***DOI:** 10.5281/zenodo.17795962*

Title

SMART HOME AUTOMATION SYSTEM USING IOT – AFRIRESEARCH

Author

WILLIAM CHAGOMA NGWIRA

Co-Author

MS. FANNY CHATOLA

Issue September 2025

Certificate AR2025FKASNH

ABSTRACT

The proposed Smart Home Automation System integrates IoT to bring intelligence and convenience into the home environment. Leveraging IoT technology, the system integrates various smart devices and sensors to automate household tasks such as lighting control, fan control, and voice speech recognition. The system allows users to remotely control and monitor their home appliances and security systems via a smartphone, offering real-time feedback and control. At the heart of the system is a central microcontroller (Raspberry Pi), which connects to the cloud and communicates with different smart devices using protocols like Wi-Fi or Bluetooth. The system gathers environmental data using sensors (e.g., temperature, light, motion) and triggers specific actions based on predefined user settings or real-time conditions. In addition to automating routine tasks, the system can enhance home security through integrated motion detectors, smart locks, and cameras. It can notify homeowners of potential security breaches and allow for remote monitoring of live video feeds. Energy efficiency is also a critical feature, as the system optimizes electricity usage by regulating lights, heating, and cooling based on occupancy or schedule, which helps reduce electricity costs and environmental impact. This project demonstrates the feasibility of creating a smart home using IoT technologies and highlights the potential for scalability as more devices are integrated into the system. Through the application of IoT, this system not only improves comfort and convenience but also addresses growing concerns about energy efficiency and home security.

KEYWORDS: Internet of Things, Smart Home Automation, Raspberry Pi, Flutter, MQTT, Speech Recognition

INTRODUCTION

Background of Study

The increasing advancement in digital technology, particularly the emergence of the Internet of Things (IoT), has drastically transformed how we interact with our environment. IoT refers to the network of physical devices embedded with sensors, software, and connectivity capabilities, enabling these devices to collect and exchange data. One of the major applications of IoT is in smart home automation, where various household appliances and systems are automated for better control, energy efficiency, and user convenience. This project focuses on implementing a Smart Lighting System using a Raspberry Pi as the control hub, a Flutter-built mobile application as the user interface, and MQTT as the communication protocol. This seamless integration of hardware and software allows users to remotely switch on or off a light bulb through a mobile app, providing a practical and real-world example of IoT. The aim of this documentation is to provide a detailed explanation of the development process, system architecture, and functionalities of this IoT-based Smart Lighting System. The Raspberry Pi, acting as the main controller, interfaces with a relay switch to control the bulb. The Flutter mobile app, in turn, sends MQTT messages to the Pi for execution. With its simple yet scalable design, this system is an ideal foundation for further enhancements in smart home automation.

Objectives

The primary goal of this research is to develop and evaluate a Smart Home Automation System capable of accurately recognizing and converting user commands into device actions using IoT techniques. The study is guided by the following specific objectives:

1. To implement an IoT solution that can be used for real-world smart home automation tasks: This objective is to practically implement an Internet of Things (IoT) solution that addresses real-world smart home automation needs. This involves designing and deploying a functional system that allows users to remotely monitor and control home appliances such as lights, fans, and other electrical devices through connected technology. The aim is to demonstrate how IoT can enhance convenience, energy efficiency, and security in everyday living.
2. To enhance accessibility and user interaction through voice and remote technology: This objective focuses on usability and inclusiveness. The project aims to build a platform that enables people, especially those with limited literacy or technological skills, to interact easily with digital devices through speech or remote access. Instead of typing or reading complex interfaces, users can speak naturally or control remotely, and the system will respond or execute the action. This improves access to information and services, especially in rural or underserved communities. It also benefits individuals with disabilities, such as those with visual impairments or motor difficulties, by offering a more natural and convenient way of communication through voice or app interaction.
3. To design an efficient and adaptable IoT model for real-time device control: The goal is to build a robust IoT model that performs device control quickly and accurately, even in noisy network environments or when users issue varying commands. The model should also be adaptable, meaning it can be extended to recognize additional devices or new features as more hardware

becomes available. Real-time processing capability is essential to ensure smooth and instant response during live interactions, educational sessions, or digital communication. Ultimately, this will make the system reliable, efficient, and scalable for broader applications across regions and devices.

LITERATURE REVIEW

A literature review serves as a critical analysis of existing scholarly works relevant to a particular topic or research question. It provides a comprehensive overview of the current state of knowledge, identifies gaps, and synthesizes key findings to inform further research. By examining and synthesizing existing literature, researchers gain insights, contextualize their own work, and contribute to the advancement of knowledge in the field.

Overview of Research Studies

In recent years, various studies have focused on IoT-based smart home automation. For example, *Gomes et al. (2015)* explored FPGA-based edge devices for IoT environments, emphasizing adaptability in ambient assisted living. *Jeya Padmini and Kashwan (2015)* highlighted effective power utilization and conservation in smart homes using IoT. *Jinsoo Han et al. (2014)* presented a smart home energy management system including renewable energy based on *ZigBee and PLC. Shiu Kumar (2014)* discussed ubiquitous smart home systems using Android applications. Additional works, such as those by *José G. de Matos et al. (2015)* on power control in AC isolated *microgrids, and Mohanty et al. (2015)* on implementing Web of Things for renewable energy monitoring, underscore the potential for improving automated control in underrepresented setups.

METHODOLOGY AND TOOLS

This study employed an Agile methodology, which emphasizes the creation, testing, and refinement of innovative technological artifacts to solve real-world problems. In this context, the key challenge addressed is the limited availability of smart home systems capable of recognizing user commands, especially within low-resource settings like Malawi.

The Agile framework was suitable as it integrates both scientific rigor and practical innovation, enabling a structured yet adaptable process for designing and evaluating an IoT-based smart home automation application. The methodology followed major phases: planning, design, development, testing, and deployment.

Each phase was guided by the Agile methodology, which supports iterative development, rapid prototyping, user feedback, and continuous system improvement. Agile

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divides the development cycle into short, manageable sprints, ensuring that user input and real-world testing inform every iteration of the system.

System Design Phase

The design phase began with the identification of both functional and non-functional requirements. Data collection involved literature review to understand IoT diversity, device variations, and user expectations.

The system's architecture was then conceptualized, focusing on modularity, scalability, and adaptability to multiple devices. The design process emphasized:

- A user interface module to capture and preprocess input;
- An IoT-based recognition engine for command-specific control and messaging; and
- A device control interface for real-time execution output.

The design also included structures for storing user data, commands, and execution results. Furthermore, experts were engaged to help identify command variations and devices commonly used in target setups. This ensured practical and technical relevance of the system.

System Development Phase

The development phase involved implementing the designed architecture into a functional prototype. Development was conducted in Agile sprints, where each sprint targeted specific components such as input preprocessing, command modeling, IoT message generation, and graphical user interface (GUI) creation.

Key tools used in this phase included Python, Flutter, and MQTT for model training and device recognition, while Eclipse Mosquitto was used for messaging management. The command-to-action pipeline integrated pre-trained models fine-tuned using locally collected samples.

Each sprint ended with functional testing, where developers validated the accuracy of recognition and execution output. Feedback from users was incorporated before moving to the next sprint, promoting an iterative and user-centered design process.

System Evaluation Phase

In the evaluation phase, the prototype system was tested in a controlled environment involving participants familiar with IoT devices. A pilot test was conducted, where participants issued various commands, and executions were analyzed for accuracy, latency, and reliability.

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Evaluation metrics included:

- Command Error Rate (CER) for recognition accuracy;
- Response Time for real-time processing; and
- User Satisfaction Scores through post-test surveys.

The system achieved high accuracy with stable performance in real-time operation. Ethical considerations such as informed consent, data anonymization, and participant privacy were strictly maintained throughout the testing process.

Justification for Agile Methodology

The Agile methodology was adopted due to its adaptability, focus on user collaboration, and iterative improvement cycle. Unlike traditional waterfall models, Agile allowed developers to respond rapidly to challenges, such as differences in command pronunciation or device clarity.

Frequent feedback from users, experts, and technical evaluators ensured that modifications were implemented promptly without disrupting the entire workflow. This approach minimized development risks, improved system usability, and enhanced stakeholder engagement—all of which are critical for a technology-sensitive system that evolves with user interaction and device diversity.

Development Tools

The implementation of Smart Home Automation System required a combination of programming languages, frameworks, and cloud-based tools to enable robust backend processing, secure data handling.

System Architecture

The development of the Smart Home Automation System relied on a combination of backend, frontend, and auxiliary tools to ensure efficiency, accuracy, and scalability. The backend tools used were Python and MQTT, which handled the system's server-side logic, user authentication, and secure data management. Eclipse Mosquitto facilitated dynamic messaging operations, while Raspberry Pi OS provided a reliable environment for storing command data, user details, and execution results. The frontend tools included Flutter, which was used to design a responsive and user-friendly interface, enabling users to issue commands or use voice and view executed actions seamlessly across multiple devices. For scripting and model development, Python served as the core programming language, supporting preprocessing, model training, and feature extraction using libraries such as paho-mqtt and

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RPi.GPIO. In addition, tools like jumper wires and breadboard were utilized for hardware prototyping, including relay control and normalization. Together, these tools created a robust and integrated technological foundation that ensured the system's ability to accurately control devices while maintaining efficiency, data security, and user accessibility.

Data Collection and Preprocessing Data Sources

The Smart Home Automation System relies heavily on the quality and diversity of its commands. Datasets were collected from a combination of open-source repositories and locally recorded samples to ensure high execution accuracy and relevance. The project adopted a multi-layered approach to curate, preprocess, and validate all datasets used to train and test the IoT model.

Open-Source Datasets: Foundational data for the system was obtained from publicly available corpora such as Mozilla Common Voice. These datasets provided general command examples across different accents and speaking styles. To ensure the system could recognize local variations, additional samples were recorded from users in community settings.

Locally Curated and Expert-Reviewed Data

To ensure accuracy, locally recorded files were reviewed by experts and users. The reviewers verified command consistency, action accuracy, and distinctions for setups with limited forms. Their contributions were essential in eliminating execution errors and ensuring that the system reflected authentic patterns.

This collaborative process helped enhance the model's reliability, appropriateness, and depth.

Data Cleaning and Noise Filtering

Before training, all collected data underwent rigorous preprocessing. Samples were cleaned using tools to remove noise, normalize, and ensure clear input. The recordings were segmented into smaller, uniform clips for easier processing.

Transcriptions were standardized to remove filler words, repeated sounds, and inconsistent spellings. This improved data quality and helped the IoT engine learn precise relationships between input and action.

Language and Tone Filtering

Because commands often express meaning through tone and inflection, classification tools were integrated during preprocessing. Each sample was labeled based on variation (e.g., neutral, emphatic, or questioning). This step was critical in helping the model distinguish between semantically similar commands that vary by tone.

Localization and Language Support

Considering diversity, the system was designed to handle multilingual input, focusing on English and related variations. Surveys and interviews were conducted to collect expressions, slang, and region-specific pronunciations. This localization ensured that the model was contextually accurate, sensitive, and adaptable to local communication styles.

Testing and Evaluation Study Design

To evaluate system performance, a pilot study was conducted involving participants who were users of various devices. Participants issued short commands, which were then processed by the system. The resulting actions were compared against manually verified references. Feedback was collected through surveys to assess usability, speed, and accuracy of the system.

Types of Testing Performed

- Usability Testing: Examined how intuitive and accessible the application interface was. Participants evaluated ease of issuing commands, playback, and action viewing.
- Functional Testing: Verified whether the main functions including input, saving, action generation, and export worked correctly under different use conditions.
- Accuracy Testing: Measured how precisely the system executed commands. Results were compared with ground truth to determine the Command Error Rate (CER) and Execution Accuracy.
- Performance and Reliability Testing: Evaluated response time, stability, and system performance under varied workloads.
- Security and Data Handling Testing: Ensured data confidentiality through encryption, secure authentication, and anonymization of files, in compliance with ethical standards.

Evaluation Metrics

The project evaluated several performance indicators:

- Execution Accuracy: Degree of precision between recognized and actual commands.
- Ease of Use: Simplicity and navigability of the interface.
- Processing Speed: Time taken to convert input to action.
- System Reliability: Uptime, crash rates, and response times.
- Relevance: Effectiveness in handling local expressions.

Ethical Considerations

All participants gave informed consent prior to testing. The project adhered to strict data protection and ethical research standards. No personal identifiers were stored; all samples were anonymized and encrypted. Participants were fully informed that their data would be used solely for research and system improvement purposes.

RESULTS

The results of the Smart Home Automation System were evaluated and analyzed based on three key dimensions: system performance, user experience, and technological impact. These dimensions provide a holistic understanding of the system's effectiveness, usability, and contribution to IoT advancement.

System Performance

The first dimension focused on the technical accuracy and efficiency of the IoT model. The system was tested using multiple command samples collected from diverse users differing in age, gender, and accent. The IoT model demonstrated high command recognition accuracy, which significantly improved after additional training and noise reduction techniques.

Processing time was found to be efficient, allowing near real-time execution. Furthermore, the system successfully handled variations and differences, achieving reliable results even in low-quality inputs. The integration of algorithms such as MQTT parsing contributed to higher accuracy in continuous recognition. These findings affirm that the system performs effectively in real-world environments and can be optimized further through additional expansion.

User Experience

Evaluated usability, accessibility, and user satisfaction. Field testing was conducted with participants from local communities, educators, and researchers. Feedback revealed that users found the system intuitive, responsive, and user-friendly, especially those with limited literacy or typing skills.

The voice-based and remote interaction allowed users to communicate naturally without switching to complex interfaces. This created a sense of inclusion among users. Additionally, the visual output was clear, and execution accuracy built trust in the system's capability. The system's interface also enabled users to toggle between modes, promoting flexibility. Overall, users rated the system as helpful and easy to use, confirming its practical value in community and educational settings.

Technological and Societal Impact

This focused on examining the broader technological relevance and social contribution of the project. The introduction of IoT-powered recognition for commands represents a major step toward inclusivity and digital equity. The system not only bridges the communication gap between technology and users but also preserves identity through digital means.

From a technological standpoint, the project demonstrated the feasibility of low-resource IoT development—a challenge often faced by underrepresented setups. The successful implementation using limited resources proves that transfer learning and modeling can overcome constraints. Furthermore, the system has potential applications in education, journalism, documentation, and governance, where control of devices can enhance data accessibility and community engagement.

In essence, the project's impact goes beyond technology—it empowers populations to interact, learn, and express themselves digitally, contributing to sustainable digital transformation.

Discussion

The findings underscore the potential of IoT-based recognition systems in promoting inclusivity and accessibility. High usability and accuracy scores demonstrate that with proper preparation and tuning, commands can be effectively digitized. Compared with conventional setups, this model performed better in recognizing patterns and expressions, making it more relatable to users.

Nevertheless, some limitations such as challenges in noisy environments and mixed inputs highlight the need for more diverse training and improvements. The system represents a significant step toward bridging the gap between technology and users.

CONCLUSION

This study successfully developed and evaluated a Smart Home Automation System tailored for multilingual and diverse environments. The system demonstrated high levels of accuracy, responsiveness, and usability. By leveraging IoT and recognition technologies trained on localized data, the project contributes to digital preservation, educational advancement, and improved accessibility. Future improvements will focus on expanding device coverage, integrating mobile deployment, and refining the model for real-time translation and multilingual transcription.

The project confirms that IoT systems for commands can serve as powerful tools for inclusion, documentation, and communication enhancement across Africa and beyond.

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