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IoT-BASED HOME AUTOMATION: MOBILE AND CHAT-CONTROLLED APPLIANCE MANAGEMENT

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ABSTRACT

This paper introduces an IoT-based home automation system by studying data and integrating it which allows remote control of household appliances via a mobile app , chat commands and voice controls. The system uses technologies such as node.js for creating restful APIs, Mobile application, MySQL database and prompt engineering concepts for utilizing LLMs to detect the natural language of the users

KEYWORDS: *IoT, Home Automation, Mobile Application, Chat-Based Control, Appliance Management, Timer-Based Automation*

I. INTRODUCTION

Home automation systems have become an integral part of modern living, offering significant improvements in convenience, efficiency, and security. These systems enable users to control and monitor household appliances remotely, often through advanced interfaces and smart technologies.

This paper introduces a study on various components used in home automation systems and along with that this conducts a study on various approaches to use the mobile phone to control and monitor home appliances.

Nitu et el. (2016) in “Wireless Home Automation System Using IoT” web services utilizing JSON data exchange provide a lightweight communication framework for IoT systems, enabling efficient data transfer through standardized methods, supporting key-value pair representations, and facilitating seamless interaction between devices and servers while addressing potential challenges in security and data parsing. **[1]**.

Rabbani and Foo (2022) in “Home Automation to Reduce Energy Consumption” utilized the PZEM-004T electrical energy sensor in conjunction with a NodeMCU ESP8266 microcontroller to monitor and analyze household energy consumption. Their system integrated multiple sensors, including motion (PIR), temperature (DS18B20), and light (LDR) sensors, to automate appliance control based on environmental conditions. The PZEM-004T sensor provided real-time energy data, which was transmitted to a web application, allowing users to track electricity usage on a daily and monthly basis, as well as estimate associated costs **[2]**

In our research, the PZEM-004T sensor is employed alongside a NodeMCU-based IoT home automation system to perform real-time energy analysis, along with that we will be employing Firebase which is cloud hosting platform by google. This setup enables accurate monitoring of power consumption, helping users optimize energy usage and improve efficiency through automated appliance control.

Along with the app connectivity, the Large Language Models such as Gemini Flash could be used to perform tasks related to NLP (Natural Language Processing), which is leveraged to control home appliances using the commands given by the user.

II. LITERATURE REVIEW

Recent advancements in Internet of Things (IoT) technology have significantly transformed home automation systems, offering improved control, efficiency, and security.

REST APIs (Representational State Transfer Application Programming Interfaces) are widely used in modern web, mobile, and cloud applications due to their simplicity, scalability, and flexibility. In this project we would make the use of REST APIs to communicate to our servers which will act as a mediator between the mobile application and the devices. They provide a standardized way for different systems to communicate over HTTP using resource-based URLs and predefined methods such as GET, POST, PUT, and DELETE. REST is an architectural style that allows developers to build lightweight and efficient APIs. By adhering to RESTful principles such as stateless operation, APIs can achieve better performance, maintainability, and interoperability across different platforms.**[3]**

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The adoption of REST APIs has significantly impacted industries like cloud computing, finance, and social media. Companies such as Amazon, Twitter, and Instagram leverage RESTful APIs to provide seamless data integration, authentication, and automation capabilities. The IoT-based home automation market has evolved from basic device control systems to sophisticated networks of connected appliances that interact and adapt according to user settings.**[4]**

These systems are designed to address common household challenges such as fragmented device control, energy waste, and home security risks. According to the research conducted by Deloitte, 77% of smart home users report significant improvements in convenience and efficiency, demonstrating that automation plays a vital role in simplifying daily tasks and optimizing energy usage **[4]**

III. METHODOLOGY

The methodology for the IoT-based home automation system involves a structured approach encompassing system design, implementation, testing, and deployment.

A. System Design

1. Hardware Components

• Pzem - 004T Sensor: PZEM-004T is an electronic module that functions to measure: Voltage, Current, Power, Frequency, Energy and Power Factors. With the completeness of these functions / features, the PZEM-004T module is ideal for use as a project or experiment for measuring power on an electrical network such as a house or building. **[5]**

2. Software Development

• Server-Side: Our project implements a node.js server for data processing and storage. Receives data, processes commands, and sends instructions. Utilizes cloud computing resources for scalability and remote access.

• Client-Side: It is used for developing a mobile application for Android and iOS platforms. To provide features such as real-time notifications, timer settings, and a chat-based control system.

• Flutter TTS: TTS is a Flutter plugin incorporating text-to-speech capabilities into your Flutter app. It's like giving a voice to your app, where plain text strings come alive as spoken language. **[6]**

• Flutter STT: A library that exposes device specific speech recognition capability. This plugin contains a set of classes that make it easy to use the speech recognition capabilities of the underlying platform in Flutter. **[7]**

• Flutter HTTP: It is a composable, Future-based library for making HTTP requests. This package contains a set of high-level functions and classes that make it easy to consume HTTP resources. Its multi-platform (mobile, desktop, and browser) and supports multiple implementations. **[8]**

3. Integration and Communication

• Integration: It is managed through a RESTful API for real-time communication and it facilitates data exchange between the mobile application and the server.

B. Testing and Validation

1. Unit Testing.
2. Integration Testing.
3. User Acceptance Testing.

C. Deployment

1. Installation: The installation process involves setting up both hardware and software components to ensure the system functions correctly. This includes installing physical devices such as sensors, controllers, smart appliances, and networking equipment. Network connectivity, such as Wi-Fi or Bluetooth integration, will be established for remote access and automation control.

2 Final Testing: After installation, the system undergoes comprehensive testing to verify its functionality, reliability, and performance within the home automation setup. This includes testing sensor responses, device connectivity, automation triggers, and security features. Simulated real-life scenarios, such as voice commands, remote access, and scheduled automation, are tested to ensure smooth operation. Any bugs, performance issues, or connectivity problems are identified and resolved before handing the system over to the user. The final phase also includes user training and guidance on system usage, troubleshooting, and maintenance.

IV. SYSTEM ARCHITECTURAL FLOW

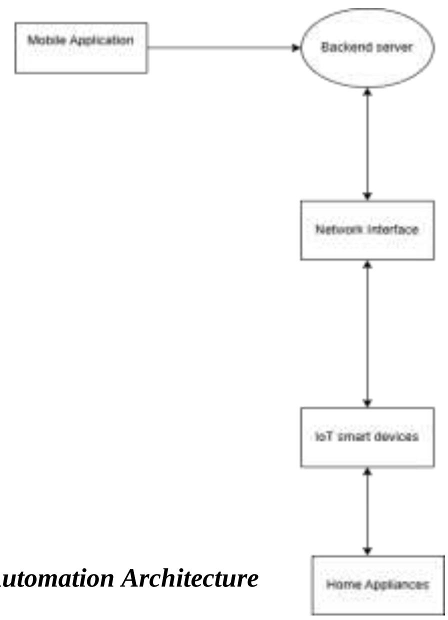

Fig 1. Automation Architecture

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A. Overall System Flow

The architectural flow of the IoT-based home automation system is structured to allow seamless interaction between users and home appliances via an intermediate server. The flow involves several interconnected components that enable monitoring, control, and automation of devices from remote locations.

B. Mobile Device and Cloud Interaction:

Users interact with the home automation system through a mobile device (e.g., smartphone or tablet). The mobile application interfaces with the cloud to send and receive commands. Through the mobile app, users can control home appliances, set automation rules, or monitor real-time sensor data. The cloud acts as a centralized hub, processing commands and relaying data between the user and the home devices.

V. NATURAL LANGUAGE PROCESSING

The chat-based control system integrates state-of-the-art natural language processing (NLP) models to understand and process user commands. Some of the AI models considered for this implementation include:

- OpenAI's GPT-3.5: Offers advanced language understanding and generation capabilities.
- Google's Gemini: Excels in understanding context within queries.

The chat-based control follows this workflow:

a) User Input: The user sends a text command through the mobile application or a chat interface.

b) AI Processing: The chosen AI model processes the natural language input.

c) Generation: Based on the interpreted command, the AI generates appropriate decimal code.

d) Execution: The system executes the generated code to control the relevant devices.

VI. VOICE AND CHAT CONTROL USING NLP

- The voice control could be implemented using various packages of flutter including flutter_tts(text to speech)
- Google Gemini LLM could be used to implement Natural Language Processing (NLP) to control the devices by understanding user commands.
- The diagram below gives an overview about the logical data flow in the system.

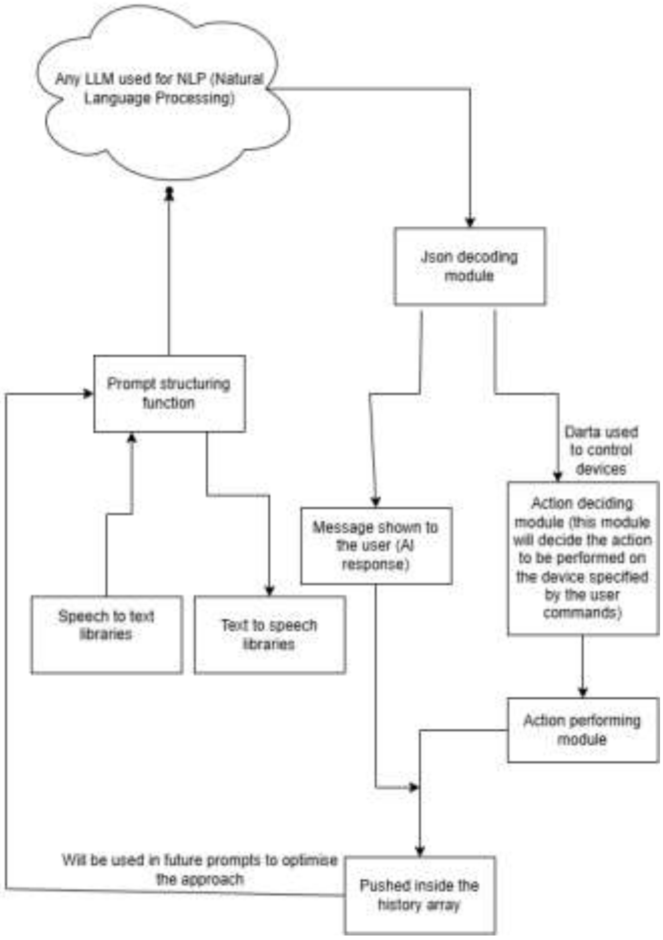

Fig 2. NLP Data flow(For AI assistance)

VII. ADDITIONS

In comparison to the home automation system described in [2] *Home Automation to Reduce Energy Consumption*, which relies on traditional IoT-based automation using sensors for controlling devices like lights and fans based on environmental conditions (e.g., motion, temperature), our project introduces an advanced approach by integrating an AI-driven assistant. As mentioned in the '*Fig 2. NLP Data flow(For AI assistance)*', we are structuring the prompts in such a way that the LLM provides the best output. Using a Large Language Model (LLM) like Gemini, the system not only helps users monitor and analyze their energy consumption data but also offers real-time insights and personalized recommendations to optimize usage. Additionally, the AI assistant enables users to interact conversationally with the system to control various smart devices such as lights, and other appliances, creating a more intuitive, engaging, and intelligent home automation experience..

VIII. SYSTEM ANALYSIS

A. Pros of Home Automation system:

- Remote control of devices via smartphone

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- Automation of tasks based on schedules or triggers.
- Automated lighting reduces unnecessary energy use.
- Remote control of smart locks and access management.
- Easier control for individuals with disabilities or limited mobility.

IX. LIMITATIONS

- Complicated setup and configuration.
- Increased server load and slower performance.
- Possible integration issues between devices from different manufacturers.

C. Statistical data for home automation market in India

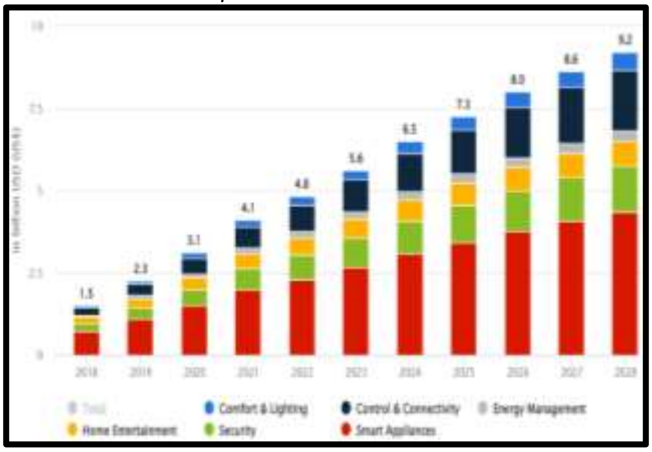

Fig 3. Statistics of home automation market in India [9]

X. FUTURE SCOPE

1. Installation and Setup provided by the Company: The company will take full responsibility for the installation, configuration, and setup of the system for users or customers. This ensures a seamless onboarding experience and minimizes technical difficulties for end-users.
2. Development of a Proxy Server to Limit Server Requests: A proxy server can be implemented to manage and reduce the number of requests sent to the central server. This will help optimize system performance, reduce latency, and enhance security by filtering traffic and pcaching frequently accessed data.
3. Expansion to Web and iOS Platforms: To improve accessibility, the system can be extended to web and iOS platforms. This will allow users to control and monitor their smart home devices from various devices, providing a seamless and flexible user experience.

XI. CONCLUSION

This research paper presented a study on existing methodologies of home automation system that includes using a web server as a middleware, JSON encoding – decoding of data, use of LLMs and the data flow created by us for the project and use of RESTful APIs for faster communication with the devices. The system demonstrated significant advancements over traditional automation methods, particularly in terms of response time, reliability, and user experience. The implementation of real-time communication protocols and a user-friendly mobile application has enhanced the system's functionality, allowing for efficient remote control and monitoring of home devices.

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