Smart Furniture Automation with IoT and a Chatbot using Natural Language Processing

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***Abstract*—Smart furniture automation - controlling the fans, lights and other electrical appliances in a house using Internet of things is widely preferred in recent days. In this paper, we propose a web application using which the fans, lights and other electrical appliances can be controlled over the Internet. The important features of the web application is that firstly , we have a chatbot algorithm such that the user can text information to control the functioning of the electrical appliances at home. The messages sent using the chatbot is processed using Natural Language processing techniques. Secondly, any device connected to the local area network of the house can control the devices and other appliances in the house. Thirdly, the web application used to enable home automation also has a security feature that only enables certain users to access the application. And finally, it also has a functionality of sending an email alert when intruder is detected using motion sensors.**

Keywords—Raspberry Pi, Chatbot, WebApp, WebIOPi, NLP, Azure, SMTP server.

I. INTRODUCTION

The global home automation system market is expected to grow from USD 32.11 Billion in 2015 to USD 78.27 Billion by 2022, at a CAGR of 12.46 between 2016 and 2022[1]. Home Automation is advancing nowadays and it can be seen in different fields .There are many technology platforms available for home automation. Using each of these platforms a smart home can be built. The basic principle behind these platforms is that each platform communicates to different connected devices and instructs them to perform a specific function.

Selecting a smart home protocol is itself considered a challenging task as a protocol that supports a large number of devices is need. Further, it must also provide the devices with the ability to talk to each other. Apart from this, there are also other factors that must considered like power consumption, bandwidth, cost, etc. The average customer would be interested in the features that are provided by home automation. The Museum of Science and Industry in Chicago says that more than 300,000 guests have toured its Smart Home exhibit since its debut in May 2008. So there rises a need to implement home automation in the best way to satisfy the user in all sense. There exist several technologies since a long time namely UPB and X10 and many relatively newer technologies like Z-Wave, ZigBee, Wi-Fi and Bluetooth [2-3].

UPB or Universal Powerline Bus is a Wire technology similar to the X10. This technology uses the existing power lines of the home which reduces the cost to send signals to control the devices in the house. While UPB and X10 are reliable powerline systems, it is difficult to combine with latest wireless technologies like Wi-Fi, Smartphone's, etc. Among wireless home automation protocols, Z-Wave that runs on the 908.42 MHz frequency band is popular because Z-Wave protocol uses a much lower band than the one used by most household wireless products (2.4 GHz). Hence, it is not affected by the interference of household wireless products. A problem in this protocol is that all the devices must be Z-Wave compatible. ZigBee is also a wireless home automation protocol. Its full acceptance is limited by the lack of interoperability between ZigBee devices[10-11]. Bluetooth protocol[5] has higher data bandwidth but its range is limited. With the new Bluetooth Low Energy technologies the power consumed by Bluetooth devices has been reduced. Home automation using Wi-Fi[8][9] or LAN is one of the most reliable systems. This system has a good range and data bandwidth. Although, the Wi-Fi based systems have interference from other Wi-Fi based devices.

Chatbots are slowly replacing applications on hand-held devices because of their ease of use and intelligence. According to a recent report from Business Insider, nearly 80% of companies have already used or plan to use chatbots by 2020[7]. Chatbots owe their intelligence to natural language processing techniques. Ideal chatbots must have the ability to understand context of a conversation, learn from the conversations and improve itself over time. This can be achieved through various machine learning and deep learning techniques.

Natural Language Processing (NLP) is a prominent field of Artificial Intelligence. Natural Language Processing is the processing of natural language in order to derive meaning from it. It helps the computer to understand text like humans do. Natural Language Processing has a lot of useful applications in Machine Translation, Information retrieval, Question Answering and a lot of other important fields.

In the proposed system, some basic techniques of Natural Language Processing like tokenization, removal of stop-words and parsing are used. The proposed system uses Wi-Fi based local area network protocol. The problem of interference can be solved if a specific local area network is given to each application. The proposed system controls the fans, lights and other device of a home using a web app over LAN. Messages for controlling devices can also be sent through a chatbot.

II. PROPOSED METHODOLOGY

A. Architecture of the proposed system

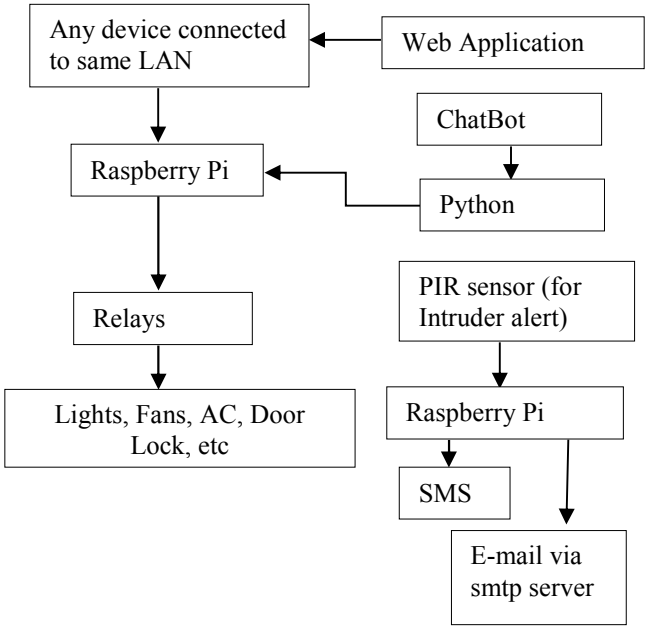

Fig. 1. Block diagram for proposed system.

B. Components Required:

1) Software Requirements

- Raspbian: A Debian based computer operating system for Raspberry Pi.
- Python: It is an open source programming language that is supported in Raspberry Pi.
- WebIOPi: It is a software for Raspberry pi that enables GPIO control over Local Area Network using a Web App.
- NLTK: Natural Language ToolKit for Natural Language Processing[6] .
- Microsoft Azure Server: It is an online cloud server that which host the web application and the chatbot algorithm.
- IFTTT: "If This Then That" approach for mail and SMS alerts.

2) Hardware Requirements

- Raspberry Pi with Wi-fi module: Raspberry Pi is a single board computer which runs on Linux based operating system and is best suited for IoT[12].
- PIR Motion Detector and Relay Board
- Electrical Lock for Door
- Temperature Sensor DHT11
- Router

III. IMPLEMENTATION

Step-1: Setting up the Raspberry Pi with WebIOPi

Open LX Terminal on the Raspberry pi and run the below codes for installation.

```
$wget http://sourceforge.net/projects/webiopi/files/WebIOPi-0.7.1.tar.gz
$ tar xvzf WebIOPi-0.7.1.tar.gz
$ cd WebIOPi-0.7.1
$ sudo ./setup.sh
$ sudo /etc/init.d/webiopi start
```

Access WebIOPi over local network URL with any of the device available in the user network. The URL of the network can be used to access the GPIO control of the Raspberry Pi from any device connected to the network.

Step-2: Creating the Web App to control fans and lights using Hyper Text Markup Language and Cascading Style Sheets. The code has an embedded Javascript for the Raspberry Pi's GPIO control which is given in Fig 2.

```
webiopi().ready(function() {

    webiopi().setFunction(17,"OUT");
    webiopi().setFunction(27,"OUT");
    webiopi().setFunction(22,"OUT");
    webiopi().setFunction(10,"OUT");
    webiopi().setFunction(9,"OUT");

    var button = webiopi().createGPIOButton(17, "BEDROOM LIGHT");
    $("#controls").append(button);
    button = webiopi().createGPIOButton(27, "KITCHEN LIGHT");
    $("#controls").append(button);
    button = webiopi().createGPIOButton(22, "BEDROOM FAN");
    $("#controls").append(button);
    button = webiopi().createGPIOButton(10, "KITCHEN FAN");
    $("#controls").append(button);
    button = webiopi().createGPIOButton(9, "MAIN DOOR");
    $("#controls").append(button);

            webiopi().refreshGPIO(true);
});
```

Fig. 2. Javascript code for GPIO control.

Step-3: Making the connections with the raspberry pi and the devices. The fans, lights, door lock and other appliances in the room are connected to the Raspberry Pi. A temperature sensor is also connected to the Raspberry Pi. The connections of the sensors and the appliances with the Raspberry Pi is as given in Fig 3.

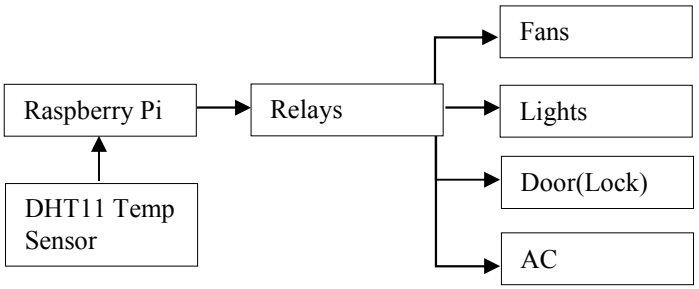

Fig. 3. Block diagram for connection to Raspberry Pi.

Step-4: Implementation of the intruder alert algorithm starts with the inputs for the PIR motion sensor being read continuously. If the sensor detects motion in the room, it checks if the door is closed or not. If door is not closed the algorithm does nothing and goes back to monitoring sensor inputs. If door is closed then a mail alert is sent to the owner of the house using SMTP server. Using IFTTT an SMS is also sent. The algorithm for the intruder alert algorithm is given in Fig 4. The code for sending the mail using SMTP server is as given in Fig 5.

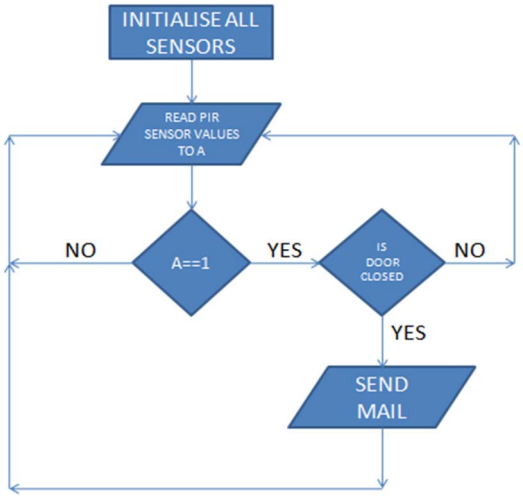

Fig. 4. Block diagram for intruder alert algorithm.

```
import smtplib
from email.MIMEMultipart import MIMEMultipart
from email.MIMEText import MIMEText

fromaddr = "zzhan145@illinois.edu"
server = smtplib.SMTP('smtp.gmail.com', 587)
server.starttls()
server.login(fromaddr, "icelove@1")
msg = MIMEMultipart()
msg['From'] = fromaddr
msg['Subject'] = "INTRUDER ALERT"
body = "Intruder detected at home. Please take necessary actions immediately."
msg.attach(MIMEText(body, 'plain'))
text = msg.as_string()
toaddr = "uraniazhanglileo@gmail.com"
msg('To') = toaddr
server.sendmail(fromaddr, toaddr, text)
server.quit()
f.close()
```

Fig. 5. Code for intruder alert algorithm.

Step-5: Implementation of the chatbot is primarily divided into two phases namely Setup phase and Use phase. The setup phase will ask the user for information required to setup the chatbot. Once the configuration of the chatbot is complete, it will have information of the number of appliances in each room of the house. The use phase will enable the users to ask the chatbot to perform various activities ranging from switching the lights and fan on/off to setting timers for the same.

The questions asked to the user in the setup phase and the use phase are shown in Fig. 6. In the setup phase, the chatbot will take in crucial information like number of rooms and the number of appliances in each room of the house.

The Use phase allows the user to command the chatbot to control all connected appliances. The use phase uses various Natural language processing techniques to process the instructions provided by the user. Once the user gives the chatbot an instruction, the following techniques are applied to the text:

I. **Tokenization:** The sentence is split into words by using a function named *word_tokenize* from the Natural Language Toolkit (NLTK)[4][7].

II. **Conversion into lowercase:** All words in the given text are converted into lowercase to maintain uniformity and make further processing easier.

III. **Removal of stop-words:** Stop-words are words which do not contribute to the meaning of a sentence individually. For example: *a, the, an, all*. All words are checked with a predefined list of stop-words, and they are removed if there is a match.

IV. **Defining keyword and action lists:** Two lists namely keywords and actions are defined in the algorithm. The keywords list contain all possible keywords relevant to this case. For example: light, fan, room, door, temperature and so on. The actions list contains all possible words that denote an action in this setup. For example: increase, decrease, switch, set, open, close and so on.

V. **Understanding keyword and action:** Now, the processed words are matched to the keyword and action lists to identify the keyword and action specified in the instruction.

VI. **Actuation:** Based on the keyword and action identified in the previous step, the relevant action is taken. For example, if the keyword is door, and the action word is close, then the door variable will be set to false, which in turn will send a signal to the Raspberry Pi to close the door.

Setup phase
Enter passkey.
How many rooms does your house have?
How many lights are there in room 1?
How many fans are there in room 1?
How many appliances are there in room 1?

Use phase
Switch on light 1 of room 1
Set timer for fan 1 of room 1 to 1 hour.
Status of appliances of room 1.
Decrease the temperature of room 1.
Switch on all lights of room 1.
Close door.

Fig. 6. Sample instructions for use and setup phase.

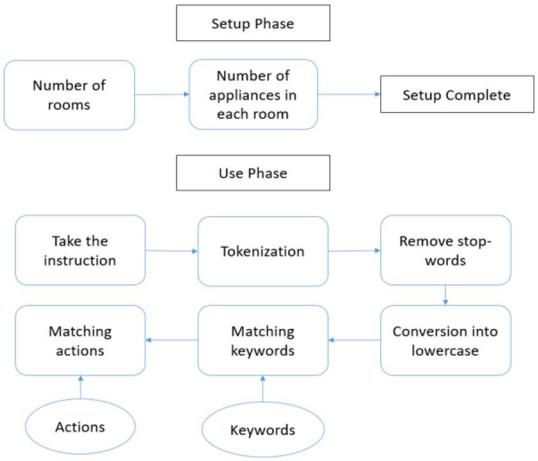

Fig. 7. Algorithm of Chatbot

Step-6: The architectural setup is that the web application developed in step 2 and the chatbot algorithm proposed in step 5 are stored on a web server. The web client and the application for the chatbot will interact with the web server. The client application and the web application will receive the queries, process it on the server and send it over to the Raspberry Pi to perform the control tasks. Once the task is completed, the Raspberry Pi sends an acknowledgement signal back to the server and hence to the client. Thus, the user is notified about the successful completion of the task.

IV. TESTING

These are the results of the testing phase.
In Fig. 8 the setup phase of the chatbot algorithm is shown and Fig. 9 shows the use phase case of turning on a light.

```
Hey there!I need to know some basic details before we start!

How many rooms do you have?
2
How many lights do you have on room 1?
3
How many fans do you have on room 1?
4
How many lights do you have on room 2?
2
How many fans do you have on room 2?
2
How many appliances are there in room 1?
2
What is the name of appliance 1?
AC
What is the name of appliance 2?
Television
How many appliances are there in room 2?
2
What is the name of appliance 1?
AC
What is the name of appliance 2?
Television
Room x Lights

       Light 1  Light 2  Light 3
Room 1       0        0        0
Room 2       0        0        0

[2 rows x 3 columns]
Room x Fans

       Fan 1  Fan 2  Fan 3  Fan 4
Room 1     0      0      0      0
Room 2     0      0      0      0

[2 rows x 4 columns]
Room x Appliances

       AC  Television
       AC  Television
Room 1  0           0
Room 2  0           0

[2 rows x 2 columns]
```

Fig. 8. Setup phase

```
Hey there!
We are ready to go!

Go ahead and give me some instructions.
Switch on light 2 of room 2
0
Room x Lights

       Light 1  Light 2  Light 3
Room 1       0        0        0
Room 2       0        1        0

[2 rows x 3 columns]
Room x Fans

       Fan 1  Fan 2  Fan 3  Fan 4
Room 1     0      0      0      0
Room 2     0      0      0      0

[2 rows x 4 columns]
Room x Appliances

       AC  Television
       AC  Television
Room 1  0           0
Room 2  0           0

[2 rows x 2 columns]
Door: Open
```

Fig. 9. Use phase - Switching a light on

Fig 10 shows the use phase cases for switching on all lights and closing the door

```
Okay,tell me what to do next.
Switch on all fans of room 1
0
Room x Lights

       Light 1  Light 2  Light 3
Room 1       0        0        0
Room 2       0        0        0

[2 rows x 3 columns]
Room x Fans

       Fan 1  Fan 2  Fan 3  Fan 4
Room 1     1      1      1      1
Room 2     0      0      0      0

[2 rows x 4 columns]
Room x Appliances

       AC  Television
       AC  Television
Room 1  0           0
Room 2  0           0

[2 rows x 2 columns]
Door: Open
Go on,give me another task.
Close the door
0
Room x Lights

       Light 1  Light 2  Light 3
Room 1       0        0        0
Room 2       0        0        0

[2 rows x 3 columns]
Room x Fans

       Fan 1  Fan 2  Fan 3  Fan 4
Room 1     1      1      1      1
Room 2     0      0      0      0

[2 rows x 4 columns]
Room x Appliances

       AC  Television
       AC  Television
Room 1  0           0
Room 2  0           0

[2 rows x 2 columns]
Door: Close
```

Fig. 10. Use phase - Switching on all fans and closing the door

V. RESULTS

The proposed system has a web application and a chatbot application to control the devices at home. The Web application (shown in Fig 11) is hosted on the local area network and any device connected to the same network can access it. There is a password for the app (shown in Fig 12) to enable security against unwanted users and to reduce unnecessary traffic in the network.

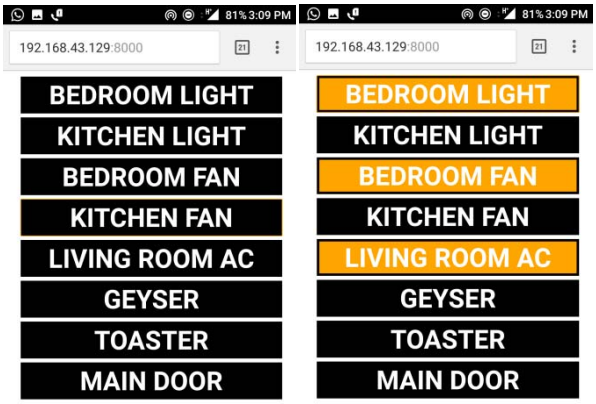

Fig. 11. Web Application on the local area network

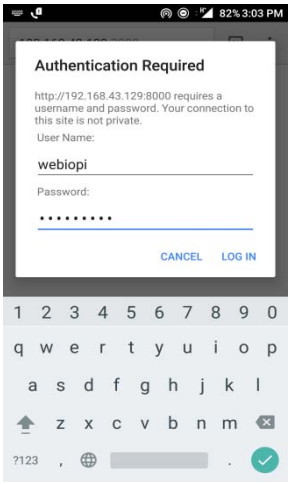

Fig. 12. Password for Web Application on the local area network

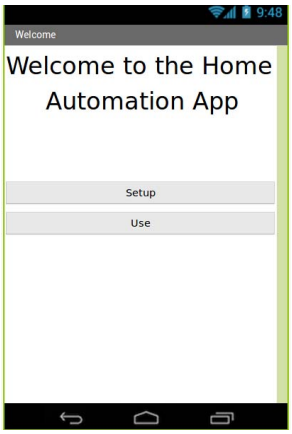

Fig. 13. Landing page of the chatbot application

The devices of the home can also be controlled using the chatbot application. The chatbot application is hosted on a web server. The implemented chatbot application is capable of parsing a given sentence and identifying keywords and actions from the given sentence. It further uses this information to perform the relevant actions.

Using the chatbot application we can control the lights, fans and appliances in the house. The initial screen of the app is shown in Fig 13. The setup phase (shown in Fig 14) is for giving information to the chatbot algorithm about the home. The use phase of the chatbot algorithm is shown in Fig 15.

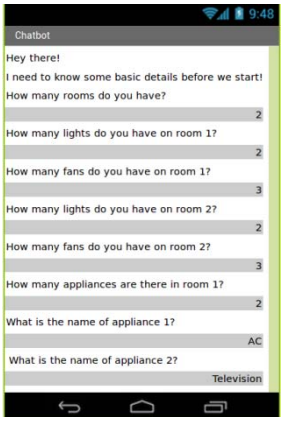

Fig.14: Setup page of the chatbot application

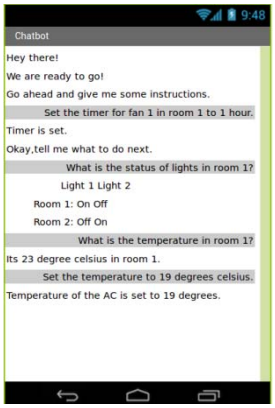

Fig. 15. Use page of the chatbot application

If the PIR motion sensor detects an intruder when the door is locked it sends a mail to the home owner as shown in Fig 16.

Hence, we have successfully implemented a home automation system with easy access and control through a web application and a chatbot which is capable of understanding the user's commands by Natural Language Processing techniques. This system is fairly unique and has a robust architecture which can be easily modified and scaled up to add support for more number of appliances.

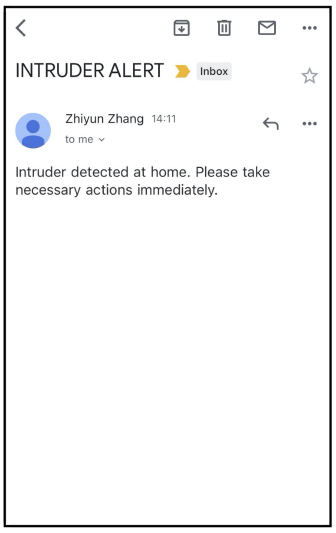

Fig. 16. Mail Alert in case of Intruder alert

IV. CONCLUSION

In the work, we have successfully developed a system which controls major appliances in a house. The user can interact with the system using either a web application or a chatbot through a computer or a handheld device. Hence, using this system, it is now more convenient to control the appliances in homes.

In the future, we are planning to make the following advancements:

1. Adding support for more entities and appliances like windows, speakers, cupboards and other such important appliances.
2. Making the system intelligent by using machine learning algorithms and neural networks.
3. Making an integrated application by combining the web application and the chatbot.
4. Making an interface to create and manage “recipes” like the service provided by “IFTTT”

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