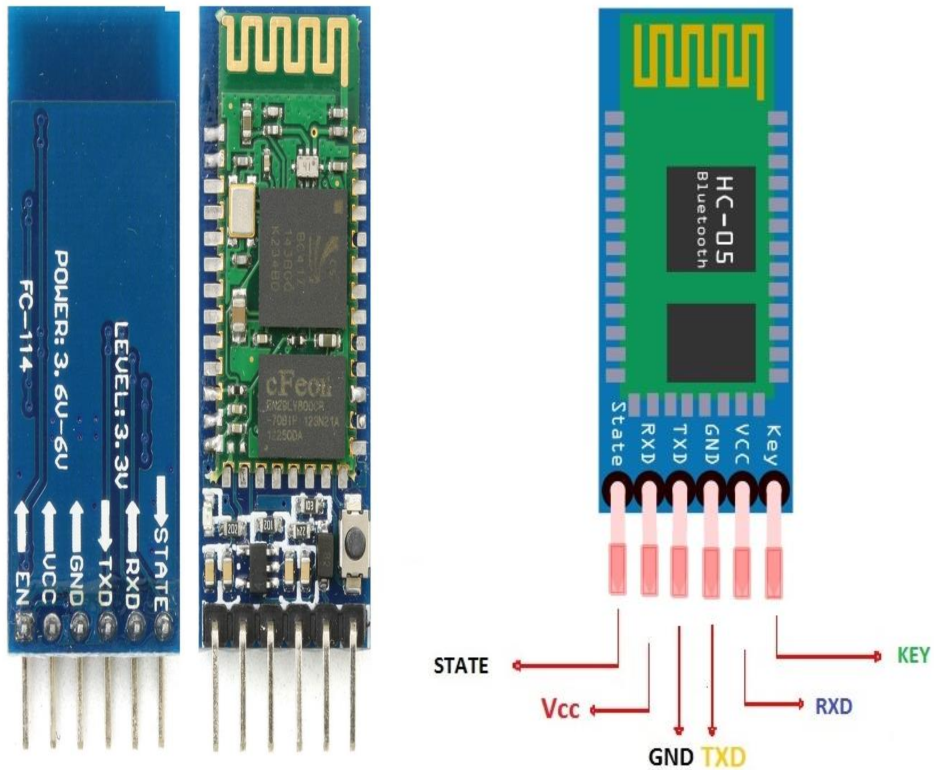

Fig. 3.2 : HC05 Bluetooth Module

iii. **4-Channel Relay Driver:**

The 4 Channel Relay Module is a convenient board which can be used to control high voltage, high current load such as motor, solenoid valves, lamps and AC load. It is designed to interface with microcontroller such as Arduino, PIC and etc.

a. **Functionality:** Controls the ON and OFF states of multiple home appliances simultaneously based on commands received from the Raspberry Pi Pico.

b. **Connections:** Powered through common 5V and GND connections; individual GPIO pins connected to relay inputs (IN1 to IN4).

c. **Device Control:** Interfaces between the Raspberry Pi Pico and home appliances, allowing for efficient control over connected devices.

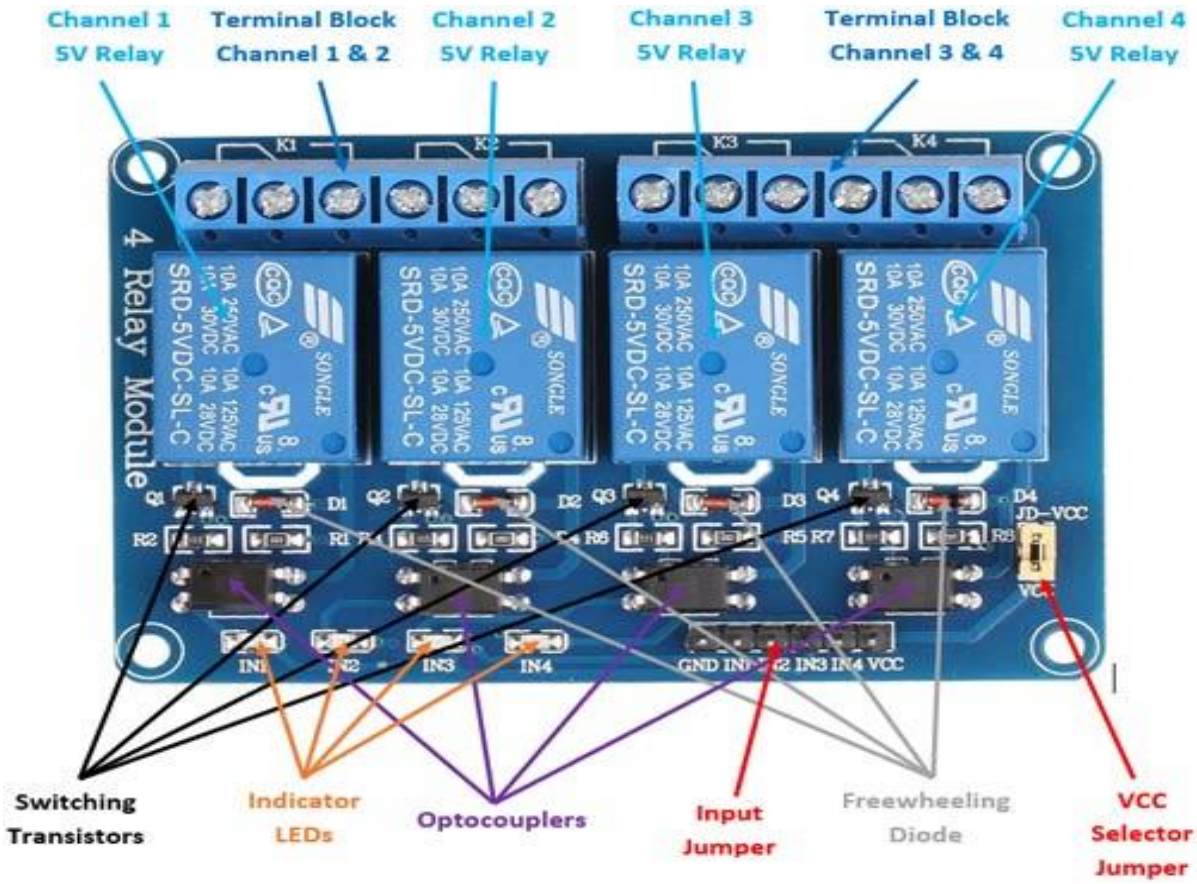

Fig. 3.3 : 4-Channel Relay Driver

3.4. Implementation

The implementation of the Voice Controlled Home Automation project involves the practical realization of the system design, including the setup of hardware components, coding in MicroPython, and integration with the Android application. Here's a step-by-step guide to the implementation:

i. **Hardware Setup :**

   To begin, the hardware setup includes connecting the Raspberry Pi Pico with the HC05 Bluetooth Module as per the provided circuit diagram. This involves powering up the Raspberry Pi Pico using a micro USB cable and establishing the necessary connections to the relay driver, allowing for device control.

ii. **Software Configuration :**

   Moving on to software configuration, the Thonny IDE is installed for MicroPython development. The MicroPython code, named main.py, is then written to enable Bluetooth communication and interpret voice commands for controlling the connected devices. This code is flashed onto the Raspberry Pi Pico using Thonny IDE.

iii. **Android Application Setup :**

The Android application, designed for user interaction, is downloaded and installed on the Android device. The pairing process ensures a Bluetooth connection between the Android device and the HC05 module, facilitating the transmission of voice commands.

iv. **Voice recognition configuration :**

Voice recognition configuration is a crucial step, involving the setup of the Android application to accurately recognize spoken commands. Permissions for microphone access are granted to enhance the voice recognition process.

v. **Circuit Testing :**

Circuit testing follows, where the system's functionality is verified. Powering on the Raspberry Pi Pico and ensuring Bluetooth connectivity precedes the issuance of voice commands through the Android app. The relay driver outputs are monitored to confirm successful ON and OFF states of the connected devices.

vi. **Troubleshooting :**

Troubleshooting is conducted if any issues arise, with the Thonny IDE being a valuable tool for debugging code-related problems. Checking Bluetooth connections and Android app settings helps resolve any connectivity issues.

vii. **Optimization**

Optimization involves fine-tuning voice recognition settings and refining the MicroPython code based on testing outcomes. Documentation is essential for recording the final circuit diagram and adding comments within the MicroPython code for future reference.

Finally, deployment in a real-world setting occurs, accompanied by the collection of user feedback for continuous improvement. This comprehensive implementation process ensures a functional and user-friendly voice-controlled home automation system.

3.5. Design Evolution

The design evolution of the Voice Controlled Home Automation project reflects a dynamic process of refinement and enhancement from conceptualization to implementation. The evolution can be traced through key phases:

i. **Conceptualization:** The project originated from the desire to extend home automation beyond conventional mechanical switches, embracing the era of wireless control and voice commands. The initial concept focused on leveraging the capabilities of Raspberry Pi Pico and HC05 Bluetooth module for a seamless and hands-free home automation experience.

ii. **System Architecture Planning:** In the planning phase, the system architecture was carefully envisioned. The Raspberry Pi Pico was identified as the central processing unit, offering a balance of cost-effectiveness and performance. The HC05 Bluetooth module emerged as the communication bridge, connecting an Android device to the Raspberry Pi Pico. The incorporation of a 4-channel relay driver provided the flexibility to control multiple appliances.

iii. **Hardware Component Selection:** The selection of hardware components played a crucial role in shaping the design. The Raspberry Pi Pico was chosen for its compatibility with MicroPython and suitability for embedded systems. The HC05 Bluetooth module, known for its simplicity and reliability, became the wireless communication medium. A 4-channel relay driver was selected to enable the simultaneous control of multiple devices.

iv. **Circuit Design Iterations:** The circuit design underwent iterative refinements to optimize connections and ensure compatibility between the Raspberry Pi Pico, HC05 module, and the relay driver. Circuit diagrams were revised to enhance clarity and streamline the connection process.

v. **Software Development:** The development of the MicroPython code (main.py) marked a pivotal phase. Initially focused on basic Bluetooth communication, the code evolved to incorporate sophisticated logic for interpreting voice commands. Voice recognition capabilities were integrated into the Android application to enhance user interaction.

vi. **Testing and Debugging:** Rigorous testing and debugging phases were crucial for identifying and resolving issues. Circuit functionality, Bluetooth connectivity, and voice recognition accuracy were meticulously tested. The Thonny IDE proved instrumental in debugging the MicroPython code, ensuring robust performance.

vii. **User Interface Enhancement:** The Android application's user interface underwent enhancements to provide an intuitive platform for issuing voice commands. Voice recognition algorithms were fine-tuned to improve accuracy and responsiveness.

viii. **Documentation and Educational Content:** Comprehensive documentation, including circuit diagrams and code comments, was compiled for future reference. Educational content was developed to facilitate understanding and encourage user engagement.

ix. **Deployment and User Feedback:** The deployment phase marked the transition from development to real-world application. User feedback was actively sought to identify areas for improvement and refinement. This iterative feedback loop contributed to ongoing enhancements.

x. **Optimization and Scalability:** The design evolution continues with ongoing optimization efforts. Fine-tuning voice recognition settings, refining code logic, and exploring scalability options for additional devices are part of the continuous improvement process.

The design evolution of the Voice Controlled Home Automation project represents a journey of innovation, adaptation, and refinement. From conceptualization to real-world deployment, each phase contributed to the project's functionality, user-friendliness, and adaptability to future enhancements.

Chapter 4: Testing, Analysis, and Evaluation

4.1. Testing Criterions

Testing criteria are essential for ensuring the reliability, functionality, and efficiency of a home automation project utilizing the Pico W microcontroller, MIT App Inventor, Bluetooth communication, and voice recognition. Relevance in testing involves scrutinizing individual features such as Bluetooth connectivity, app compatibility, and customizable voice commands to ensure alignment with project requirements.

4.1.1. Relevance

i. **Feature Testing:** Assess each individual feature's functionality to ensure it aligns with the project requirements. For instance, test the Bluetooth communication for connection stability and data transmission accuracy.

ii. **Compatibility Testing:** Verify compatibility with a variety of Android devices to ensure that the MIT App Inventor interface functions seamlessly across different screen sizes and resolutions.

iii. **Customization Testing:** Evaluate the ability to customize voice commands within the system to accommodate diverse user preferences and needs.

4.1.2. Effectiveness

i. **Unit Testing:** Conduct unit tests on individual components, such as the Pico W microcontroller, Bluetooth module, and voice recognition system, to verify their correct operation in isolation.

ii. **Integration Testing:** Verify the seamless integration of hardware and software components to ensure they work together cohesively. This includes testing the interaction between the Pico W and the MIT App Inventor interface.

iii. **Usability Testing:** Engage potential end-users in usability testing sessions to evaluate the system's overall user-friendliness and identify any aspects requiring improvement.

4.1.3. Efficiency

i. **Performance Testing:** Evaluate the system's performance under different conditions, such as varying loads and data transmission rates, to ensure it operates efficiently even during peak usage.

ii. **Resource Utilization Testing:** Monitor the utilization of resources like CPU, memory, and battery life to identify and optimize any resource-intensive processes.

iii. **Testing Response Time:** Measure the response time for voice commands and device actions to ensure that the system operates with minimal latency, providing a smooth and responsive user experience.

By incorporating these detailed testing criteria, the project team can thoroughly assess the system's functionality, integration, and performance. Conducting a diverse range of tests ensures that the home automation project not only meets its technical specifications but also delivers a reliable, user-friendly, and efficient solution.

Effectiveness is achieved through rigorous unit and integration testing, assessing the correct operation of individual components and their seamless collaboration. Usability testing engages end-users to evaluate the system's user-friendliness. The efficiency criterion involves performance testing under varying conditions, resource utilization monitoring, and response time measurements, ensuring optimal functionality and a smooth user experience. This comprehensive approach to testing guarantees that the home automation system not only meets technical specifications but also delivers a robust and user-friendly solution.

Chapter 5: Socio-Economic Issues associated with the Project

5.1. Detailed Cost Analysis

The project involves a comprehensive cost analysis to assess the financial implications associated with hardware components, software development tools, and other resources. This includes expenses related to microcontrollers, Bluetooth modules, MIT App Inventor, and any additional peripherals.

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5.1.2. Bill of Materials

A detailed Bill of Materials (BOM) is compiled, outlining all the components, their quantities, and individual costs. This document provides transparency in budgeting, procurement, and serves as a reference for future modifications or upgrades.

S. No.	**Description**	**Qty**	**Rate**	**Amout**
1.	0.5 W LED Bulb	3	25.00	75.00
2.	Bulb Holder	3	10.00	30.00
3.	5 V 4-Channel Relay	1	180.00	180.00
4.	HC05 Bluetooth Module	1	260.00	260.00
5.	Flexible wire	3	7.00	21.00
6.	Jumper wires (M-M, M-F)	20	2.00	40.00
7.	Breadboard	1	75.00	75.00
8.	Sun Board	4	35.00	140.00
9.	Raspberry Pi Pico	1	565.00	565.00
10.	5 V Adapter	1	120.00	120.00

Table 5.1 : Bill of Materials

The total bill came to be around Rs. 1600.00

5.2. Safety issues

Safety considerations are paramount, particularly when implementing home automation systems. Potential electrical hazards, fire risks, or malfunctioning devices must be thoroughly evaluated and mitigated. Adherence to safety standards ensures the protection of users, their homes, and the surrounding environment.

i. **Electrical Safety:** The implementation of electrical components in the project necessitates strict adherence to electrical safety standards. Ensuring proper insulation of wires, using insulated components, and enclosing high-voltage AC lines contribute to mitigating the risk of electrical shocks.

ii. **Device Overload:** Preventing the overload of the relay driver is crucial for system safety. Clearly defining the maximum load capacity of the relay driver and educating users to avoid exceeding this limit helps prevent overheating and potential damage to the devices.

iii. **Voice Recognition Limitations:** Acknowledging the limitations of voice recognition systems is essential for user understanding. Proper user education about the system's capabilities and potential misinterpretations helps manage expectations and encourages cautious use.

iv. **Bluetooth Security:** Given the wireless nature of Bluetooth connections, securing the communication channel is imperative. Implementing secure pairing mechanisms and regular updates to passwords and encryption protocols enhances the overall security of the system against unauthorized access.

v. **Privacy Concerns:** Privacy considerations arise with the processing of voice data. Clearly communicating the system's privacy policy, ensuring secure handling of voice data, and obtaining user consent for data storage contribute to addressing privacy concerns.

vi. **User Interface Clarity:** Ambiguity in the user interface can lead to unintentional device control. Designing a clear and intuitive interface, along with incorporating confirmation prompts for critical actions, helps prevent accidental commands and enhances overall usability.

vii. **Circuit Protection:** To safeguard against malfunctions and short circuits, incorporating fuses or circuit breakers for overcurrent protection is essential. Regular inspections and maintenance of the circuitry contribute to early detection and resolution of potential issues.

viii. **System Reliability:** Ensuring the reliability of the system is paramount to prevent unexpected device states. Thorough testing, debugging, and the implementation of error-handling mechanisms contribute to a more dependable system. Regular updates further enhance system reliability.

ix. **Accessibility for Users with Disabilities:** Inclusivity is a key consideration, especially for users with disabilities. Designing the system to be accessible through alternative control methods and providing clear instructions tailored to users with varying abilities contribute to a more inclusive user experience.

x. **Educational Material:** Providing comprehensive educational materials, including user guides and safety instructions, is crucial. Clear documentation ensures users are informed about proper system usage, safety precautions, and potential risks, contributing to responsible and secure utilization.

5.3. Global Impact

The project's global impact is assessed in terms of its ecological footprint, considering the energy efficiency of the devices and their environmental impact. Additionally, the project's scalability and potential widespread adoption contribute to its global implications in terms of technological advancements and sustainable practices.

i. **Energy Efficiency:** The project can positively impact global energy efficiency by providing users with a convenient means to control and monitor home appliances. Through voice commands and remote access, users can efficiently manage the usage of electrical devices, reducing unnecessary power consumption and contributing to overall energy conservation.

ii. **Environmental Sustainability:** Enabling users to control appliances remotely can lead to a reduction in standby power consumption. This not only contributes to energy savings but also aligns with global efforts towards environmental sustainability. By promoting responsible energy usage, the project indirectly supports initiatives addressing climate change and reducing carbon footprints.

iii. **Accessible Home Automation:** The use of voice commands in home automation enhances accessibility for individuals with disabilities. Voice-controlled systems provide an inclusive solution, allowing people with mobility challenges or visual impairments to interact with and control their home environment independently. This inclusivity aligns with global efforts to promote accessibility and equal opportunities for all.

iv. **Digital Divide Reduction:** The affordability of components used in the project makes home automation technology more accessible to a broader audience. This can contribute to reducing the digital divide by making smart home solutions available to a wider demographic, including individuals in economically diverse regions. Bridging this gap aligns with global goals of promoting digital inclusivity.

v. **Inspiration for Educational Initiatives:** The educational content associated with the project, including documentation and tutorials, can serve as inspiration for educational initiatives worldwide. By providing resources for learning about embedded systems, programming, and home automation, the project contributes to the global educational landscape and encourages the pursuit of STEM (Science, Technology, Engineering, and Mathematics) disciplines.

5.4. Lifelong Learning

The development of the Home Automation Project Report not only serves as a documentation process but embodies the principles of lifelong learning, encouraging a continuous journey of personal and professional growth for the project team. Here's how the ethos of lifelong learning can be seamlessly integrated into the report development for the Voice Controlled Home Automation using Raspberry Pi Pico and HC05 Bluetooth Module:

i. **Research and Exploration:** Emphasize the importance of thorough research in understanding the latest trends in home automation, Bluetooth technology, and voice recognition systems. Encourage team members to explore diverse sources, stay updated with advancements, and incorporate relevant findings into the report.

ii. **Adaptation to Feedback:** Position feedback as a tool for continuous improvement. Team members should be encouraged to view feedback not just as a formality but as an opportunity to refine their understanding of the project, enhance their technical skills, and improve the overall quality of the report.

iii. **Skill Development Through Documentation:** Recognize the act of documenting the project as a skill development opportunity. Team members should approach the report writing process as a chance to enhance their technical writing skills, communicate complex ideas effectively, and present information in a clear and concise manner.

iv. **Incorporating New Perspectives:** Advocate for the integration of diverse perspectives into the report. Encourage team members to consider alternative approaches, explore different solutions, and include insights from various team members. Highlight the value that diverse perspectives bring to the project and the learning experience.

v. **Technology Integration:** Promote the use of cutting-edge technologies in presenting the project report. Encourage team members to explore innovative ways to showcase data, leverage visualization tools, or incorporate multimedia elements. This not only enhances the report's quality but also exposes the team to emerging technologies.

vi. **Reflection on Project Challenges:** Allocate space in the report for a reflective analysis of the challenges encountered during the project. This section should go beyond problem-solving and delve into the lessons learned, providing team members with an opportunity to reflect on their individual and collective growth throughout the project.

vii. **Encouraging Continuous Learning Culture:** Instill a culture of continuous learning within the team. Discuss the broader implications of the project, prompt team members to consider how the knowledge gained can be applied in future projects or extended to other domains. Emphasize that the project report is a snapshot in an ongoing journey of learning and development.

viii. **Professional Development Opportunities:** Connect the project report development with opportunities for professional development. Encourage team members to attend relevant workshops, webinars, or conferences related to home automation, voice recognition, or IoT technologies. This proactive approach aligns the project with the broader landscape of advancements in the field.

By infusing the principles of lifelong learning into the Home Automation Project Report, the document transforms into more than just a record of accomplishments; it becomes a testament to the team's commitment to growth, adaptability, and the pursuit of knowledge in the dynamic field of home automation.

Chapter 6: Engineering Tools and Standards used in the Project

6.1. Engineering Tools

The following are the engineering tools used for making of this project.

6.1.1 Programming Environment

i. Thonny is an integrated development environment (IDE) for the Python programming language. It was used in this project to write, edit, and run the MicroPython code on the Raspberry Pi Pico. Thonny provides a user-friendly interface, facilitating efficient code development for embedded systems.
ii. Version control systems, such as Git, are implemented for collaborative development and effective code management.

6.1.2. MicroPython

MicroPython, a light version of Python designed for microcontrollers, served as the programming language for the Raspberry Pi Pico. It allows for effective code execution on low-memory devices, making it suitable for the project's requirements.

6.1.3. HC05 Bluetooth Module

The HC05 Bluetooth module adheres to the Bluetooth 2.0 standard and was chosen for its reliability in wireless communic ation between the Android device and the Raspberry Pi Pico. It operates within a range of 8-10 meters and supports data transfer rates of up to 2.1 Mbps.

6.1.4. Raspberry Pi Pico

The Raspberry Pi Pico is a microcontroller board based on the RP2040 chip. It served as the central processing unit for the project, executing the MicroPython code and controlling the relay driver based on received Bluetooth commands.

6.1.5. 4-Channel Relay Driver

The 4-channel relay driver is designed based on standard relay principles. It allows the Raspberry Pi Pico to control multiple devices simultaneously. The relay driver adheres to standard switching principles, enabling the ON/OFF control of connected devices.

6.1.6. AC Bulb Holder and Bulb:

Standard AC bulb holders and bulbs were used in the project to demonstrate the ON/OFF control of household appliances. These components adhere to electrical safety standards and are commonly used in home automation projects.

6.1.7. Connecting Wires and Breadboard:

High-quality connecting wires and a standard breadboard were employed for circuit connections. The connecting wires adhere to electrical standards, ensuring safe and reliable connectivity, while the breadboard facilitates prototyping without soldering.

6.1.8. 5 V AC to DC Adapter:

A standard AC to DC adapter was utilized to power the Raspberry Pi Pico. This adapter adheres to power supply standards and provides a common and reliable power source.

6.2. Engineering Standards

The following are the engineering standards used for making of this project.

6.2.1. Python Coding Standards:

The project followed coding standards for the Python programming language, ensuring readable and maintainable code. Adhering to coding standards enhances collaboration, code review processes, and the long-term sustainability of the software.

6.2.2. Bluetooth Communication Protocols:

The project leverages Bluetooth communication protocols, specifically Serial Port Profile (SPP), to establish a reliable and secure connection between the Android device and the HC05 Bluetooth module. Standard Bluetooth protocols ensure compatibility and interoperability between devices.

6.2.3. Documentation Standards:

Comprehensive documentation standards were maintained throughout the project, including clear circuit diagrams, code comments, and a well-structured project report. Documentation adheres to best practices, facilitating knowledge transfer and future development.

By incorporating these engineering tools and adhering to established standards, the Voice Controlled Home Automation project ensures robustness, compatibility, and maintainability in both software and hardware components. These tools and standards contribute to the overall success of the project and align with industry best practices in the field of embedded systems and home automation.

Chapter 7: Problems, faults, bugs, challenges

7.1. Problems

Interference issues and power consumption challenges are anticipated problems in the home automation project. Potential sources of interference, such as other wireless devices, require thorough identification and mitigation strategies. Additionally, managing power consumption through energy-efficient programming practices and effective battery monitoring is crucial to ensure sustained and reliable system

7.1.1. Interface Issues

i. **Potential Sources:** Identify potential sources of interference, such as other wireless devices or electronic signals, and implement shielding or frequency management to mitigate disruptions.
ii. **Testing and Validation:** Conduct extensive testing in environments with various interference sources to ensure robust Bluetooth communication.

7.1.2. Power Consumption:

i. **Energy Optimization:** Explore energy-efficient programming techniques and hardware power management to address potential power consumption challenges.
ii. **Battery Monitoring:** Implement battery monitoring mechanisms to alert users and optimize power usage based on the device's state.

7.2. Faults

Hardware failures and software glitches are potential faults that can impact the system's performance. Strategies to address hardware faults include redundancy planning and diagnostic features for identifying and managing issues. Software glitches can be mitigated through enhanced error-handling mechanisms and regular updates, ensuring a resilient and stable operation.

7.2.1. Hardware Failures:

i. **Redundancy Planning:** Develop contingency plans for critical hardware components, incorporating redundancy where possible to mitigate the impact of failures.
ii. **Diagnostic Features:** Implement diagnostic features that can identify and report hardware faults to facilitate troubleshooting.

7.2.2. Software Glitches:

i. **Error Handling:** Enhance error-handling mechanisms within the codebase to gracefully handle unexpected situations and prevent system-wide crashes.
ii. **Regular Updates:** Plan for regular software updates to address bugs and glitches, ensuring the system remains resilient to evolving issues.

7.3. Bugs

Data transmission bugs and voice recognition errors represent challenges in maintaining the system's accuracy. Implementing error-checking algorithms and data integrity checks addresses transmission bugs, enhancing reliability. For voice recognition, continuous testing, user feedback mechanisms, and regular updates are crucial to refining the system's interpretation of commands and minimizing errors.

7.3.1. Data Transmission Bugs:

i. **Error Correction:** Implement error-checking and correction algorithms to address data transmission bugs, ensuring accurate and reliable communication.
ii. **Data Integrity Checks:** Introduce mechanisms to verify the integrity of transmitted data and retransmit in case of errors.

7.3.2.Voice Recognition Errors:

i. **User Feedback Mechanisms:** Integrate user feedback mechanisms to improve the voice recognition system over time, learning from user corrections.

ii. **Continuous Testing:** Regularly update and test the voice recognition algorithms to adapt to diverse speech patterns and accents.

7.4. Challenges

Cross-device compatibility, real-time responsiveness, and security concerns present overarching challenges. Adaptive UI design and extensive user testing address compatibility challenges. Techniques like code profiling and optimization strategies are employed for achieving real-time responsiveness.

7.4.1. Cross-Device Compatibility:

i. Adaptive UI Design: Implement adaptive user interface design principles to accommodate various Android devices, ensuring a consistent and user-friendly experience.
ii. User Testing: Conduct extensive user testing with a diverse group of individuals using different devices to identify and address compatibility challenges.

7.4.2. Real-time Responsiveness:

i. Optimization Techniques: Employ optimization techniques, including code profiling and parallel processing, to enhance the real-time responsiveness of voice commands and device actions.
ii. User Expectation Management: Set realistic user expectations regarding the response time, considering factors like network latency and device processing capabilities.

7.4.3. Security Concerns:

i. Encryption and Authentication: Implement robust encryption and authentication mechanisms to secure communication channels and prevent unauthorized access.
ii. Regular Security Audits: Conduct regular security audits to identify and rectify potential vulnerabilities, staying proactive against emerging threats.

Chapter 8: Teamwork

8.1. Summary of team work

8.1.1 Attributes

1	Attends group meetings regularly and arrives on time.
2	Contributes meaningfully to group discussions.
3	Completes group assignments on time.
4	Prepares work in a quality manner.
5	Demonstrates a cooperative and supportive attitude.
6	Contributes significantly to the success of the project.

8.1.2 Score

1=strongly disagree; **2**=disagree; **3**=agree; **4**=strongly agree

Student 1: ______Siddhant Vatsyayan____________

Student 2: ______Syed Eebad Reza______________

	Evaluated by	
Student 1	Attributes	Student 2
	1	4
	2	4
	3	4
	4	4
	5	4
	6	4
	Grand Total	24

	Evaluated by	
Student 2	Attributes	Student 1
	1	4
	2	4
	3	4
	4	4
	5	4
	6	4
	Grand Total	24

Signature of Student 1

Signature of Student 2

Chapter 9: Conclusion

In the culmination of the Voice Controlled Home Automation project using Raspberry Pi Pico and HC05 Bluetooth Module, a transformative blend of cutting-edge technology, engineering ingenuity, and user-centric design has been achieved. This innovative endeavor aimed to elevate the conventional home automation experience by integrating voice commands, wireless communication, and the Internet of Things (IoT) principles.

The project successfully addressed the paradigm shift from traditional mechanical switches to a dynamic, mobile application-driven interface. By implementing the MicroPython code on the Raspberry Pi Pico, coupled with the versatile HC05 Bluetooth module, the system provided users with a seamless and wireless means to control household appliances using intuitive voice commands.

The adoption of engineering tools such as Thonny IDE, MicroPython, MIT App Inventor, and Bluetooth communication protocols demonstrated a commitment to industry-standard practices. The utilization of the Raspberry Pi Pico, 4-Channel Relay Driver, and standard electrical components ensured a reliable and efficient home automation system.

Throughout the project, the team embraced the ethos of lifelong learning, considering each phase as an opportunity for growth and skill development. From the initial research and exploration to the adaptation to feedback and the reflection on challenges faced, the project served as a dynamic learning platform. The integration of diverse perspectives, the incorporation of new technologies, and a commitment to continuous improvement underscored the team's dedication to excellence.

The global impact of the project extends beyond the confines of individual homes. The system's contribution to energy efficiency, accessibility, and technological innovation aligns with global trends toward sustainable and inclusive technologies. By fostering a culture of curiosity, adaptability, and collaboration, the project not only fulfilled its immediate objectives but also contributed to the broader landscape of smart home technologies.

As the project concludes, the team envisions this endeavor as a stepping stone in the ever-evolving field of home automation. The lessons learned, challenges overcome, and the fusion of engineering tools and standards collectively form a foundation for future innovation. The Voice Controlled Home Automation project stands as a testament to the possibilities unleashed when technology converges with human-centric design, and lifelong learning becomes an integral part of the engineering journey.

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[5] Nainsi Soni, Manish Dubey,"A review on home automation system with speech recongition and machine learning."in IJARCSMS, vol.5, Issue 4.April 2017

Appendix

Appendix A: Diagram

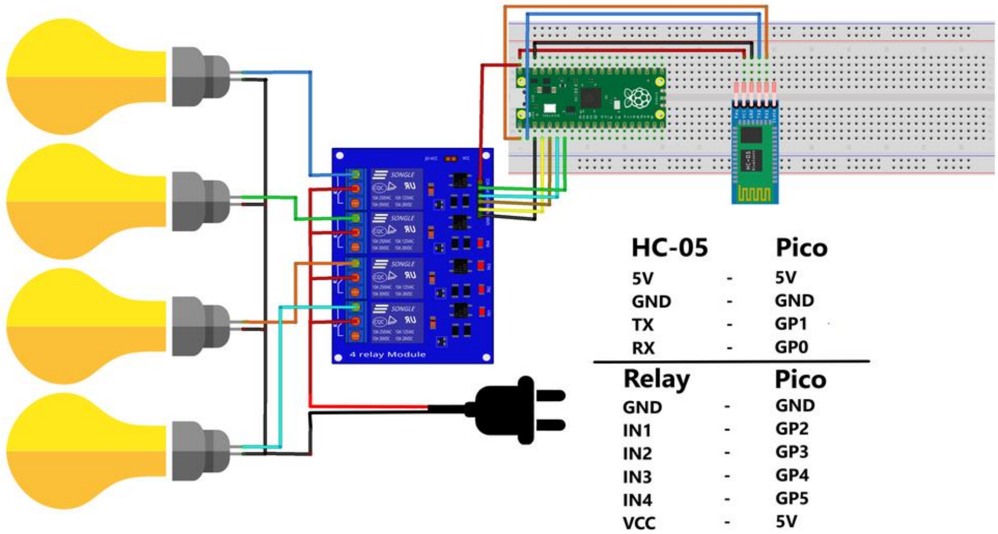

Fig 1: Circuit Diagram

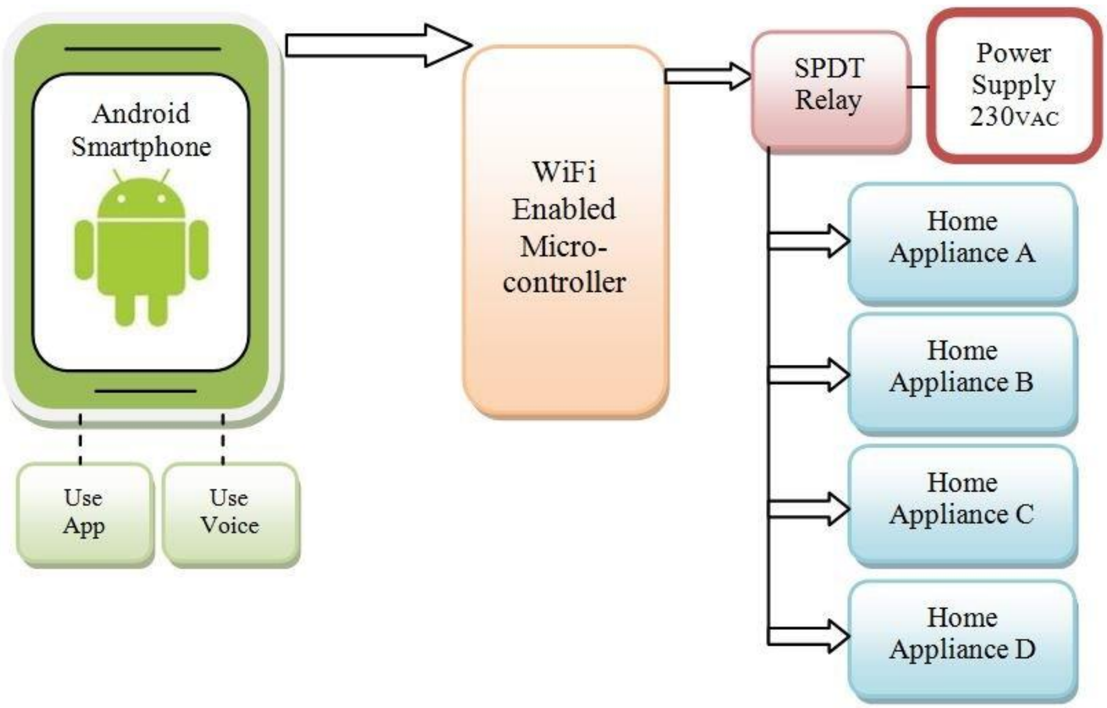

Fig 2: Block Diagram

Appendix B: Hardware Implementation

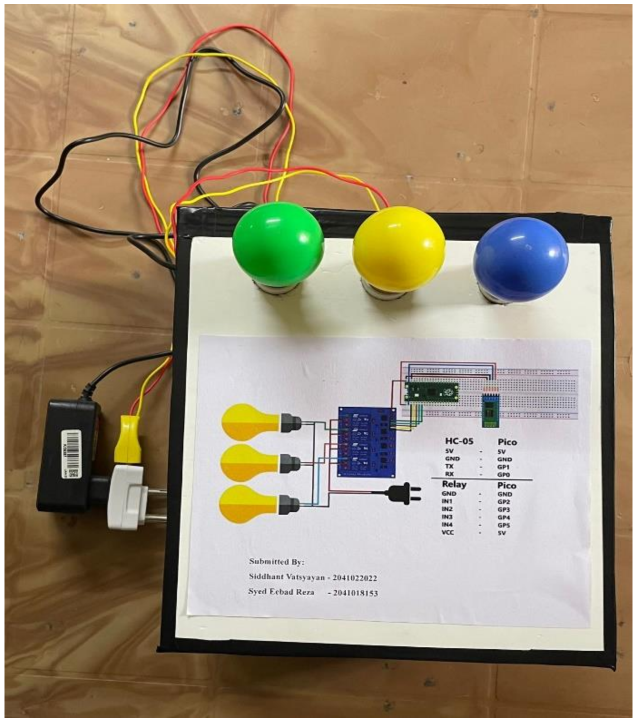

Fig 5 : Main interface of the Android application.

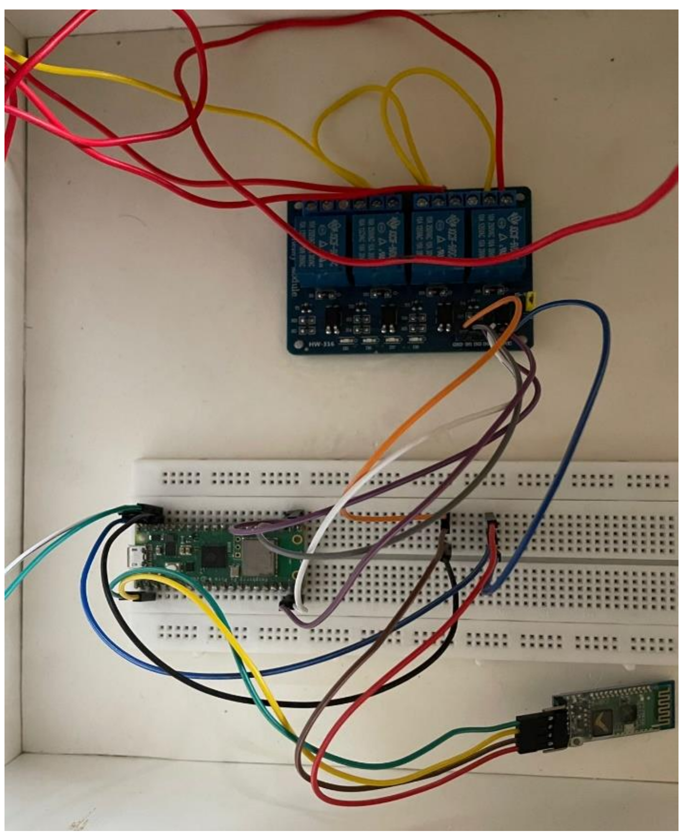

Fig 5 : Main interface of the Android application.

Appendix C: Android Application Screenshot

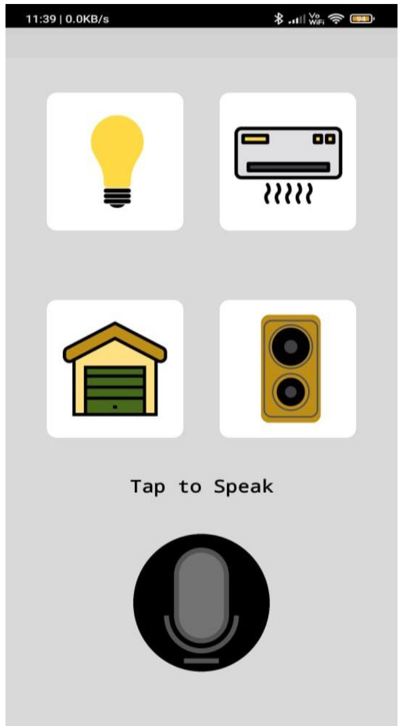

Fig 5 : Main interface of the Android application.

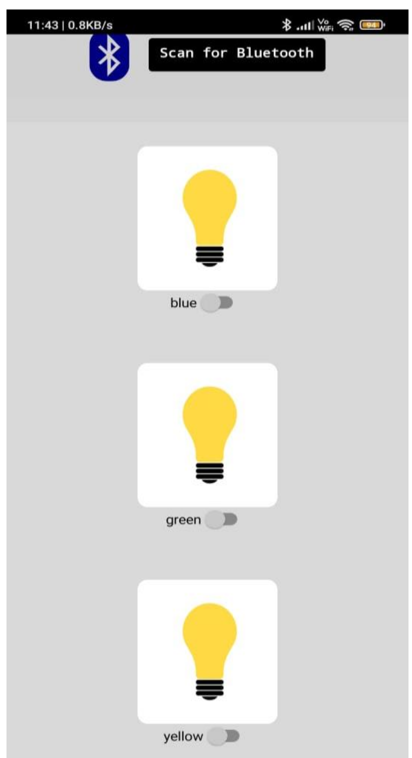

Fig 6 : Voice command input screen in the Android application.

Appendix D: Micropython Code

```
from machine import Pin,UART
    uart = UART(0,9600)

    led1 = Pin(14, Pin.OUT)
    led2 = Pin(15, Pin.OUT)
    led3 = Pin(16, Pin.OUT)

    while True:

        if uart.any(): #Checking if data available
            data=uart.read() #Getting data
            data=str(data) #Converting bytes to str type
            print(data)

            if ('red on' in data):
                led1.value(1)
            elif ('red off' in data):
                led1.value(0)
            elif ('yellow on' in data):
                led2.value(1)
            elif ('yellow off' in data):
                led2.value(0)
            elif ('green on' in data):
                led3.value(1)
            elif ('green off' in data):
                led3.value(0)
```

Appendix E: PicoNest App Code Block

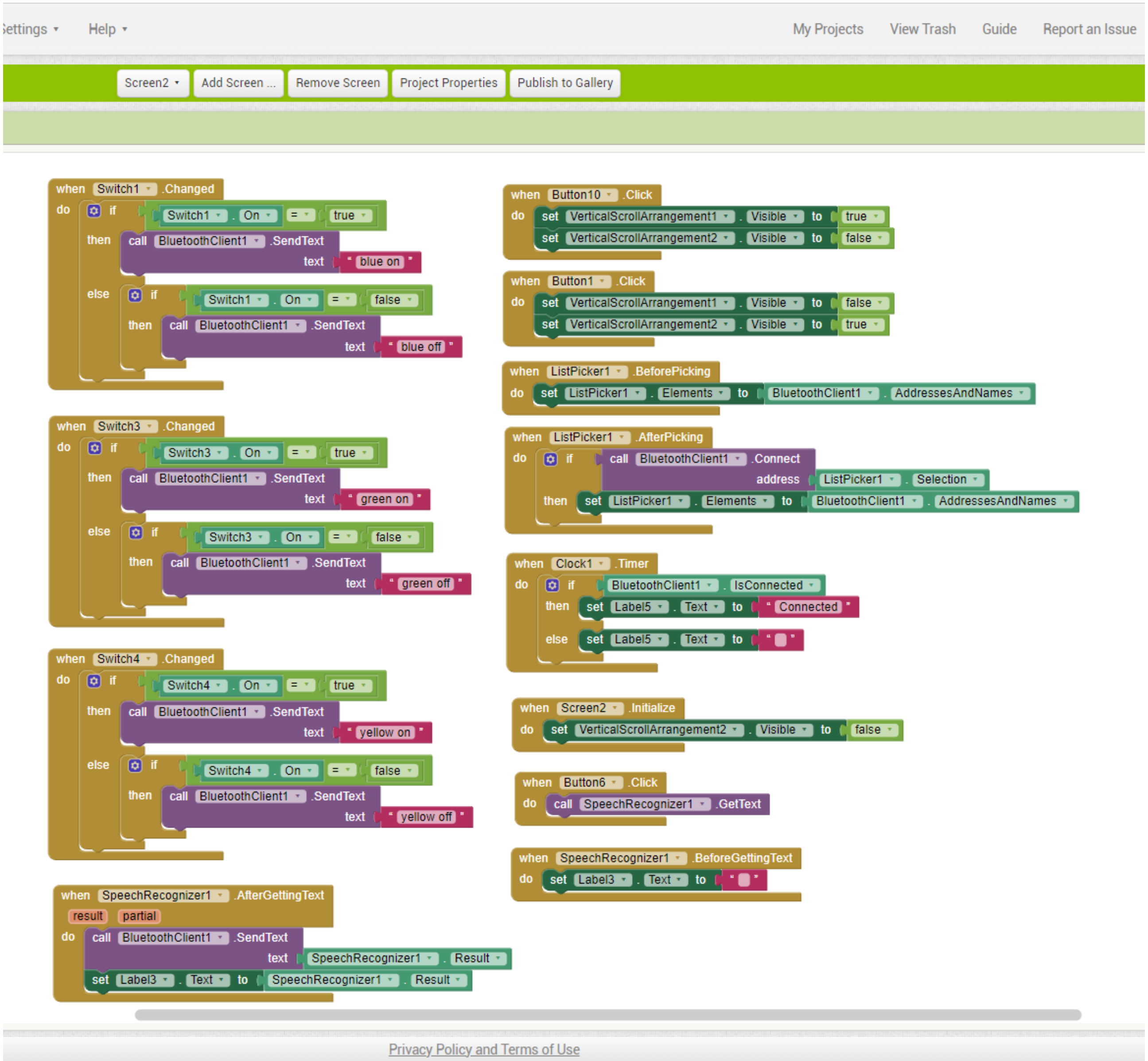

Fig 7 : MIT App Inventor code block for android application