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RESEARCH ARTICLE

IoT based home automation with energy management

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Abstract

Automation of home appliances has become the prime utility of embedded systems. This automation method is inclusive of a sensor-based automated system that requires no human/conventional interventions. This paper proposes the usage of voice commands to have control over the entire appliances, which is easy to handle by old age/disabled people. The major aspect of this paper is to introduce a new system for disabled and normal people. This method involves a Raspberry-Pi-3 control board, which has a WiFi module termed Raspberry-Pi-3. For sending the voice instruction to the Raspberry-Pi-3 a mobile application is used. The function of the application is to record the voice and convert the voice note into a command for Raspberry-Pi-3. This process is facilitated by WiFi communication. This system also uses IoT for measuring the power consumed by the active appliance over the current sensor and the Webserver can preview the power consumption.

Keywords: Home automation, IoT, Raspberry-Pi-3, Embedded systems, Wi-Fi.

Introduction

A home is where an individual would prefer to relax and rest after a tiring day. Every individual returns home after having a busy schedule at their workplace. The exhausted individual lands on his sofa or bed to rest and feel good. In the contemporary modern era, they would like to have devices playing their favorite movies/songs to switch on/off their electrical appliances like lights, fans, etc. They will feel more comfortable operating those devices with their voice command. They also like activities such as warming the water for a bath and maintaining the temperature of the room to be carried by voice command. Moreover, home automation systems also enable individuals to control their electrical appliances, such as lights, fans, and even thermostats, through voice commands or smartphone apps. This allows them to create a cozy ambiance by adjusting the lighting or fan speed to their liking without manually operating switches or knobs.

Furthermore, with the advent of smart home technologies, individuals can also automate tasks like warming water for a bath or maintaining the temperature of the room. Smart water heaters can be programmed to heat the water to a desired temperature at a specific time, ensuring a relaxing bath experience. Similarly, smart thermostats can learn the occupants' preferences and automatically adjust the room's temperature to provide optimal comfort.

Overall, these advancements in technology have made it possible for individuals to create a more comfortable and convenient living environment where they can control various aspects of their home with voice commands or through smartphone apps, leading to a more relaxed and enjoyable experience after a tiring day.

In the past, the rich maintained their properties by engaging domestic housekeepers. Even today, innovative technology is affordable only to wealthy members of society. Since the cost of these new smart home appliances is high. Not everyone has the financial means to invest in a personal assistant or a smart home kit. Considering the above facts, there is a surge in demand for practical and affordable means to make it accessible to average households. This system suggests the easiest means of using Raspberry-Pi-3 microcontroller, Blynk, IFTTT, and Google Assistant as their primary components. The components are coupled with a relay board with 4 to 8 relays and a ULN 2803 IC. The Google Assistant receives/accepts commands in natural language voice. As every component is connected to the Internet via

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Wi-Fi, this system comes under the ambit of the Internet of Things (IoT).

The proposed system suggests such an easiest system. Raspberry-Pi-3 microcontroller, Blynk, IFTTT, and sensors are used as their primary components, coupled with a relay board with 4–8 relays and a ULN 2803 IC. As a prime component, the sensors are connected to the Internet via Wi-Fi. This system fall under the umbrella of the IoT. It is an analytics and advanced automation method. It utilizes AI and large data for delivering the entire system. Those systems make transparency when it is applied to the network.

IoT is flexible and easily portable to any environment. These characteristics make it suitable for diverse industrial fields. It handles the collection of data, carries automation more deeply, databases, networking, etc. This element induces vast changes in the social media platform and has an advanced economic impact on services and goods. When IoT is brought to the home, it turns the normal home into an automated and, safe, intelligent home (Uma S *et al.,* 2019).

IoT enables remote monitoring and control of devices and systems. By connecting devices to the internet, users can control and automate functions such as turning on/off lights, adjusting thermostat settings, or managing industrial processes.

IoT is commonly associated with smart home applications. Smart home devices include smart speakers, thermostats, lighting systems, security cameras, and appliances that can be controlled and automated through smartphone apps or voice commands.

IoT is very effective enough for the enhancement of all aspects of the collection of data, networks, and concepts of AI. Networking of the IoT ensures makes sure that any of the networks connected is tied with the major provider. The network can exist at the smallest and cheapest scale; these smaller networks are created over small devices. Sensors behave as elaborating instruments. It changes IoT from a passive to an active network for an efficient system that is needed for real-world integration. Also, the equipment became smaller, cheaper, and more compact. IoT provides precision, scalability, and versatility.

The following Figure 1 demonstrates the systematic representation of automated home using cell phones modern technologies like home automation enable comfort at home. Data may be rapidly captured, transmitted across devices, and evaluated simultaneously with home automation. Home appliances can be conveniently accessible from anywhere by being connected to the internet (K. Loga Priya & S..Saranya 2020).

Literature Survey

The home automation system can be set up via cell phones or other remote controls. A new speech-controlled home automation system that employs Google Assistant for receiving voice commands as input was designed

Figure 1: Home automation

and implemented by (K. Loga Priya & S. Saranya 2020). This monitoring and home automation solution is both affordable and adaptable. The user can use a system for home automation built on the network of things thanks to it (IoT). Lights and fans in the home can be regulated. The main goal of this work is to operate electronic appliances according to the user's specific requests and situational needs.

A controlled home application system was created by (Uma S *et al*., 2019), facilitating customers to access household appliances from a distance. The consumers only need to send text messages or voice instructions to turn the devices on or off according to the requirements. While they are not fully present in the surroundings, customers can schedule the state of the appliances. Also, users will receive details on previous schedules and can turn on electronic appliances for a predetermined period. The functionality of the application is embedded with an IoT-based device that employs the Node-RED technique (Raspberry-Pi-3). The dialog flow account is created on application installation. Connected to the Raspberry-Pi-3 are usual household products. The Raspberry-Pi-3 operates the home products following the attributes it has obtained from the cloud. This application uses high-quality, low-priced equipment, so the implementation cost is quite low. This program is incredibly reliable and effective for senior citizens and differently-abled people who can't reach the switch to turn the gadget on mode or off mode.

Nowadays, everyone's main preference is to have a level of comfort. The recommended concept uses Raspberry-Pi-3, Blynk, and Google Assistant (GA) to operate the home appliances in an automated manner. In essence, (Mansi Solanki *et al*., 2021) explain how to set up IFTTT to use GA for remotely operating home products like bulbs. Raspberry-Pi-3 cannot directly link to GA; a middle application, like the Blynk app, is required. The Blynk application can correlate with Raspberry-Pi-3 directly and supply data to it. The transparent transition of GA-interpreted commands to the Blynk application enables receiving of that information by Raspberry-Pi-3. The GA, however, cannot autonomously grasp requests like "turn on the light" or "turn off the light." IFTTT, another transitional technology, is deployed to handle this situation and to bridge the distance between voice

search and the Blynk app. When someone gives the GA a voice command, IFTTT will understand it and transmit the demand to the Blynk application via the Blynk server, and the Blynk app will then send the command to the node.

An all-encompassing, cloud-based intelligent home automation system is presented by (Olutosin Taiwo *et al*. 2021) in their paper. The system uses an android application to manage, oversee, and regulate a home's security and atmosphere. One module will be in charge of the home's security by spotting motion and capturing pictures, while the other module manages and monitors environmental variables and electrical appliances. In this work, detecting an object's motion triggers the camera to take pictures of the thing. To distinguish between photographs of typical home inhabitants as opposed to an intruder and prevent false alerts, they applied the idea of ML. The SVM technique is suggested for this study to categorize the image's attributes and identify whether it represents an intruder or a regular home occupant before warning the user. The mobile-based application's arrangement enables a graphical representation of household activity. This research demonstrates how ML methods improve home automation systems' usefulness and boost home safety. A Raspberry-Pi-3 board, an ESP32- CAM board, a 5 V four-channel relay segment, and sensors were used to implement the prototype for the work.

Energy Management

Energy management refers to the strategic and systematic process of monitoring, controlling, and conserving energy resources in various settings, such as residential, commercial, and industrial buildings. The primary goal of energy management is to optimize energy usage, minimize waste, reduce costs, and improve overall energy efficiency. Here are some key aspects and strategies involved in energy management.

Energy Monitoring

Energy management starts with monitoring energy consumption and understanding the utilization of energy. It involves collecting data on energy consumption, analyzing patterns, and identifying areas of high energy usage.

Energy Audits

Energy audits are assessments conducted to identify energy inefficiencies and potential areas for improvement. These audits are carried out by energy professionals who analyze energy consumption, building systems, equipment, and operations to recommend energy-saving measures.

Energy Efficiency

Energy management focuses on implementing energy-efficient practices and technologies. It includes upgrading to energy-efficient appliances, optimizing building insulation, using energy-efficient lighting, adopting smart heating and cooling systems, and implementing energy management systems.

Load Management

Load management involves strategically managing the timing and intensity of energy consumption to reduce peak demand and lower energy costs. It strategized through load shifting, load shedding, demand response programs, and smart grid technologies.

Renewable Energy Integration

Energy management incorporates renewable energy sources, such as solar panels or wind turbines, into the energy mix. It involves assessing the feasibility, installing renewable energy systems, and optimizing their usage to reduce reliance on traditional energy sources.

Energy Conservation

Energy management emphasizes the importance of conservation measures to reduce energy waste. It includes promoting energy-saving behaviors, such as turning off lights when not in use, unplugging unused devices, and implementing energy-efficient practices in daily operations.

Energy Management Systems

Energy management often involves advanced technologies, such as energy management systems (EMS) or building energy management systems (BEMS). These systems enable real-time monitoring, control, and optimization of energy consumption, allowing for better energy management decisions.

By implementing effective energy management practices, organizations and individuals can achieve significant energy and cost savings, reduce their environmental impact, and contribute to a more sustainable future.

Calculation of Power Management

To determine the total power consumed by all electrical equipment in a given carpet area or building, one needs to add up the power consumption of each device. The steps followed are as follows:

Step 1: Identify all the electrical equipment to include in the calculation. It should include all appliances, lights, electronics, heating or cooling systems, and any other devices that consume electrical power.

Step 2: Track power rating or power consumption information for each device. This information is typically displayed on the device or in the user manual. Power rating carried in watts (W) or kilowatts (kW).

Step 3: Convert the power ratings to a consistent unit, such as kilowatts (kW), if necessary. If the power ratings are calculated in watts (W), divide the values by 1000 to convert them to kilowatts.

Step 4: Add up the power ratings of all the devices. I will give you the total power consumption in kilowatts.

Power consumption of various electrical equipment is

Television: 100 watts
Refrigerator: 150 watts
Air conditioner: 1200 watts
Lights: 200 watts
Computer: 250 watts

To calculate the total power consumption:

Total Power Consumption = (100 + 150 + 1200 + 200 + 250) / 1000 = 1.9 kilowatts (kW)

Therefore, the total power consumed by all the electrical equipment in this scenario is 1.9 kilowatts. The actual power consumption may vary depending on factors such as the operating conditions and efficiency of the devices. Additionally, this calculation assumes that all devices are running simultaneously. In reality, the power consumption may vary based on the usage patterns and duration of operation for each device. The Equation for calculating the Energy consumption is as follows:

Energy Consumption (in kilowatt-hours, kWh) = Power (in kW) x Time (in hours)

For example, the device with a 1 kilowatt (kW) power rating has been running for 3 hours. The energy consumption would be:

Energy Consumption = 1 kW x 3 hours = 3 kWh

It means that the device has consumed 3 kilowatt-hours of energy. Keeping track of safety in the house and environment is essential given the rising incidence of burglary, violent threats to home inhabitants, and property damage.

Prioritizing the safety and security of people's lives and property is imperative. Hence, a home should have a smart system that can track remotely, control, and inform the resident of actions. An intelligent home automation system is required to achieve a house's security, safety, comfort, and controlling mechanism.

The smart house is an IoT application that enables residents to monitor, control, and oversee their home operations from anywhere, which is implemented by (Olutosin Taiwo *et al.,* 2021). Also, it is now possible to remotely operate the entire house via Wi-Fi, wireless, or other network-related modules using smartphones, computers, tablets, and other similar products. It gives users of the IoT the required level of comfortability. Intelligent home automation refers to utility of IoT technologies to monitor and manage household activities and environmental factors.

The hardware required for this implementation is Raspberry-Pi-3, current sensors, and relay. Software needs for this system are Arduino IDE, language-embedded C, and speech recognizer android application.

Working of the Proposed Automation System

A transformer is used to reduce the AC voltage, usually 220V rms, to the level mandated for the required DC output. After being originally filtered by a direct capacitor filter to supply a DC voltage, a diode rectifier then creates a full-wave rectified voltage, usually, there will be some rippling or AC voltage alteration in the ensuing DC voltage. Even if the input DC voltage deviates or the load supplied to the output DC voltage varies, a regulator circuit removes the ripples and sustains the ideal DC value. The upcoming Figure 2 shows the structure of the automation of the proposed model.

This IoT based voice-controlled home automation method enables the operation of various appliances, including lights, fans, AC coolers, pumps, and more by integrating a 2/4/8 channel relay with Raspberry-Pi-3. A signal is sent to Raspberry-Pi-3 using an android app equipped with voice control and multiple ON/OFF buttons.

Raspberry-Pi-3

The IoT is a network of physical matters, including equipment, cars, utilities, and other goods, that are linked and facilitate the movement of data. Such things are integrated with circuits, programming, connectivity, actuators, and sensors. Everything comes along with a powerful computational system that makes it distinctly unique. Still, they function together inside the current Web infrastructure (Figure 3).

Straighter incorporation of the normal world into computer-based systems is made unlikely by the IoT, which also decreases the need for human communication while increasing effectiveness, precision, and financial improvement. IoT can become a member of the broader category of cyber-physical networks when it is enhanced with sensors and actuators stated by (S. Nirmala Sugirtha Rajiniet NIR 2021). This category also includes smart sensors, digital power plants, smart homes, autonomous vehicles, and smart buildings.

An open-source IoT platform is Node MCU. It uses protocols that utilize the Raspberry-Pi-3 Wi-Fi System on Chip, which has a data speed of 115200 and a CPU speed of 80 MHz. The Raspberry-Pi-3 is a low-cost Wi-Fi chip made by a Chinese company with headquarters in Shanghai that has incorporated a complete TCP/IP stack and microcontroller

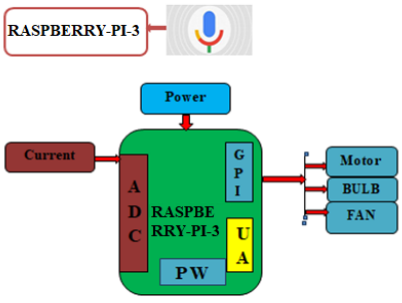

Figure 2: Block diagram of proposed automation system

functionality, as mentioned by (K. Anuradha *et al.* 2020). It is a low-cost, simple, intelligent, accessible, interactive, and Wi-Fi-capable module. Figure 3 describes the configuration of Raspberry-Pi-3.

In the arena of microchip technology, the term computerization is frequently spelled. The need for computerization sparked a series of scientific revolutions. Due to their easy accessibility, these techniques receive more importance than others. They are used in the location of the switches, which could trigger fire occurrences and produce sparks. An enhanced automation system was created to operate the home's appliances in light of the benefits of Wi-Fi discussed (Kotiyal, B *et al.,* 2016). The word "home automation" defines the automatic and remote management of home components, functions, and appliances. People can effortlessly manage their home's utilities and online features. A home automation model is composed of three elements: sensor elements, controllers, and actuators, (Kalyan Chenumalla *et al.,* 2019). An android app for home automation is installed on a smartphone device. The value IP address of Raspberry-Pi-3 is given in the android application IP container to control Raspberry-Pi-3's, GPIO Pins.

Results and Discussion

The simulation diagram of the home automation system is shown in Figure 4 using Blynk platform that enables users to build and control IoT.

It resembles the basic of home automation with two loads, a bulb and fan. Both these loads are operated without any human interference. Since the bulb gets on and off with the help of LDR sensor. The LDR helps in controlling the light based on the luminous available in nature. This helps the bulb to be operated based on the LDR output.

The bulb will also get operated based on the decision of the motion sensor or IR sensor in order to identify the availability of the persons in that area. Similarly, the fan is also operated based on the temperature and humidity in the air. This implies that the fan may turn on or off automatically depending on the specified temperature and humidity thresholds. The users can also operate their home utilities via the Android applications while traveling Figure 4 Home Automation Systems any place in the world when this setup is complete. Here, the Raspberry-Pi-3 serves as the receiver,

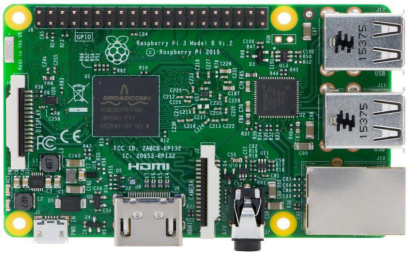

Figure 3: Raspberry-Pi-3

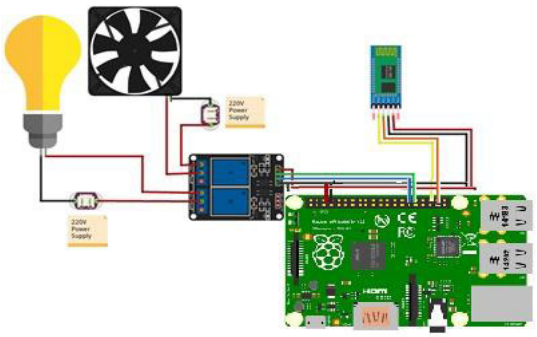

Figure 4: Home automation systems

and the Android phone as the remote control. In reality, signals are sent through the internet.

The simulation output of the operation of light in the Blynk platform is given in Figure 5. From this Figure, it is inferred that the orange color shows LDR output and blue color shows the Motion or IR sensor output. Here, lights to turn on/off automatically based on occupancy or specific times, ensuring that lights are not left on when not needed.

Figure 6 shows the result obtained for the operation of the fan, the orange color represents the humidity of air and the blue color represents the room temperature of the house. Based on the room temperature and humidity, the fan gets operated.

Figure 7 shows the output of the home automation control devices. It is clear that the temperature is 34.3 and the humidity is 38, showing that the fan is on condition. Also, the LDR sensor is on, which resembles that the light is also in on condition.

Figures 8 and 9 shows the graphical representation of the various sensors in a particular time period.

From the results obtained, the project on home automation efficiently controls all the devices without human interference. Moreover, it also calculates the energy consumption daily and gives a detailed report to users. Figure 10 to 11 depicts how the relay operated within the specific timing window, which ranged from 5.31 p.m. to 5.35 p.m. The diagram suggests that sensors are the foundation for the relay's functionality. Period 1 of Figure 10 depicts all components connected to the 4 relays being ON. In

Figure 5: Operation of light

Figure 6: Operation of fan

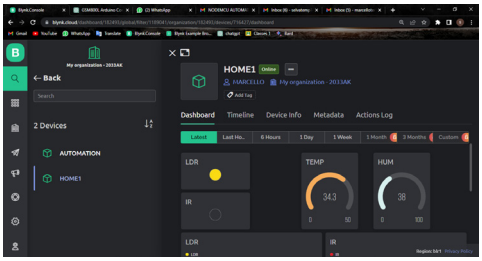

Figure 7: Home automated output

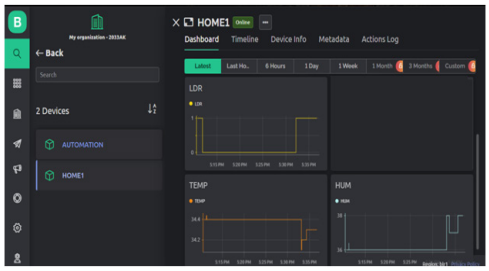

Figure 8: Graphical representation of sensors

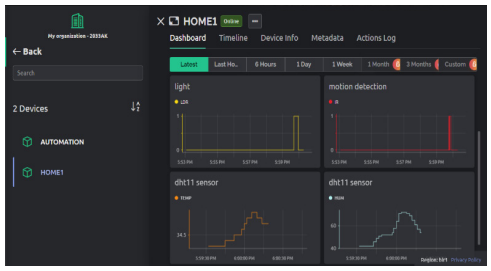

Figure 9: Graphical representation of sensors

Figure 11, all devices linked to the relay are seen turning off instantly during Period 2. Figures 12 and 13 shows the relay's immediate on and off of all linked components, respectively, while Figure 14 shows the relay's immediate off of all connected components.

Automating devices such as lights, fans, and appliances can help optimize their usage and reduce energy waste. By incorporating energy monitoring capabilities into your home automation system, users can track their energy consumption patterns and make informed decisions to further enhance efficiency. Daily energy consumption reports provide users with valuable insights into their energy

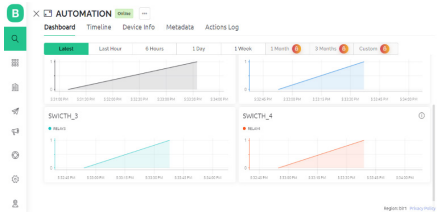

Figure 10: Graphical representation of Relay operation during time period 1

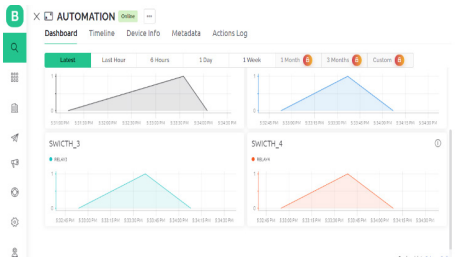

Figure 11: Graphical representation of Relay operation during time period 2

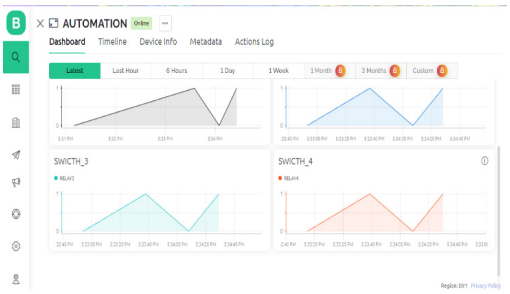

Figure 12: Graphical representation of Relay operation during time period 3

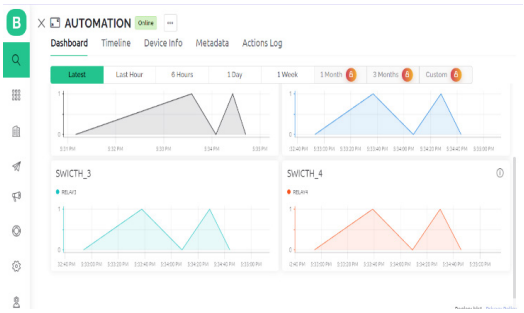

Figure 13: Graphical representation of Relay operation during time period 4

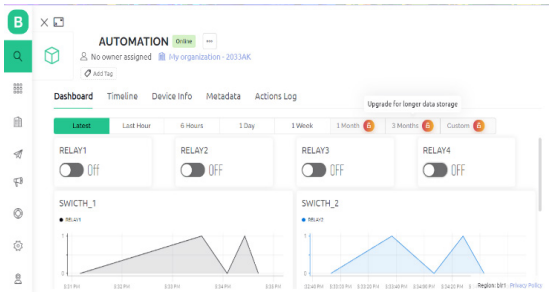

Figure 14: Graphical representation of Relay operation during time period 5

usage, helping them identify areas where they can save energy and reduce costs. With this information, users can make adjustments to their routines or implement energy-saving measures to promote sustainability and reduce their environmental impact.

Combining home automation with energy consumption monitoring and reporting creates a comprehensive solution that enhances convenience, promotes energy efficiency, and empowers users to make informed decisions about their energy usage.

Conclusion

This paper gives a new idea of home automation with intelligent sensors. The integration of IoT technologies and home automation systems offers immense potential to improve the quality of life, enhance energy efficiency, and provide personalized experiences within homes. This system has been put into place and tested, and it works extremely well. Regardless of the term, home automation can be used in any setting. This system's operation is incredibly all-encompassing and simple to implement at home. The advancements in this field continue to drive innovation, making smart homes an increasingly popular choice for homeowners seeking a more comfortable and connected living environment. This type of automation is fully without human inference compared with previous papers of home automation. Combining energy management features with home automation systems empowers users to have better control over their energy consumption, reduce waste, and ultimately save on energy bills. They promote sustainability and contribute to a greener and more energy-efficient in future.

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