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Smart Home Automation using Raspberry Pi, Motion Sensor and Android with Gesture based Controls

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Abstract— With the rapid growth of Smart Technology in the recent times, it has become imperative for us to explore different types of exciting automation systems concerning simple parts of life. One of these areas is Smart Home Automation that can control all the domestic appliances in one's house smartly and securely using innovative technologies like PIR Motion sensor and Voice Control. Our system aims at tackling the problem of manual labour associated with existing smart home automation systems by performing pre-defined, automated functions using intelligent sensors that are managed by a highly cost-effective and efficient Raspberry Pi. This system brings scalability, security and most importantly, ease-of-access to the smart home automation process by adopting a user-friendly Android app.

Index Terms— Raspberry Pi, PIR Motion Sensor, Relay, Android app, Home appliances, Gesture based controls, Python

1 Introduction

Today, in every aspects of our day-to-day life, we see Technology making things more efficient and easier to handle. Life itself is getting more and more adept and productive. It is becoming increasingly smart, secure and cheap. One of the major areas of life to automate is our own home. Smart home automation forms a major IoT-based process, in which all the domestic appliances used in one's own house communicate with each other to perform functions and act in a way desirable to the occupants.

In smart home automation, we can control all the devices and appliances in a house so that they perform functions like switch ON and OFF on our commands with a single tap or sound, track status of average electricity-consumption per month or year, give regular updates about each appliance's current status and more. It provides convenience, comfort, security and saves energy [1].

Automation makes not only an efficient but also an economical use of the electricity and water and reduces much of the wastage [2]. With increasing adoption of internet technologies like Wi-Fi and 4G, it has become easier to connect two things with each other, be it humans or devices. Due to the same reason, even controlling simple appliances in one's home has become progressively efficient. And because of this, home automation has also gained popularity.

By the rapid developments of new technologies, monitoring, controlling services have been started to be served along with internet as an instrument providing interaction with machinery and devices [3].

There is a need for a simple, efficient and accessible home automation system that works smartly according to the pre-defined settings set by the users. This will enable a simple home to turn into a truly Smart Home.

2 Review of Literature

Currently, there are many papers on home automation systems already published by different authors that provide similar functionality on a smaller scale.

For example, in "Smart Home Control by using Raspberry Pi & Arduino UNO", the system utilizes network-based Raspberry Pi 2 and Arduino Uno Microcontroller with an aim to provide flexibility and to lower the cost to the smart home automation process. However, this system requires many components, which adds to its complexity and cost [4].

One of the systems in "Internet of Things based Home Automation using Raspberry PI" describes the use of Internet of Things (IoT) concept to interface home appliances with each other using Raspberry Pi. This system, however, uses a web-based interface, which lacks the ease-of-access for its user [5].

Another unpopular system in "Home automation using Raspberry Pi" suggests making the use of an older version of Raspberry Pi, which does not contain inbuilt Wi-Fi support [6]. This increases the costs significantly, whilst also increasing complexity of the circuit.

However, our proposed system not only aims to be smart and efficient, but also simple, cost-effective and technologically up-to-date.

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3 Problem Statement

The proposed system consists of the following components:

i. Raspberry Pi 3:

The Raspberry Pi is a series of credit card-sized single-board computers developed in the United Kingdom by the Raspberry Pi Foundation [7]. The Raspberry Pi 3 was released in February 2016. Being the most recent version of the Pi, it has a feature set similar to the previous versions of the Raspberry Pi and it is backwards compatible with Raspberry Pi 1 & 2. The CPU speed of Raspberry Pi ranges from 700 MHz for Pi 1 to 1.2 GHz for Pi 3 and system memory, i.e. RAM, ranges from 256 MB to 1 GB respectively. Secure Digital (SD) cards are used to store the operating system and program memory in either the SDHC or Micro SDHC sizes. Most boards have between one and four USB ports, HDMI and composite video output, and a 3.5 mm phone jack for audio. The B-models have an Ethernet port, while the Pi 3 has on board Wi-Fi 802.11n and Bluetooth. Lower level output is provided by a number of General Purpose Input Output (GPIO) pins. The Pi 3 has 40 GPIO pins.

The access of the GPIO pins can be easily controlled using Python. The script will automatically make changes to the states of GPIO pins based on the configuration set by the user.

ii. ULN2803 Based Relay Board:

A Relay board is used for controlling higher current loads from a microcontroller development board, PC parallel port for Raspberry Pi or Arduino. This board has four (4) on-board relays which can switch up to 7Amps. A relay module with higher amperage can be used for high-load appliances. Relay terminals (C, NC, NO) are accessible through mounting which makes wiring up the board very easy. The relay is safely driven by ULN2803 IC hence the input device (such as Raspberry Pi), is protected from the relay circuit and the IC will further protect your microcontroller from relay kick back. This 12V 4-Channel Relay interface board which can be controlled directly by a wide range of microcontrollers such as Raspberry Pi, Arduino, AVR, PIC, ARM, 8051 and so on.

iii. HC-SR501 PIR Motion Sensor:

The Passive Infrared (PIR) sensor is responsible for detecting activity in any room. It does so by monitoring the changes in the heat signature of the room. A PIR sensor is an electronic device which is used in some security systems to detect an infrared emitting source [8]. Every living thing having temperature above absolute zero (i.e. -273.15°C) emit infrared radiation. Energy in this form is invisible to the human eye but is effortlessly detectable by electronic devices that are designed specifically for this purpose.

A PIR-based motion detector is used to sense movement of people, animals, or other objects. In some cases, PIR detectors instead of camera sensors are installed over the stairs in the building to count the passers-by [9]. They are also commonly used in burglar alarms and many other security systems. They are frequently called simply "PIR", or sometimes "PID", for "passive infrared detector" [10]. The Passive Infrared PIR sensors are moderately priced and are readily available in the market. Because of this, these sensors can be used innovatively in many advanced systems, without raising its cost.

iv. Android-powered Smartphone:

An Android app will be implemented as a part of this system. The main function of the Android app is to allow the user to configure the smart home automation system. The user can set his preferences which will determine the behaviour of the system in a particular scenario. This component will also increase the 'Ease-of-Access' functionality of this system.

The Android app will be developed using Java & the IDE is Android Studio.

This app will run on a basic Android smartphone with the following minimum requirements:

- Android Version 4.4 & above (API level 19)
- 25 MB free internal storage
- Wi-Fi 802.11 b/g/n

v. Microphone

The gesture based control feature will use a small microphone as Input to the system. The system will be able to recognise gestures such as a double clap. It provides a quick & easy way to control appliances.

4 Block Diagram

The system proposed in this paper aims to overcome the drawbacks provided by the existing smart home automation systems. It is simple, with a limited number of cheap and effective components, efficient and user-friendly. It also will be easily available, interactive and will facilitate the decrease in human efforts and electricity. It includes a Raspberry Pi 3, PIR Motion Sensors, a voice-input device like a Microphone, Relays, an Android-powered smartphone and a Wi-Fi router. The block diagram for the proposed system is as follows:

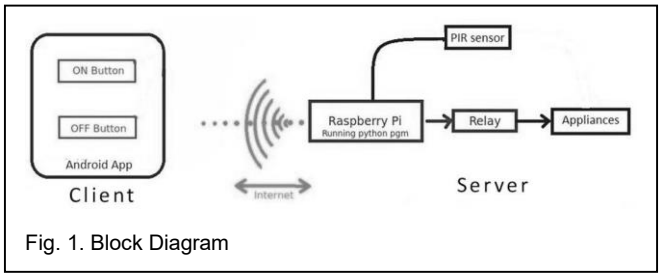

Fig. 1. Block Diagram

5 Working of the PIR sensor

PIR sensors will identify alterations in the infra-red radiation, in forms of the heat emitted by several bodies that includes human being, cars and other animals [11]. PIR sensor detects the change in infrared radiation of warm blooded moving object in its detection range [12]. A PIR motion sensor consists of a fresnel lens, an infrared detector and supporting detection circuitry. The lens on the sensor focuses any infrared radiation present around it towards the infrared detector. Our bodies generate infrared heat and as a result this gets picked up by the motion sensor [13].

Pyroelectricity is the ability of certain materials to generate

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a temporary voltage when they are heated or cooled [14]. A PIR sensor uses this concept in its working. It generally consists of a window equipped with a light filter on top of the pyroelectric sensor in order to filter out a specific wavelength of infrared light. Due to this, a PIR sensor detects motion of a human or a living thing, as it only absorbs the human IR radiation, leading to motion sensing. The detection radius of the sensor is approximately 6 metres.

Another thing to note is that PIR sensor is made up of crystalline material that generates a surface electric charge when exposed to heat in the form of IR [15].

6 Wireless Connectivity

The proposed system includes the use of an android app to monitor & control the smart home automation system. The app will allow the user to monitor current state of appliances and configure various parameters involved in the working of the system. The android app is expected to be on the same wireless network as the controller or needs a data connection. Connectivity will be achieved using HTTP Sockets. Sockets provide the communication mechanism between two devices using TCP. The client android app creates a socket on its end of the communication and attempts to connect that socket to a server. When the connection is made, the server creates a socket object on its end of the communication. The client and the server can now communicate by writing to and reading from the socket. A sequence of pre-determined characters is sent by the android app in the form of a string to carry out a command. After the execution of the command, server responds with an acknowledgement string. The socket server is implemented using Python. A script will make changes to the state of relays via GPIO pins based on the command.

7 Implementation

The smart home automation system is an autonomous system. Based on the configuration, the smart home automation system will monitor the environment using the PIR Motion Sensor. If it detects motion, the system will turn on the lights or other appliances based on the user preference. Once it stops detecting motion after a pre-configured time, the system will turn off the appliance.

Meanwhile if the system receives any command from the android app or from gestures, it will override the presence detection system. The smart home automation system connects to the internet using Wi-Fi. However, the user can be on local network or on a data connection. If on data connection, the commands will be addressed to a dynamic DNS server. The DNS server will forward the command to the current IP address of the server. Whereas on the local network, local IP of the server will be addressed.

The appliances will be controlled using Relays. In layman's term, relays are switches operated by wire. When power is supplied on the low voltage side, the circuit completes on the high voltage side. When power is disconnected, the high voltage circuit is cut.

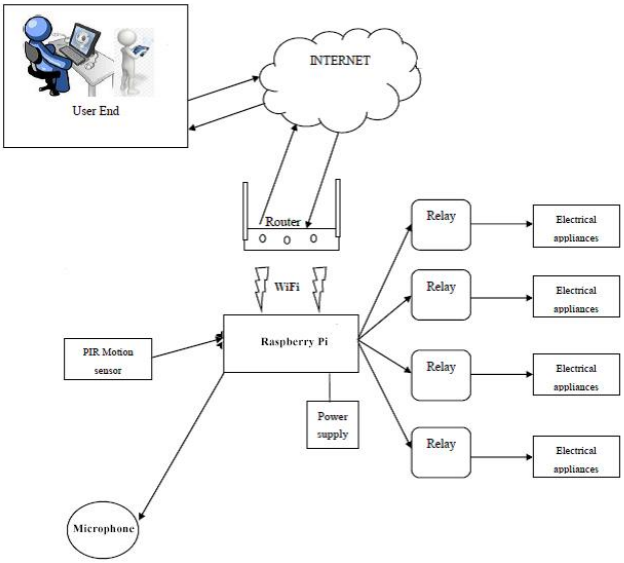

Fig. 2. Working of the system [18]

8 Benefits

Smart home automation can offer many benefits. In this section, we present some examples that illustrate how home automation can be used to better manage consumption of energy. Several measures can be taken in order to reduce consumption and achieve a better balance between expenditure and comfort.

As an example, consider home lighting. This can account for a significant part of the electric bill, particularly if incandescent bulbs are used instead of high efficiency ones like LEDs. With smart home automation, lights and other electrical appliances can be controlled automatically by using presence detection. This can be especially handy in the case of children and physically challenged people, who may not turn off any lights.

Time-based programming can be used in conjunction with presence detection to provide a good functionality and also increase security. The measures described can contribute to significant savings, while keeping adequate levels of comfort.

Heating and cooling is typically one of the areas with more impact in energy consumption. In this domain, home automation can also offer many benefits as it can perform intelligent control, taking into account rooms which are occupied and vacant. This can be further improved using Location Tracking. Whenever the user comes in near vicinity of home, the heating /cooling system will turn on automatically. This improves upon comfort without compromising the energy savings for the user.

Another area where a home automation system can help reduce the energy bill relates to the ability to program the

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working times of appliances such as water heaters. This minimizes the energy wasted by having the water heaters turned on 24x7.

In this section, our main aim is to briefly point out several areas of intervention where home automation can offer benefits regarding a more rational use of energy. It has also been our intention to show that the best results require a basic level of control over the electrical systems. Current solutions that offer the needed flexibility are extremely expensive & designed for corporate use with a requirement for technical support. The proposed system is extremely simple & cost effective. The main focus of this system is to bring home automation to homes of common people at a price they can afford.

9 Conclusion

In the rapidly growing and ever-changing world of technology, it is necessary to explore the area of Smart Technology as much as possible. It is also crucial to implement current trends in technology to improve quality of life. With excellent devices like the Raspberry Pi 3, which stores and processes information at fast speeds, the PIR Motion Sensor, which tracks changes in temperature efficiently and economically and Android-powered smartphones, which improve accessibility of the user to different kinds of information systems, now is the time to use it to the advantage to construct a smooth, productive and inventive home automation system that helps all [16].

Not only industrially but also domestically, using simple scripts and programs and with the right combination of devices, we can fulfil our goal of implementing the Internet of Things (IoT) concept in our daily routine and make a truly Smart Home a reality. A smart home automation system like this one will prove to be beneficial for the rich and the poor alike, decrease the day-to-day power consumption, increase the security in everyone's homes, reduce human efforts greatly and solve many problems related to flexibility of control in home appliances [17]. With the right dedication, this system will also serve as a platform for future growth in an Artificial Intelligence (AI) powered smart home and any similar areas of technology.

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