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Gesture Controlled Home Automation System Using Internet of Things

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Abstract: With the rapid advancements in the field of technology, home automation systems are growing in popularity. Amazon's Alexa and Google Home have taken the market by storm. A Smart Home System gives access to all controllable household appliances and can help render the electricity supply in a household, reducing consumption by controlling usage. Existing innovations in this field operate predominantly on sound. This paper presents a system which relies on gestures to control household devices. A glove with sensors & Arduino microcontroller works as the central hub. Performing gestures while wearing the glove performs certain tasks. Additionally, there is a machine learning module to predict the electricity bill based on usage. With such technology, we can truly usher in the digital age.

Keywords: Flex sensors, Home automation, Internet of Things, Long Short Term Memory (LSTM), NodeMCU, Relay

I. INTRODUCTION

Automation increases the productivity, efficient use of materials and improves the safety. Home Automation is the use and control of home appliances remotely or automatically. With the initial systems, the problem was the presence of a central hub, which contained the UI and the entire functionality present in the hub. The user needed to physically change the working of the devices from the hub, as no intelligent system was applied. Using IoT overcomes the drawbacks of systems currently in effect. Proposed system aims to create a home automation system which uses IoT. This system is capable of controlling and automating almost all of the devices through easy hand gestures. Each gesture is uniquely interpreted and the task is performed in accordance. The second phase of this system includes machine learning which analyses the behaviour of a household and predicts the electricity bill based on usage. Hence, the system promotes ease of use and provides efficiency to the household.

II. LITERATURE SURVEY

Authors Arathi P.N et.al[1] use image processing as the basis for their system. At first the image is captured by the camera and it is processed by the MATLAB, if the preloaded gesture is matched with the existing gesture the data will be sent to the microcontroller, then the home appliances are controlled. Image processing lacks in accuracy & mobility. Capturing images would require full-time recording of images from various parts of the household which is infeasible.
Authors Krishna Rathi et al.[2] propose to use an accelerometer and flex sensor for hand gesture recognition to control electronic/electrical devices. The signals are wirelessly transmitted using Bluetooth module HC-05. Raspberry pi receives and processes data. Bluetooth module restricts range of the signal and can only be used within a single room.
Authors Kunal Nayak et al.[3] proposed a system which uses PIR(Passive Infrared Sensor) to detect the presence of people in a room by heat signatures and automatically switch on/off the lights. The gesture-controlled section involves the use of a microphone which can record voices such as clap, double clap and accordingly perform the necessary actions. Heat and sound sensors suffer from drawbacks such as inaccuracy, short range and accidental triggering.

III. PROPOSED DESIGN

The current Home Automation systems are mostly in the early experimental stages and accuracy is a major issue. Glove-based system is better in terms of accuracy and rarely gives an incorrect output. The lack of wearable tech stems from the unwillingness of users to wear bulky devices. However, it is more efficient, requires less power. The whole system consists of-

1) A glove module to read and transmit gestures
2) A receiver module to map those gestures and accordingly perform actions
3) A database and User Interface

The hardware components include microcontroller Arduino Uno, WiFi module 8266 NodeMCU, flex sensors, servo motors and relay.

IV. METHODOLOGY

The glove consists of flex sensors and an accelerometer with a gyroscope installed on it. The readings from these sensors will be transmitted to a microcontroller. The microcontroller processes this data accordingly and transmits it via the NodeMCU WiFi module to receiver module containing another NodeMCU. The various devices are connected to this module. The devices receive power as per the signal received. Fig. 1 shows the block diagram of this process. Further, data of each activity is sent to a database. Data consists of timestamp and duration. Using this data, power consumption is calculated.

Same data can be used to predict and generate a rough estimation of electricity consumption in the household.

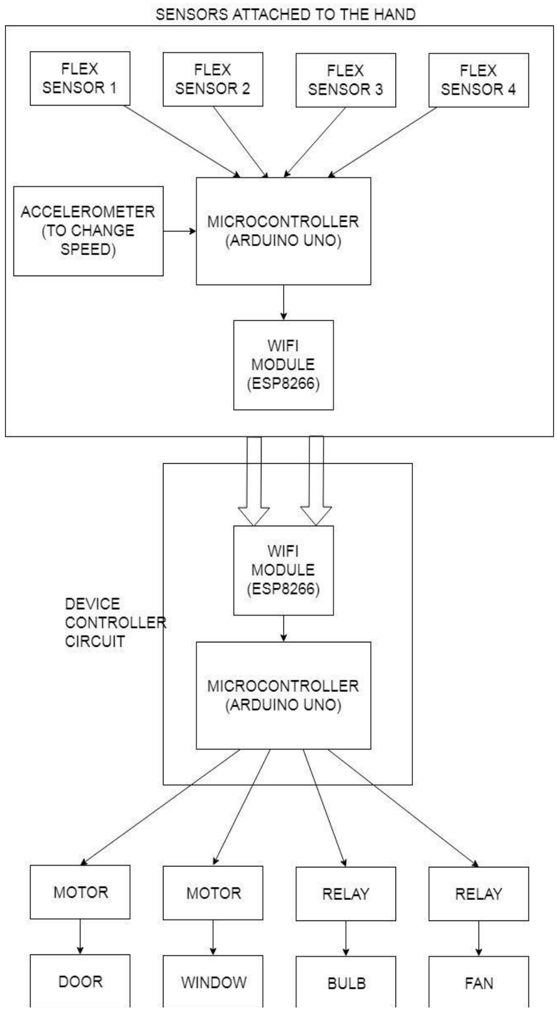

Fig. 1: System Block Diagram

A. The Glove

Fig. 2 shows the design of glove along with the circuitry. Each flex sensor is connected to the breadboard and then to the Arduino. It is the same for the accelerometer. The Wifi module is also connected. These connections can be made into a Printed Circuit Board(PCB) for stability and compactness leading to a lightweight glove module. Fig. 3 shows the circuit including light, fan, relay and motor connected to the second Wifi module. The configuration of flex sensors and Arduino can be done using simple conditional statements. As the resistance of the flex sensors changes on bending, certain boundary values are established. The resistance readings are sent to the Arduino. These are interpreted and each finger is found to be flexed or not flexed. Accordingly, the control statements perform the necessary task. Accelerometer sends readings of yaw, pitch and roll. Depending on certain threshold values, these can be similarly mapped to gestures to change the speed of the fan.

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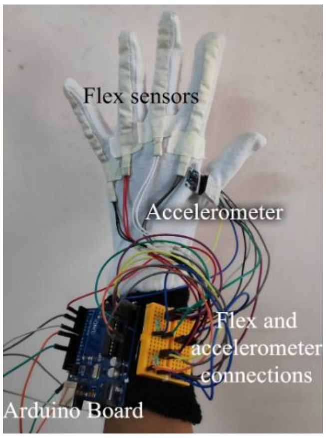


Fig. 2: Glove with connections

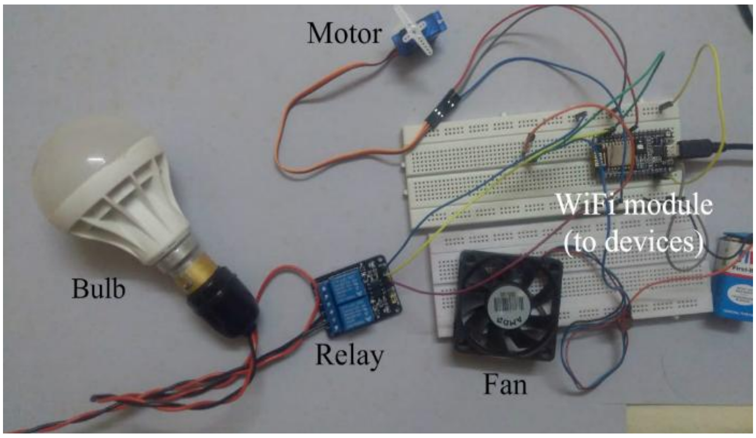


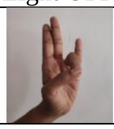
Fig. 3: Circuit with devices

```
For flex sensors F1,F2,F3,F4:
        Read sensor data
Convert to digital (0 for flexed, 1 for relaxed). If greater than threshold, set to 1 else 0
/* Threshold resistance value is set initially for each flex sensor */
        If (Reading = 0000)
Enter device control mode.
Read sensor data, convert to digital.
Interpret gesture and perform task as per mapping.
If(Reading == 1001)
                Enter fan control mode
                Read accelerometer values
Interpret gesture and perform task
        If(Reading == 1001)
                Exit Fan control mode
If(Reading == 0000)
        Exit device control mode
/* Arduino automatically loops control statements continuously */
```

B. Gesture Mapping

Table 1 shows the gesture mapping for performing different tasks. Each gesture is mapped to a unique action.

Table I Gesture Mapping

Gesture			
Action Performed	Device Control Mode	Light ON	Light OFF
Gesture			
Action Performed	Fan ON	Fan OFF	Window OPEN
Gesture		 (Clockwise and towards left)	 (Anticlockwise and towards right)
Action Performed	Window Close	Light ON	Light OFF

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C. Electricity Consumption Prediction

1) Data Preprocessing:

The data collected is split into training and testing data so that the model can be trained appropriately to high accuracy. The data is formatted into rolling windows using pandas so that importing of data and analyzing data becomes easier.

2) Developing model using RNN and LSTM[4][5][6] *:*

In this step a model is built using Recurrent Neural Network and Long Short Term Memory[7]. Then this model is trained on the data accordingly.

3) Training the Model:

In this step the model is trained for large number of epochs. Three layers are added for the process. There is one input layer, one hidden layer and one output layer.

We use the linear activation function for the final layer and Rectified Linear Unit. Mathematically 'relu' activation function is defined as:

$$y = max(0, x)$$

The advantage of using 'relu' function is that it does not suffer from vanishing gradient function as compared to other functions.

We use following Mean Squared Error (MSE) as the loss function to measure the how good model predicts the expected output. MSE works by calculating the sum of squared distances between our target variable and predicted values.

$$\mathrm{MSE} = \frac{\sum(\mathrm{y} - \bar{\mathrm{y}})^2}{n}$$

During training to optimize the function we use Root Mean Square Propagation (RMSprop) thus it adjusts learning rate automatically.

$$E[g^2]_t = \beta \mathrm{E}[g^2]_{t-1} + (1-\beta)\frac{\delta C}{\delta w}$$

$$w_t = w_{t-1} - \frac{\eta}{\sqrt{\mathrm{E}[g^2]_t}}\frac{\delta C}{\delta w}$$

After training the model is validated on some part of data to validate the working of model.

4) Results:

The model trained is used to predict the electricity consumption for 24 hours. Fig. 4 shows the graph obtained.

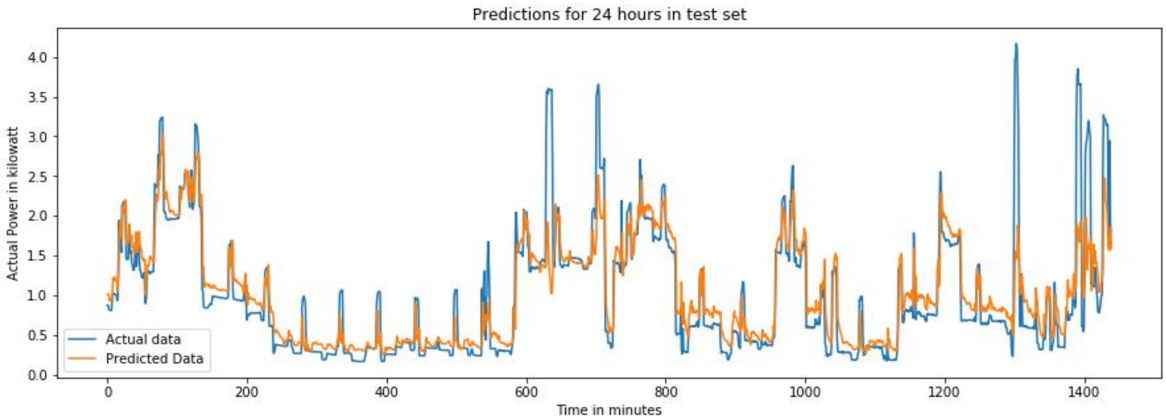

Fig. 4: Graph for prediction

D. User Interface

For the frontend Ajax is used to dynamically display the device status. Whenever the gesture is performed, the respective action occurs, the database is updated and correspondingly, webpage is also be updated. Database used is phpMyAdmin.

Whenever any device is switched ON, a log is created containing the time it was switched on and NULL duration. When the same device is switched OFF, the same log is updated with off_time as the time it was switched off. Duration is also calculated and added in the same record. An entry is made into the power table with the duration and power usage for the same. Fig. 5, 5a, 5b, 5c show the user interface.

User Interface also allows some extra features such as adding/deleting a device in the event that any device is replaced, and showing the power consumption between any two dates.

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Fig. 5: User Interface

Fig. 5a: Add device

Fig. 5b: Remove a Device

Fig. 5c: Power Consumption

V. CONCLUSION

The system is based on IoT and utilizes its quick functionality and ease of access for providing a stable system. Automation of simple tasks such as opening/closing doors and windows, regulating speed of fan, switching on/off lights etc. is successfully achieved. Simultaneously, data entry for usage of various devices into the database is also done. An aesthetic webpage is available for the user to view the status of various household devices and the electricity usage in a particular period. User is also provided with information about the approximate consumption of electricity in the future, i.e. electricity bill prediction. The system is robust, efficient and accurate, allowing easy access to control as well as monitor household devices. Configuration and installation of new devices is possible and easy to do.

VI. FUTURE SCOPE

The system can be further enhanced by considering the following:

1) The system can be expanded to provide unique identification using RFID tags which will be embedded on glove and this data can be sent along the gesture interpretation for multiple users and more importantly, for security purposes.
2) An LCD screen can be attached on the glove itself for ease of use and displaying notifications.
3) Pattern-recognition is a major scope of improvement where the system will learn from behaviour and predict the actions of the users so as to automatically alert user and perform some action such as closing windows, switching off the light etc.

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