Smart Home Lighting System

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Abstract*— Smart Home System involves controlling home appliances using the Internet of Things (IoT) allowing us to have a user-friendly home automation system. It allows us to auto control electronic appliances in the house such as fans, lights, gates, doors, windows, and many more including security access systems and alarm systems. In this paper, we have implemented the operation of lights through the voice-controlled home automation system by giving voice commands as an input to the system for the user to turn ON and turn OFF the lights at home. The system mainly uses the Raspberry Pi module, which happens to be an important component of our smart light system implementation. It consists of both hardware and software components, which have a speech recognition module implemented using Natural Language Processing (NLP) and has voice commands that can be understood, and accordingly, lights can be operated with its usage. It has a special feature that when the light gets turned ON or OFF, it will be ensured to the user through an audio output by the speaker. The main working of a voice-automated system depends on the recognition of the voice given by the user as an input. Raspberry Pi module keeps all electrical home appliances connected through a single interface for complete smart home system automation. Today's modern world is shifting from conventional switches to centralized control systems with less human intervention, as result, the use of manual operating switches is slowly deteriorating. In this paper, we have used voice recognition for operating the home appliances where there is no need to use the conventional switches, and hence human effort required for the system is comparatively very less. Research work on smart home systems mainly aims to satisfy the needs, which help elderly and disabled people etc. in operating home appliances without any helping support from others. The main purpose of our paper is to build a perfect smart home-helper for the users to operate the home appliances easily through voice commands.

Keywords- Smart Home System, Raspberry Pi, Voice Recognition

I. INTRODUCTION

Information Technology has made a drastic change in mankind by bringing in smart home systems by its constant revolution in technology. Smart home systems make use of microprocessors to integrate and control electronic appliances at home. The idea behind smart home systems is to make efficient utilization of electricity. So a variety of research solutions have been proposed in the field of smart home systems, which uses a personal computer, laptop, mobile Internet, GSM, Bluetooth, Smart Phones, and ZigBee network, etc that are used for network communication. Research on smart home systems ensures to fulfill our everyday needs and requirements more importantly focusing on the application needs of visually blind, elderly, and physically disabled people, etc. In such applications, voice recognition technology that uses wireless communication for smart home implementation has a relatively high performance in the last few years.

Wireless communication ensures to reduce the complexity associated with the installation and maintenance of smart home applications compared to its wired communication systems. A smart home system comprises low power wireless sensors and actuators. Some of the popular choices for the wireless backbone systems include Bluetooth, Z-Wave, Wi-Fi, and ZigBee. These choices can be further implemented in remote monitoring facilities. The easy availability of cheap wireless sensors, actuators, and modules has reduced the gap between the mass-market and comfortable effortless life using smart home systems, which makes use of the latest technological advancements.

II. LITERATURE SURVEY

Earlier research studies about many smart home systems carried out using Web, GSM, Bluetooth, Wi-Fi, Z-Wave, and ZigBee helps us to give a comparative analysis of how different wired and wireless technologies have been opted in the past for building home automation systems.

Related research work done by Sikandar et al. [1] shows how the wireless technology along with smartphone SMS (short message service) service could be used to provide smart home appliances automation and security from a remote place by the user. The work aimed to use the results of the previous implementation done on the same grounds referring to the previous research papers of [2] and [3]. Since the work uses the functionality based on GSM (global system for mobile communication) technology, power failure was the main concern of hurdle notices for smart home systems implementation.

Another research by A. Jacobsson, M. Boldt, and B. Carlsson [4] shows the literature survey done by comparing different technologies and applications used in smart automation systems. The paper gave an insight into various risk analyses done in different areas of security, privacy, and industry-based smart automation systems implementation. The drawback in the paper was the challenge to combine both security and privacy in the same design implementation.

Research work by Bhatt and Verma [5] showed how a wired security system could react to an alarm sound and send an alert to the phone using voice commands. They worked on the event of gas leakage by using the opening and closing of the door and window glass. The results of web-based application development using virtual components had to run with many local and remote monitoring systems along with controlling buildings. As the

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entire setup was based on wired network technology, the work needed upgrading of technology towards wireless networks.

Research work by C. Maternaghan [6] uses a smartphone and wireless technology to provide remote access for controlling smart home systems. The experimental results show using simple algorithms an appreciated behavior of appliances control could be seen in the smart home system automation. The design of the system was done using an Arduino UNO and the user interface was done using an Android application. The Internet was used to reflect the intrusion in the home appliances to the android application. But usually, the Internet lacks to provide complete connectivity to its 100% during a power failure or any other kind of network service interruption which was the drawback of this research work.

Another research work by Ryu et al. [7] shows how the Process Control System (PCS) security can be improved to know the dependency of Internet open protocols on supervisory, control, and acquisition (SCADA) systems. The research discussed the study on the SCADA process on natural gas control systems used in the United States and sensor networks used by Korea. The study says till date only physical security measures were used to operate the system on a closed network. The system had to be developed which required both encryption algorithm and intrusion detection system implementation.

Research work by S. Das, S. Ganguly, S. Ghosh, R. Sarker, and D Sengupta [8] uses Bluetooth technology for controlling home appliances using the Arduino board microcontroller and Android application. Controlling the light intensity was the major work proposed by the researchers in system automation. Though Bluetooth technology provides a cost-effective way to implement the application, Internet technology could have covered a wider area of controlling and monitoring the system.

Another research work by R. Alcarria, D. M. De Andres [9] had a different way to automate and monitor the home appliances smartly by using rule-based service. The system works in real-time rules-based on Near Field Communication (NFC) and the results had variations in concluding the analysis as temporarily violated, satisfied, and permanently violated.

A web-based smart home application work was proposed by V. Patchava, H. B. Kandala, and P. R. Babu [10] using Raspberry Pi and the Internet of Things (IoT). The system reduced the human effort of surveillance on the home appliances using a simple recursive algorithm. The web application uses a camera and sensor, which helps energy monitoring applications at home. Power fluctuations may result in the restart of the entire automation system of monitoring the home appliances which affected the implementation work proposed and required a backup plan to reboot the system to its normal working.

A research paper was presented by Waghmare [11] on different wireless technologies such as Bluetooth, ZigBee, and Wi-Fi for comparing the implementation and controlling of the smart home systems. Another web-based application by A. Chaudhari, B. Rodrigues, and S. More [12] gives a comparative analysis of different types of smart plug energy monitoring and control systems. The application uses Raspberry Pi and Aurdino along with different sensors, which together connect all the devices providing automation of the system. The task also provides a graphical user interface using a web application to notify the users about the auto-monitoring of the system remotely.

A new wireless technology Z-Wave [13] was described which allows the smart home appliances to be developed with minimum power usage. It has better network reliability with no interference from Wi-Fi or any other wireless technology, which makes its usage available in commercial applications [14] easily. The research paper [15] presents the use of digital assistance to make the disabled person interact naturally with sign language communication. The digital assistants such as Apple Siri, Amazon Alexa, etc. helps to capture the voice commands. Though the system provides simpler, easy, and less expensive interactions to control home electrical appliances, it has shortcomings on persons who cannot speak or use sign language communication.

The research paper [16], proposes controlling the room lights based on activity sensed by the mobile application from the smartphone. This requires a microcontroller with Bluetooth module to sense the circuit controlled light illumination variations. The paper [17] focuses on voice commands controlled smart home systems using smartphones, which requires Internet network connectivity to be available at a good speed. Also, the voice commands communication and pronunciation should function correctly without any errors to make the smartphone work according to the trained datasets.

The paper [18] works on the design and implementation of voice commands using Google assistant specifically. Though the users get the convenience of using voice commands compared to the text messages, the signal strength of the Internet network is the main challenging requirement for better performance. Though the paper [19] uses a low-cost NodeMCU Arduino system with MIT application running on a smartphone for a user interface for smart home controlling, the delay time in the speed of information transfer was the main hurdle for automatic smart home controlling.

The paper [20] focuses on developing a system with a graphical user interface using an android application for smart home control. The application requires connecting to Wi-Fi across a cloud network. Since the requirements for the system are based on the user's comfort zone parameters, adjusting the system based on suggestions given by the crowd preferences is the major problem highlighted in the paper. The paper [21] presents the use of virtual assistants by name Oliva integrated into the systems and appliances for allowing notification to the user through email or SMS. The system makes use of raspberry Pi for sensing the system appliances working.

Another paper [22] based on Embedded System was used for controlling the smart home system appliances using an android application and Bluetooth for transferring data. The system requires Google assistance with good network connectivity. The paper [23] speaks on using a single remote controller for controlling different home appliances using voice recognition systems. The paper [24] implements a smart home system using a single chip computer and a speech recognition module. The system demands real-time display status to prove functional accuracy. The research paper [25] proposes a smart light system using controlled genetic algorithms. The algorithm falls short of working in a real-time environment using optimized light patterns.

III METHODOLOGY

The methodology involves both hardware and software components used in the current system implementation.

Software Components

Raspbian Pi uses a Debian-based computer operating system.

• Python 3.5.3 version is used.

• Xshell is an open-source terminal emulator; serial console and network file transfer application.

• Virtual Network Computing (VNC) Viewer is a program that represents the screen data originating from the server-side.

• MySQL Database runs as a server providing multi-user access to several databases required.

Hardware Components

Raspberry Pi is a single-board computer running on a Linux based operating system that is best suited for IoT.

- Micro SD card with NOOBS or USB pen drive.
- Micro USB power supply (2.1 A).
- Relay Board connected to lights, fans, and other appliances of the home.
- USB Mic: Audio input for Raspberry Pi is done through a mic.

The system required the Raspbian flavor operating system to be installed on Raspberry Pi single-board computers. To remotely view and control the system we need Virtual Network Computing (VNC) to display the system monitoring status remotely. A free and open-source terminal emulator supporting several network protocols is used to secure remote system login. MySQL database is used for data storage required by the smart system application.

IV. DESIGN AND IMPLEMENTATION

This paper uses Google Voice and Speech APIs. The microphone captures the voice command from the user, which is then converted to text by using Google Voice API. The text is later compared with the given commands inside the command configuration file. If it matches any of them, then the bash command associated with it will be executed. This is achieved by using the Google speech API, which converts the text into speech.

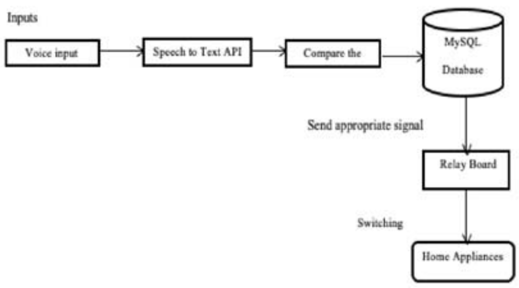

Figure 4.1 Voice Controlled Smart Home Systems

Initially, the input information is given with voice modules. The voice information is converted into text information and the text obtained is compared with the original information and is matched. All the inputs are checked and status is changed accordingly. According to the obtained status received the appropriate signals are routed to the relay board resulting in inappropriate operations getting performed on the home appliances.

A. The architecture of the Proposed System

The architecture proposed by the system depicts the conceptual model defining the structure, behavior, and more views of a system.

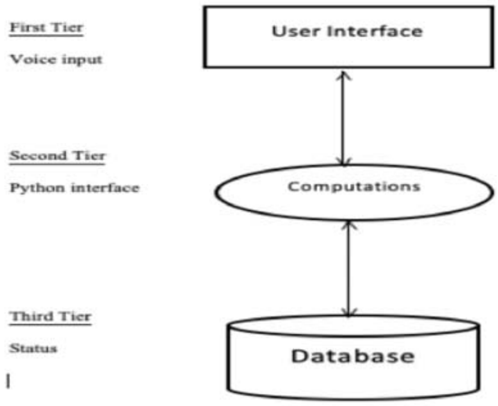

Figure 4.2 Three-tier architecture

The First Tier consists of input data given as voice input. Voice input is read through USB mic. The voice is further converted into text information (speech to text). Then the text information obtained is matched with the original information. The Second Tier consists of Python as a scripting language. Logical operations are programmed in python. The front end is connected to the database using the python scripts. Raspberry Pi's all functions are controlled using python language. Speech to text API and Speech recognition API is used to recognize the voice input and convert them into text and then it is compared with the status. The last Third Tier consists of the status of the system stored in the MySQL database. Initially, the required status is stored here and this status is compared with the input status to provide further commands to relays. Relays then operate according to the appropriate commands.

B. Sequence Diagram

In this paper, the identified object heads and the sequence of interactions are highlighted in fig 4.3 below. The module functions explain the sequence diagram. The modules are User, Database, and Raspberry Pi and Home appliances. The user module is used to give the inputs, which are given by input devices, and it goes to the database. The database consists of status values, by which appropriate operations are performed. Raspberry Pi component gets the control signals from the database containing user input status to interact with the home appliances connected. It gets status from the database and sends control signals to appliances to perform specific operations. Appliances are operated according to status values given by the user.

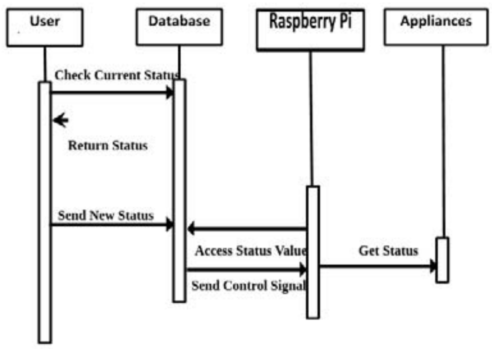

Figure 4.3 Sequence diagram of the Smart Light System

C. Use Case Diagram

The use case model shows the significant activities carried on by the user using the smart light system. This analysis model depicts both dependent and extended use cases involved in using the system. The user reads the status of the home appliances fan or light to auto operates them using voice commands.

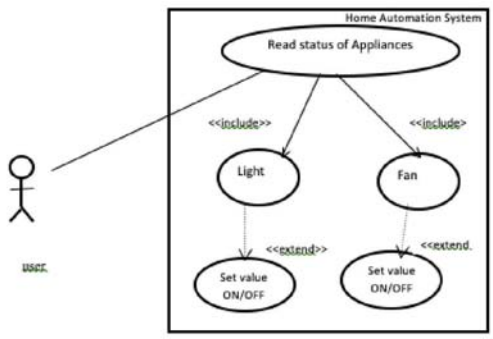

Figure 4.4 Use Case Diagrams

D. Algorithm

The algorithm for hardware connections:

Step 1: Connect Raspberry Pi to the router through Ethernet Cable.

Step 2: Connect the USB mic to one of the four USB ports.

Step 3: Connect the speaker to the audio port.

Step 4: Further connect the relay board to the Raspberry Pi through the pins and female-to-female jumper wires.

Step 5: Connect the bulbs along with 220v power supply to the Relay board.

Step 6: Finally turn on the Raspberry Pi and router then connect it to the system through Wi-Fi.

The algorithm, which is designed for operation of Raspberry Pi, is as follows:

Step 1: Open the Xshell.

Step 2: Obtain the associated IP address of the Raspberry Pi Component through Advanced IP scanner.

Step 3: Enter the Internet Protocol (IP) address of the Raspberry Pi component in the Xshell screen as input.

Step 4: Xshell terminal will be opened. Input the user name and password of the Raspberry Pi component.

Step 5: Run the RPi_GPIO.py in the terminal with the command: python RPi_GPIO.py [11]

Step 6: Open another Xshell terminal. Repeat the same steps from 1 to 5. Run the speechrec.py with the command: python speechrec.py

Step 7: Give the voice command through USB mic.

Step 8: Speech is converted to text through Google API and is compared with the existing system.

Step 9: Appropriate signal will be sent to the relay board through Raspberry Pi and Home appliances will get operated.

V. RESULTS AND DISCUSSION

The system works with a certain set of voice input commands. Raspberry Pi is first connected to a router using the Internet connection followed by a relay board being connected to the same Raspberry Pi. The home appliances of the smart light system are connected to the relay board and the Raspberry Pi module will be accessed through Xshell to the system. When the RPi_GPIO.py runs successfully, the relay board will be activated. Further when the speechrec.py runs successfully Google voice API will be ready to accept the voice commands.

Following voice commands are used:

- Turn ON first light
- Turn OFF first light
- Turn ON second light
- Turn OFF second light

The given commands will be detected through Raspberry Pi's voice recognition. The voice command is then converted to text through Google voice API. It is then compared with the specified commands and the corresponding action takes place as the result.

A. Outputs through Voice Inputs

The figure shows the input screen for accepting the voice command inputs. This screen appears once the speechrec.py program has been successfully executed. As soon as the screen appears the system will be ready to accept the voice commands. Finally, input voice command will be given and the given voice command will be displayed on the screen.

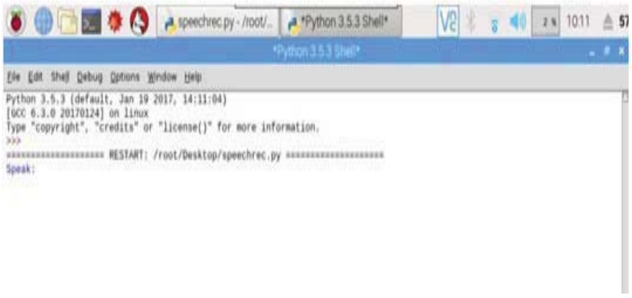

Figure 5.1 Accepting Voice Input

RESULT 1:

The input screen, which has accepted the voice, command to turn ON first Light and will be waiting for the next voice command. Once the given command “TURN ON first LIGHT” is accepted, the corresponding linked PIN 12 gets activated. Finally, the light will be turned ON. The speaker will ensure the light glows to the user through the audio output. If the voice command does not get recognized, the command “COULDN’T RECOGNIZE THE VOICE” will be shown.

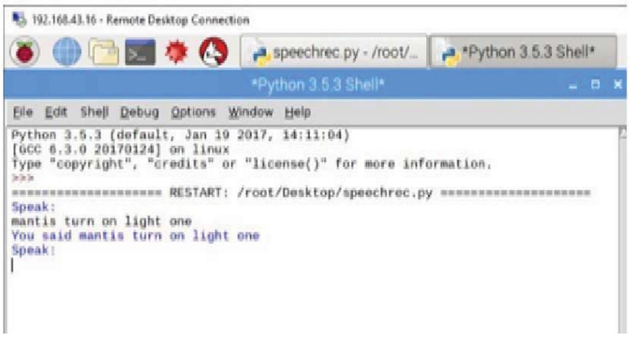

Figure 5.2 Input screens which accepted the command to turn first light ON

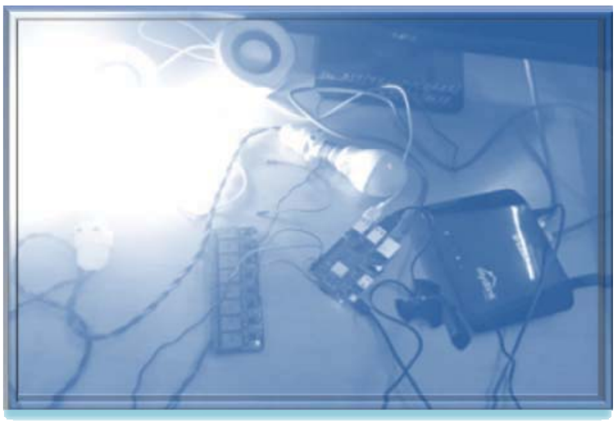

Figure 5.3 Output when light is turned ON

RESULT 2:

The input screen, which has accepted the voice, command to turn ON Light 2 and will be waiting for the next voice command. Once the given command “TURN ON SECOND LIGHT” is accepted, the corresponding linked PIN 18 gets activated. The light 2 will be turned ON. Finally, both the lights will be turned ON. The speaker will ensure the light glows to the user through the audio output.

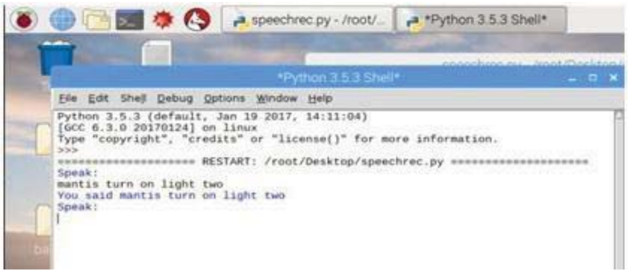

Figure 5.4 Input screens which accepted the command to turn light two ON

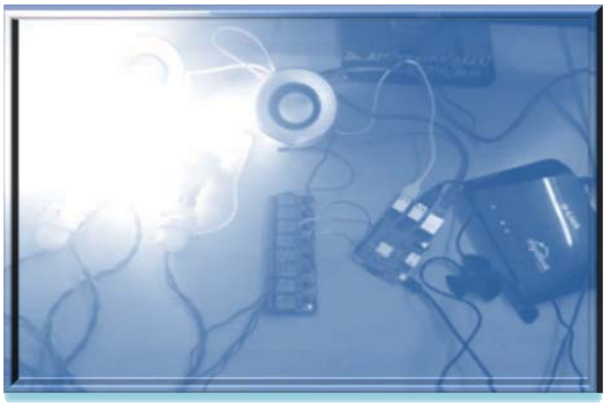

Figure 5.5 Output when both the lights are turned ON

RESULT 3:

When the voice commands “Light1 TURN OFF” and “Light2 TURN OFF” are given to turn off both the lights (i.e. Light1 and Light 2) respectively, the corresponding output will be shown in the model. Hence we will get the audio output through the speaker once the light gets turned off.

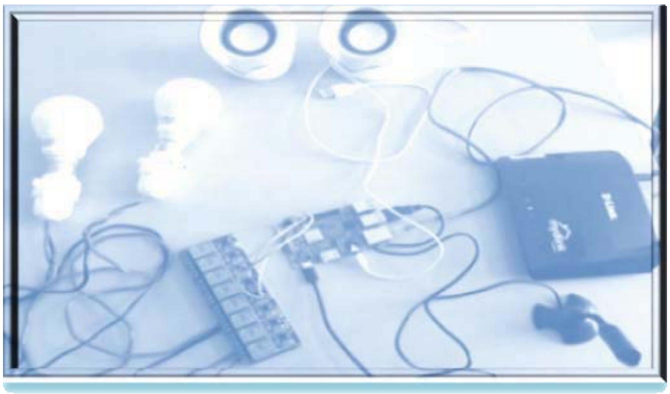

Figure 5.6 Output when both lights are turned off

B. Advantages

- Manages all the home devices from one place: The smart light system can keep all the electrical home appliances connected through a single interface for complete home management.
- Ease of use: This is very easy and operations can be performed at fingertips. The main advantage is that it can be even handled by physically challenged and disabled people.
- Control: With this technology, we can know what is happening inside the home at all times.

C. Limitations

- If Raspberry Pi is powered off, then the whole system will not work which implies that the home appliances cannot be controlled.
- The Raspberry Pi 3 is having 40 GPIO pins. Only 40 GPIO pins are not enough to control full home appliances.
- Though there are certain limitations, the system is very convenient to the users as it is technically very much upgraded to make a smart home. The system is very reliable as the operations are at the fingertips.

VI CONCLUSION

The smart home system has been successfully developed which can control lighting appliances in the house. This allows the user to interact with system voice commands. Using the commands like 'Turn ON first light', 'Turn OFF first light', 'Turn ON second light' and 'Turn OFF second light' we can control the lights at home. Thus our smart home system provides a convenient way to control the lighting appliances without any manual human effort. When the actions take place a voice is generated indicating the action has taken place. The smart home system application program is quite satisfactory and the response received from the community, in general, is encouraging.

VII FUTURE SCOPE

In the future, we would like to plan to make the following advancements for our smart home system.

• Implement a system that can similarly be used to control and monitor lights for large buildings with many rooms and floors.

• Applying a similar idea to Gas leakage detection system and to give warning through voice output.

• Training the automated smart systems using statistical models and algorithms for improved system learning and controlling.

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