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HOME AUTOMATION USING IOT LINKED WITH FACEBOOK FACIAL RECOGNITION

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ABSTRACT

In recent years, the world has seen a lot of progress in automated home systems. The existing home automation systems are basic: turning switches on/off, etc. over the Internet. But this leaves a lot to be desired in the Home Security department. While there are systems that let you view your security camera feed, this is highly time consuming and counter-productive. Pressing of buttons also needs to be replaced with a voice-to-text and a text-to-voice feedback system to enable ease of access. Also, using the Internet servers to control devices makes the systems prone to server-related issues like lag when the servers are overloaded, etc. Hence, there is a need to access the devices in Real Time. This paper deals with all of the above mentioned issues. It deals with the idea of using PubNub Networks as a real time operator, and using facial recognition interfaced with the Facebook account of the home owner to make the surveillance of homes more time saving and accurate, and usage of a mobile application-based interactive feedback system.

Keywords: internet, home security, real time, PubNub, Facebook.

1. INTRODUCTION

Home automation allows us to focus on getting our work done without worrying about the safety and security of our home, while enabling us to control the appliances in our home on the go. All of our devices and appliances are networked together to provide us with a seamless control over all aspects of our home and more. Home automation has been around from many decades in terms of lighting and simple appliance control, and only recently has technology caught up for the idea of the interconnected world, allowing full control of your home from anywhere, to become a reality. With home automation, you dictate how a device should react, when it should react, and why it should react. Home automation is a necessity these days as it helps save up on power consumption, makes our homes more secure, provides a way to monitor our home when we are away, and makes our home secure in every way possible.

2. EXISTING ARCHITECTURES

The existing Home automation architectures available in the market today are:

A. Bluetooth based home automation

It is cheap and secure. It has a low range (10 to 100 meters). It uses 2.4GHz bandwidth and the speed can be up to 3Mbps. Some of its drawbacks are its low range, the fact that it takes a long time to discover and connect to devices, and that real time access is not possible using Bluetooth.

B. Phone based Home automation

In this, the system can be accessible from anywhere with a telephone line [1]. It doesn't provide Real time control. It is fast, but because DTMF has only 12 frequencies, maximum of 12 devices can only be controlled. Two phones are required: one to which the circuit is connected, and the other from which the call is to be made.

C. ZigBee based Home automation

ZigBee based architecture provides high security due to end-to-end encryption. It uses two microcontrollers- one on the transmitter side, another on receiver side. It has a low range and isn't that fast.

D. Wireless based Home automation

In this architecture, IoT and Wi-Fi are used to communicate between the controller and the devices [2]. Various devices can be connected using different networking techniques. It also provides the added benefit of providing speech based command support [3].

E. Existing IoT based Home automation

These use internet servers to communicate between controller and devices [4]. If there is a server overload, or if the server crashes, the system can be rendered useless. Therefore, there is a need to overcome this problem.

As we can see, the existing home automation architectures have something or the other working against them, making them either unreliable, or limited in some way. Therefore, there is a need to address these issues in order to make a stable, more expansive home automation system that can be used by everyone in their homes.

3. PROPOSED ARCHITECTURES

The proposed system architecture uses a Raspberry Pi (microprocessor) as the core of the system. The Pi is a tiny computer about the size of a credit-card, and it features a processor, RAM and all the important hardware ports that can be found in a computer. Then

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ARPN Journal of Engineering and Applied Sciences

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there is also an iOS-based Mobile application with a User Interface to control the device in specific rooms of the home. Along with this, a PIR sensor is used, which is linked to a PiCamera (an 8MP camera). This is then linked to the Facebook account of the user to provide an accurate identification of the person who has triggered the sensor, provided the user has them on their friends' list. Relays are used instead of normal switches as they can be triggered with a low voltage change. A temperature and humidity sensor is also used to measure and communicate the readings of the home to the user's mobile application directly. Raspberry Pi, cloud server and the mobile app are connected using lower latency network which is called PubNub network. PubNub is a secure global Data Stream Network (DSN) and easy to use API that enables its customers to connect, scale, and manage real time applications and IoT devices. Raspberry Pi controls all the IOT devices and gets the input from the cameras and sensors and processes them for real time communication.

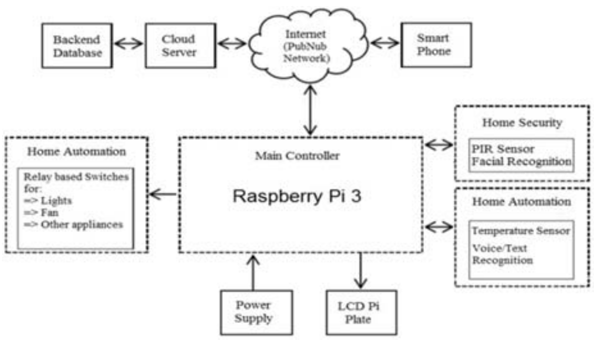


Figure-1. Block diagram of proposed architecture.

4. COMPONENTS USED

A. Raspberry PI 3

Raspberry Pi 3 is the third generation Raspberry Pi. It has a 1.2GHz 64-bit quad-core ARMv8 CPU. It uses Bluetooth 4.1 and Bluetooth Low Energy. Along with that, it has a 1GB built-in RAM, 4 USB ports, a HDMI port, an Ethernet port and a combined 3.5mm audio jack and composite video. It also has a direct Camera Interface and a Display interface. Along with this, it has a micro-SD card slot, and built-in 3D graphics card.

Figure-2. Raspberry Pi model 3B.

B. PIR Sensor

The PIR sensor is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. It can be interfaced directly with the Raspberry Pi 3 and can send the readings to it. The readings can then be read and necessary steps can be taken.

C. DHT11 temperature and humidity sensor

It is a basic, low-cost digital temperature and humidity sensor. It uses capacitive humidity sensor and a thermistor to measure the surrounding air, and gives a digital signal on the data pin.

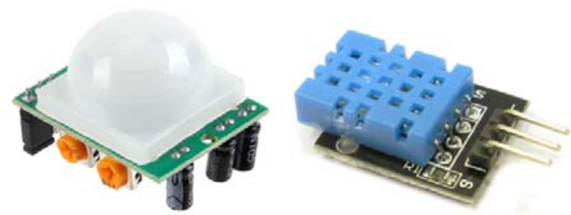


Figure-3. PIR sensor and DHT11 sensor.

D. PiCamera

The PiCamera is an 8 megapixel camera that can be interfaced directly with the Raspberry Pi.

Figure-4. PiCamera.

E. Miscellaneous components

A Microphone and speaker system is also used to assist with the text-to-voice and voice-to-text conversion. 3.5inch LED Screen that can be interfaced with the Raspberry Pi is also used to help set up the device.

5. WORKING

A. The PIR sensor and PiCamera

Having a camera monitor the home 24x7 can be really expensive, considering the storage and power consumption. This can be overcome by using the PIR sensor as a trigger to start running the camera. When there is a visitor at the door, the PIR sensor detects the movement. If there is movement for a specific amount of time (say, 2-3 seconds), the PIR sensor triggers the PiCamera, which then takes a photo of the visitor and sends it to the owner of the home. This helps the owner monitor what is going on around his/her home without spending a fortune on the storage and power consumption.

B. The temperature and humidity sensor

When triggered, the temperature and humidity sensor record the temperature and humidity in their location for a specified number of times (say, 10 times), since the readings might not be accurate on the first try. The system is then programmed to take a mode of the readings, which is, isolate the reading occurring the highest number of times and sending it to the user.

C. Face recognition using machine learning

In our project, we'll be using Facial recognition that is linked with the Facebook account of the user, in order to provide access to people whom the user is acquainted with, and thereby eliminating the need for duplicate keys.

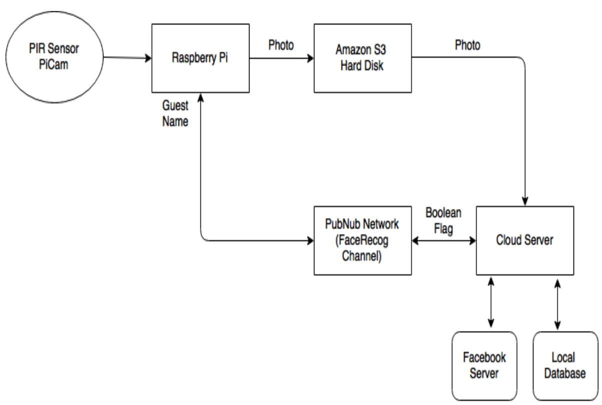


Figure-5. Block diagram of facial recognition.

Nowadays, we can see that Facebook automatically recognizes the faces of our friends whenever we post any photo. With almost 98% accuracy, it is probably as good as any human. Merely recognizing faces is easy in terms of today's technological prowess. But the challenge lies in distinguishing between similar looking people, like sibling or direct relatives.

But before tackling that, we need to look at how face recognition actually works.

- Firstly, finding all the faces in the picture.
- Secondly, making sure that the machine recognizes a face as that of the same person, even if it is turned in a weird direction, or is in bad lighting.
- Thirdly, picking out the unique features of the face, like size of eyes, shape of the face, etc., to tell the person apart from other people.
- Lastly, comparing the unique features of that face to all the people we already know to determine the person's name.

Our brain is hardwired to do all this subconsciously and instantly. But computers aren't able to do such computations. So each step has to be considered a problem, and then be solved. A *pipeline* is required to solve each of these steps, and to pass the result to the next step. Hence, the following steps are followed:

A. Finding all the faces: First, the image is made black and white, as color data is not needed to find faces. Next, every pixel is scrutinized by looking at the pixels surrounding it. This is done to figure out the comparative darkness of the pixel when compared with its surrounding pixels. An arrow is used to show the direction in which the image is getting darker. This process is repeated for every pixel in the image.

Figure-6. Sample image (Black and white).

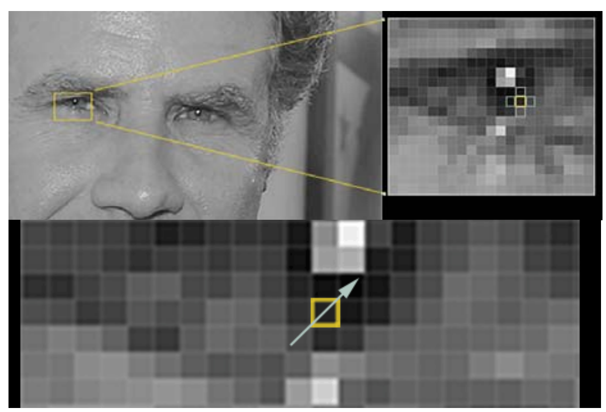


Figure-7. Analyzing Pixels and replacing them with Arrows.

These arrows signify the gradients in an image, showing the flow from light to dark in the image. This is done so that difference in lighting of the image doesn't hinder the facial recognition. Thus, dark and light images will end up with the exact same representation.

Since this is way too much data to be stored, the image is divided into 16x16 square pixels. Each square is then replaced with an arrow pointing in the direction that has occurred the most in it. This leaves us with a very simple representation that captures the basic face structure. The idea is to reduce the entire data acquired through the scanning and reading of the face into data that the computer can easily analyze in a short period of time to reduce the computation delay.

This is a Histogram of oriented Gradients image, or HOG image. By generating many HOG images of the

VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

same person, a HOG pattern can be derived, which can be used to correlate with the face that is to be detected and thereby recognizing it.

B. Faces turned in different directions: To overcome this, we need to represent the face in such a way that the eyes and lips are always in the same place in the image, thereby making comparing of faces easier. This is done by Face Landmark Estimation (invented by Vahid Kazemi and Josephine Sullivan in 2014). What this does is it comes up with 68 specific points (or landmarks) that occur on every face, like the edge of the lips, or the tip or the nose, etc. Then the machine is trained to find these points on the face of any person. This gives us the exact location of the eyes and mouth, enabling us to rotate, scale and shear the image so that these are as centered as possible.

Figure-8. The HOG image received by analyzing multiple images of the same Person.

What this does is it gives all the pictures of any given person a specific orientation. So, whatever the pose of the person is in that image, the face can still be easily recognized as the basic features will always be positioned in the same manner. This is a necessary step, as the computer cannot process faces like humans do. It needs data to be presented in a way that it understands and can analyze easily. Since a large delay in recognizing the face is counter-productive, it is mandatory that the image be presented in as simple a data as possible for the computer to easily process it in a minimal amount of time.

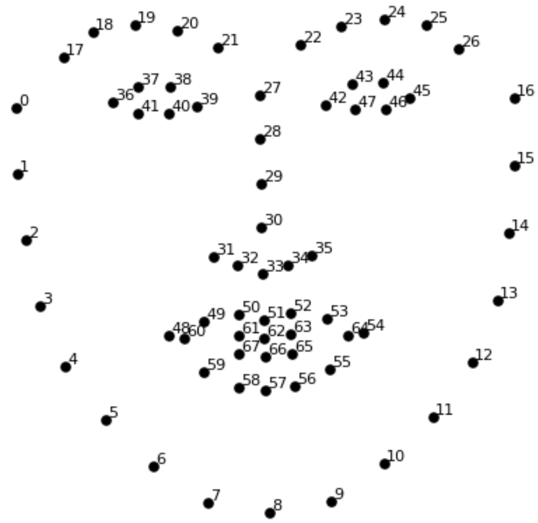
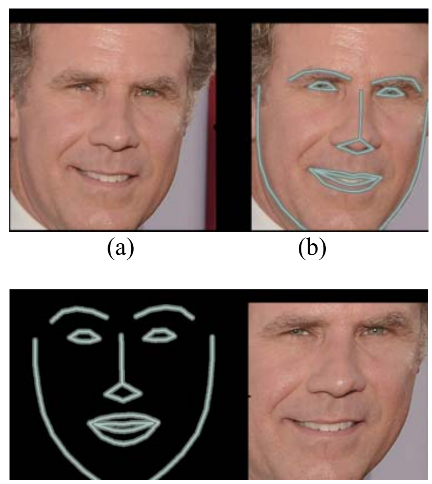


Figure-9. The basic 68 Landmarks that can be found on any given face.



(a) (b)

(c) (d)

Figure-10. (a) Face area detected in image. (b) Face landmarks detected. (c) Perfectly centered result that's wanted. (d) Face transformation to be as perfectly centered as possible.

C. Distinguishing faces: Rather than always going through old images of the same person to compare with the given image to come up with a match, which is both time consuming and counter-productive, a method needs to be used to recognize faces in the blink of an eye.
For this, some measurements of each face have to be extracted. Then, the unknown face can be measured in the same way, and the known face with the closest measurements can be found. The extractions of the measurements have to be done by the computer on its own. This is done using Deep Convolution Neural Network. This will be used to train the system to generate 128 measurements for each face.
This works as follows:

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a) Take the training image of known person.

b) Take another picture of same person.

c) Take the picture of different person.

Then, the algorithm tweaks the neural network to make sure that the measurements for #1 and #2 are closer and that of #2 and #3 are slightly different. This machine learning of the 128 measurements of each face is known as an Embedding. It helps break down complicated data like images into a series of computer generated numbers.

The next step is to train the neural network to output a face embedding. This is time consuming and requires a lot of computing power and data. But it can generate measurements of any face once it has been trained. This training is a one-time thing. Then we can run any face through the trained network and the 128 measurements are generated. We don't really know what measurements are being generated, but the fact that the neural network gives us nearly the same numbers for different images of the same person tells us that it is pretty accurate.

Input Image

128 Measurements Generated from Image

0.097496084868908	0.045223236083984	-0.1281466782093	0.032084941864014
0.12529824674129	0.060309179127216	0.17521631717682	0.020976085215807
0.030809439718723	-0.01981477253139	0.10801389068365	-0.00052163278451189
0.036050599068403	0.065554238855839	0.0731306001544	-0.1318951100111
-0.097486883401871	0.1226262897253	-0.029626874253154	-0.0059557510539889
-0.0066401711665094	0.036750309169292	-0.15958009660244	0.043374512344599
-0.14131525158882	0.14114324748516	-0.031351584941149	-0.053343612700701
-0.048540540039539	-0.061901587992907	-0.15042643249035	0.078198105096817
-0.12567175924778	-0.10568545013666	-0.12728653848171	-0.076289616525173
-0.061418771743774	-0.074287034571171	-0.065365232527256	0.12369467318058
0.046741496771574	0.0061761881224811	0.14746543765068	0.056418422609568
-0.12113650143147	-0.21055991947651	0.0041091227903962	0.089727647602558
0.061606746166945	0.11345765739679	0.021352224051952	-0.0085843298584223
0.061989940702915	0.19372203946114	-0.086726233363152	-0.022388197481632
0.10904195904732	0.084853030741215	0.09463594853878	0.020696049556136
-0.019414527341723	0.0064811296761036	0.21180312335491	-0.050584398210049
0.15245945751667	-0.16582328081131	-0.035577941685915	-0.072376452386379
-0.12216668576002	-0.0072777755558491	-0.036901291459799	-0.034365277737379
0.083934605121613	-0.059730969369411	-0.070026844739914	-0.045013956725597
0.087945111095905	0.11478432267904	-0.089621491730213	-0.013955107890069
-0.021407851949334	0.14841195940971	0.078333757817745	-0.17898085713387
-0.018298890441656	0.049525424838066	0.13227833807468	-0.072600327432156
-0.011014151386917	-0.051016297191381	-0.14132921397686	0.0050511928275228
0.0093679334968328	-0.062812767922878	-0.13407498598099	-0.014829395338893
0.058139257133007	0.0048638740554452	-0.039491076022387	-0.043765489012003
-0.024210374802351	-0.11443792283535	0.071997955441475	-0.012062266469002
-0.057223934680223	0.014683869667351	0.05228154733777	0.012774495407939
0.023535015061498	-0.081752359867096	-0.031709920614958	0.069833360612392
-0.0098039731383324	0.037022035568953	0.11009479314089	0.11638788878918
0.020220354199409	0.12788131833076	0.18632389605045	-0.015336792916059
0.0040337680839002	-0.094398014247417	-0.11768248677254	0.10281457751989
0.051597066223621	-0.10034311562777	-0.040977258235216	-0.082041338086128

Figure-11. Input image, and the 128 measurements that are generated.

D. Finding the name of the person from the Encoding: For this, we need to run the measurements through the database of the people known to the user, and isolate the person with the closest measurements. This can be done by any machine learning classification algorithm. A classifier can get the measurements from any image and tell us who the closest match is.

D. Talk-back feature (Voice-to-text and text-to-voice)

The system also has a talkback feature, using which we can control the devices without pressing any buttons. This is done using API.AI. The features in api.ai help us develop a conversational function, which can be incorporated into the mobile application. This enables the system to listen to the queries made (in the voice format, which is converted to text), analyze it, and then respond in a way that was specified by the coder.

Api.ai has agents, which use machine learning algorithm to understand the user requests by matching it to specific intents that have been defined. It also uses entities to get relevant data from them. These agents learn from the data that has been provided in it, and from the language models developed by API.AI. On the basis of this, it builds a model that makes a decision of triggering which intent by which user data and what data has to be extracted from it. This model adjusts in accordance to the changes that have been made in the agent and the API.AI platform. The agent has to be trained on real conversation logs in order to improve it.

Any command that the user gives can be turned into a structured object that the agent can understand. It uses Intent Recognition and recognizes what the user means. For our project, it isolates the state (switched on/off), the device (lights, etc.), and the room for which the action needs to be taken (bedroom, kitchen, etc.). So, if the user says “Turn on the Bedroom Lights”, it’ll set the state to “on” for the Lights in the Bedroom. Then the bot is also trained to understand context, so that it can link multiple commands and perform the required action.

For the talkback feature, various replies have been entered to the various queries. The bot can also be trained to say specific things for specific situations, like, if it didn’t register what the user said, the message “I didn’t understand” can be said. This has been done, and the bot can do basic conversations.

E. Controlling switches

A home automation is not complete without the ability to turn switches on/off. This is done by using Relays. Relays are switches that can be triggered by passing a very low current through it, thereby controlling a much larger current through the smaller current. Hence, if we give the command to the microcontroller to turn the relay off, it can do it easily by sending a low current. Thus, appliances connected to the relay can be turned on/off.

F. Mobile application

VOL. 12, NO. 17, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Figure-12. User interface of the mobile application.

The system also features a mobile application that acts as an interface between the user and the system. It provides all the necessary functions that are needed to control the different appliances in the home of the user.

6. RESULT

- **Temperature and humidity sensor:** The readings from the DHT11 sensor are recorded and sent to the server. They can either be viewed on the mobile application, or the bot can be asked to tell us the readings via speech.
- **PiCamera and PIR sensor:** The PIR sensor, when triggered, activates the PiCamera and the camera then takes the picture of the intruder. This image can be viewed.
- **Facial recognition:** The image captured by the PiCamera runs through the facial recognition process. The result of the same is then displayed, or given as speech by the bot.
- **TalkBack feature:** The talkback feature is done for any result the system obtains. Also, any command given by the user in speech format is converted to text, comprehended by the AI, and the desired function is performed. Then the result is spoken back through the speakers.
- **Mobile application:** The different lights in different rooms can be triggered using the Mobile application. Also, the readings from the DHT11 sensor can be viewed here.

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