Secure Home Automation by MFCC and Dynamic Time Wrapping

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Abstract: In today's world of wireless lifestyle home automation attracts consumers from all around the world. Home automation will make the life smarter and energy efficient. It is also a boon for elderly persons and physically disabled people. Due to these advantages home automation has always remained an important research field. Numerous models have been proposed using Bluetooth, mobile application and other wireless technologies. However it is found that people are reluctant to adopt home automation due to intrusive architecture, complex handling and security. Undoubtedly security and user convenience are crucial factors that must be considered while developing a home automation system. The aim of our project is to develop a secure home automation by MFCC and Dynamic Time Wrapping .MFCC is a voice feature extraction algorithm which is used to authenticate users.

***Index Terms* – Home Automation, User Authentication, Mel Frequency Cepstral Coefficients, Dynamic Time Wrapping.**

I. INTRODUCTION

With the continuous and exponential growth in technology consumers from all around the world are getting accustomed to the wireless lifestyle. Consequently developing a product based on the ongoing technology which is for society's good is main concern of the research professionals. The advent of wireless technologies will end the era of 'cable chaos'. Today most of the home appliances can be controlled by wireless techniques such as Bluetooth and digital networking. The devices can not only be controlled by human but the wireless technology instills abilities among devices to even communicate with each other. The X10 industry standard, developed in 1975 for communication between electronic devices, is the oldest standard identified from the author's review, providing limited control over household devices through the home's power lines.

One of the largest application of Bluetooth technology is home automation. Berngeim and etal[1] has defined home automation as the advent of in home technology so as to improve the life quality of occupants by providing various services such as energy conservation, e health , remote control, multimedia entertainment etc. A home automation system was developed by Ali and etal[2] using JAVA. The devices to be automated were connected to an embedded board. The embedded board was integrated with a personal computer. Web server was used to provide remote access. The security of the proposed system relies solely upon the inbuilt security features of JAVA programming platform. However, the system requires an intrusive and expensive wired installation and the use of a high end PC .Another home automation system but using Bluetooth technology was proposed by Sriskanthan and etal[3].The system comprised of primary and sub controllers. Sub controllers are the Bluetooth systems connected with home devices. Wired connections were used for communication between devices and sub controllers.

Ardam and etal[4] preferred a mobile phone controlled automation system which is ideal for home and offices. However the communication occurred via telephone instead of Internet. In other words a Dual Tone Multiple Frequency(DTMF) and a telephone support is essential for deployment of the proposed system .A major drawback of the proposed system is the absence of graphical user interaction as users had to remember the buttons required to be pressed for controlling devices. A control network employing hand gestures was proposed by Baudel and etal[5].A specialized glove was used to relay hand gestures into the system. The system is not much reliable due to inherent accuracy in hand gestures by different users. Moreover the system may negatively affect users health due to fatigue.

Saito and etal[6] built up a web server based home portal to interconnect IEEE1394, with an electrical cable based home mechanization framework, and the Internet. To make the framework increasingly appealing to property holders, a continuous AV transcoding ability was incorporated. The framework offers a canny investigate the improvement of a home portal; nonetheless, the utilization of electrical cables as the correspondence medium confines the situating of gadgets inside the home to territories in closeness to control attachments. Kushiro and etal[7] proffered an energy management system for home via internet. The proposed system was installed in Tokyo . Park and etal[8] proposed a home gateway based on the OSGI (Open Service Gateway Initiative), which permits specialist co-ops to access home automation frameworks for organization and support administrations. The proposed framework is partitioned into two subsystems. The first is the DSM (Digital Home Service Distribution and Management System), which gives a UI to the control and checking of associated home computerization gadgets. The second is the Home Gateway, which is in charge of dealing with the home computerization framework. This open engineering raises protection issues which, for certain clients, might be a lot more noteworthy than the favorable circumstances offered by giving outsider access.

Yoon and etal[9] actualizes a home door that acknowledges cell phone flag and enacts or deactivates a LED speaking to a home gadget. Anyway there are numerous issues identified with home mechanization, for example, interoperability. intricate and costly engineering, meddling establishment, absence of system interoperability, interface firmness, security and wellbeing ,as referenced by Gill and etal[10].Scalability, easy to understand interface, symptomatic administrations, deftness and cost viability were recommended in Piyare and etal[11] legitimize its application in home automation.

A survey was done in [12] highlighted that households are making trade-offs between security and desired functionality. Not only must home security primitives be simple to configure, users need to be able to fully understand the implications of their security settings, so they can build confidence in them. Without this, users are likely to give up some of the convenience (e.g., remote access) for peace of mind, as we observed, or inadvertently live in insecure environments.

It can be thus concluded believe that research is needed to develop simple security primitives that are custom-designed for the home environment. Voice of a person conveys a lot of important information like gender, ethnicity, and emotional state. Moreover

every human being's voice exhibits unique characteristics; this property is utilized by voice authentication systems for speaker identification and verification.

Voice based home automation system can only increase user convenience not security. Federal Communications Commission (FCC) and Better Business Bureau (BBB) issued warning about spam callers who records user voice and use the same to authorize fraudulent utility charges or credit activities. In an experiment the HSBC's voice recognition system was cracked by a journalist using his twin brother. Thus voice recognition as a standalone security solution is not sufficient and must be used as a hybrid technology However if feature extraction algorithms such as MFCC are used security comes as an added benefit. Fig 1.3 shows the dominant speech automation systems. The aim of our research is to develop a secure and more user friendly home automation system by using Mel Frequency Cepstral Coefficients and Dynamic Time Wrapping.

II. RESEARCH METHODOLOGY

The entire process flow is demonstrated in Fig 2.1. The approach can be divided into following steps.

2.1. Database Creation: In this research we have considered four voice commands namely "FAN", "LIGHT", "TV", and "ALL". The voice samples are acquired from five test subjects two man, two women and a girl. For each command ten samples were taken from each test subject. After acquiring all speech samples i.e. 120 samples. The dataset is split into training and testing dataset in the ratio of 7:3.

2.2Deployment of Speech Recognition System in MATLAB : A speaker verification and speech recognition system is built in MATLAB GUIDE using MFCC .MFCC extracts features from a person's voice and also possess ability of speaker verification. Thus the developed system provides both security and increased efficiency. The steps involved in the process are listed below

Feature Extraction is a crucial part of Speaker Recognition greatly influences the performance of the process. Every human being's voice has unique features for instance the maximum frequency or pitch. Feature extraction techniques extracts the useful data from a voice signal and converts it into a sequence of vectors which acts as unique voiceprints. MFCC stands for Mel Frequency Cepstral Coefficients and is a technique for feature extraction. It consists of the following steps.

2.2.1 Pre-Processing: Pre-Processing is used as a silence removal system and also to remove noise from the speech samples. If the signal to noise ratio (SNR) is less at a particular frequency than the amplitude is increased at that frequency and is also used to make the speech signals uniform. The speech signal consists of voiced and unvoiced speech signals. So to detect the voices and unvoiced speech signals, energy level detection and zero crossing detection is used in pre-processing.

2.2.2 Framing The audio signal which is continuous in time is framed into 20-40ms range. This is done to simplify the things and to observe the audio signal in shorter time frames.

2.2.3 Windowing After framing, for minimization of the discontinuous signal Windowing technique is used preferably hamming as it gives Gaussian characteristics unlike other windowing techniques. For hamming window, the formula is given in Equation 2.1.

$$W_{ham}(n) = 0.54 - 0.46 * cos\frac{2\pi n}{N_{sam}-1}, 0 \le n \le N_{sam} - 1 \quad 2.1$$

2.2.4 Fourier Transform (FFT) of each frame is then calculated which converts time domain to frequency domain. The frequency domain is effective than time domain because frequency of a speech signal is effective way to describe rather than the amplitude of the signal. The DFT of N samples of each frame is calculated using following formula mentioned in Equation 2.2.

$$X_k = \sum_{k=0}^{N_{sam}-1} x_k\, e^{\frac{j2\pi nk}{N_{sam}}},\ 0 \le n \le N_{sam} - 1 \quad 2.2$$

2.2.5 Mel Frequency Transformation: This operation makes the feature match closed to what human ears actually hear the Mel scale filter characterizes the human ear preciseness of the frequency. In other words, it acts as a band pass filter for this stage of identification. Equation 2.3 shows frequency conversion into Mel scale.

Frequency (Mel scaled) = 2595 log (1+ f (Hz) / 700 2.3

2.2.6 Mel Frequency Cepstral Coefficients: This is the final step in which the log Mel spectrum using Discrete Cosine Transform (DCT) are converted back to time i.e. into Mel frequency cepstral coefficient. Here the cepstral coefficients of the speech spectrum gives a better direction of the local spectral properties of the signal. In the last step the Mel spectrum coefficients are denoted as C_k, k=l, 2, ... , K

The equation of DCT to convert the mel frequency spectrum into time is as mentioned in equation 2.3

$$A_n = \sum_{k=0}^{K} \log(C_k)\, cos\left[n\left(k - \frac{1}{2}\right)\frac{\pi}{K}\right], n = 1, 2, .. k \quad 2.3$$

2.2.7 Classification : In classification layer test and train feature vectors are contrasted against each other. For user verification Euclidian distance is used. A user is said to be recognized if the Euclidian distance match is greater than 80 percent. Once the user is recognized Dynamic Time Wrapping (DTW) distance is applied to recognize the voice command. DTW is an efficient algorithm used for comparing two time series.

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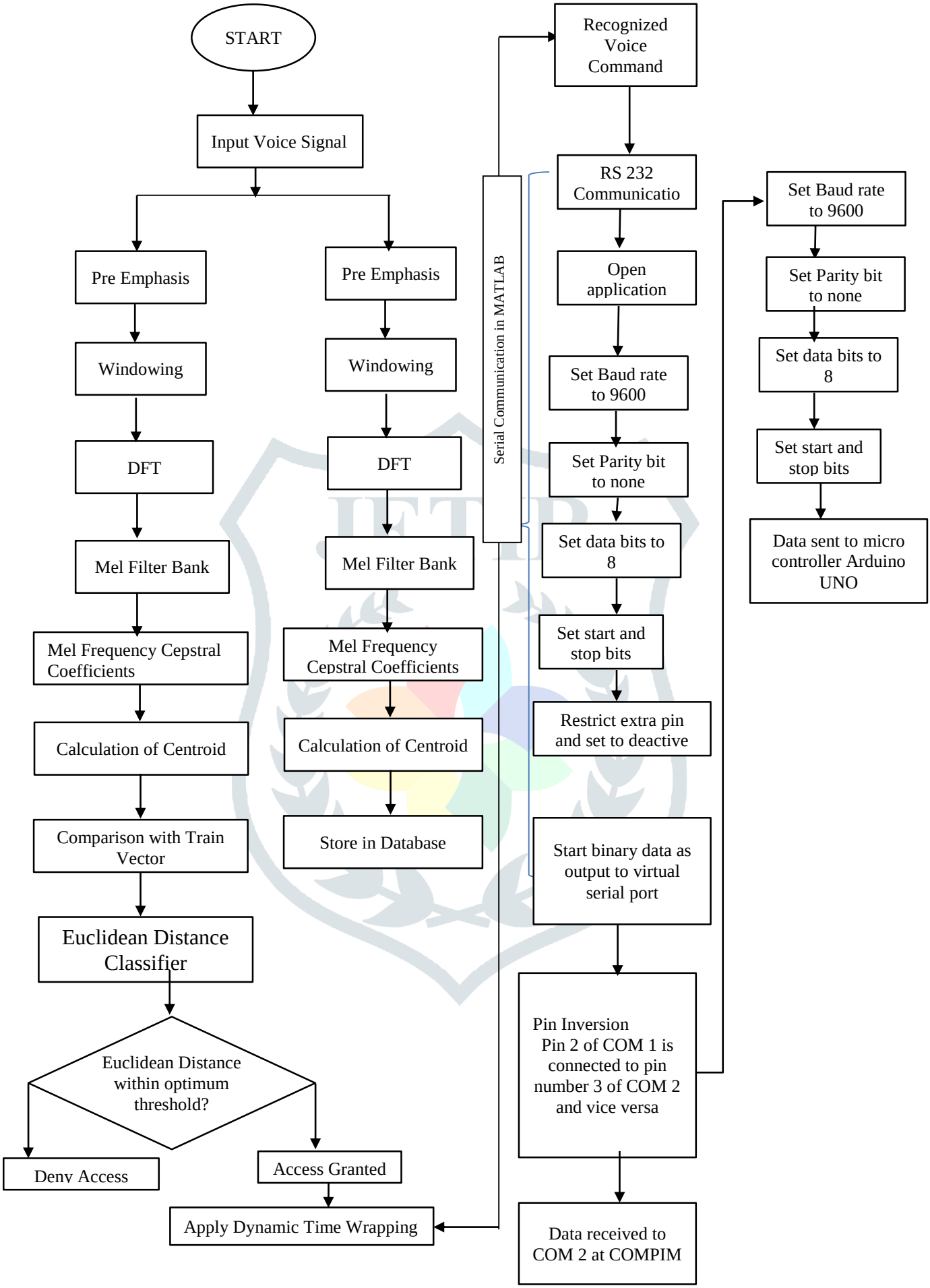


Fig 2.1:Process Flow of Proposed Algorithim

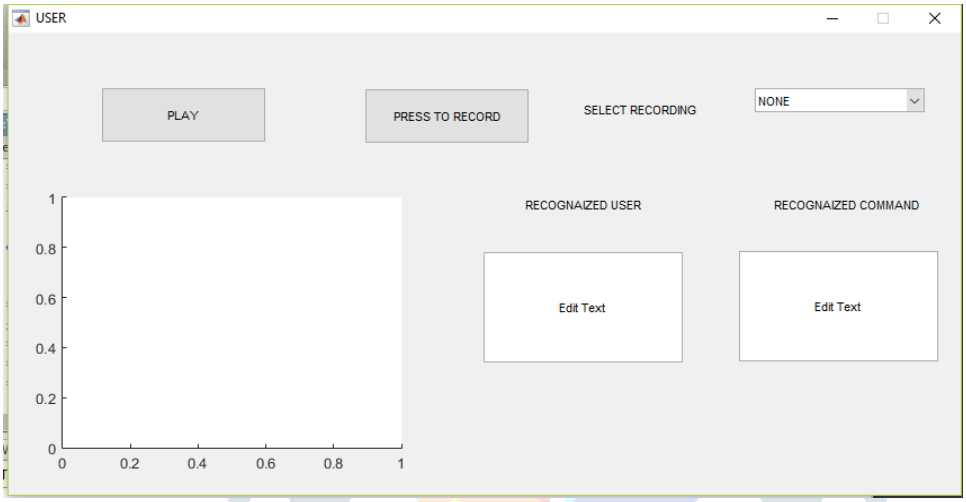
3**..Serial communication between Arduino UNO microcontroller and MATLAB :** Universal Asynchronous Receiver Transmitter Communication Protocol is employed by virtual serial port driver and COMPIM to facilitate data transfer between two applications.

4. **Simulation of home automation system in PROTEUS and Arduino Microcontroller:** The Arduino Uno microcontroller is programmed to perform the necessary action based on the input speech command.

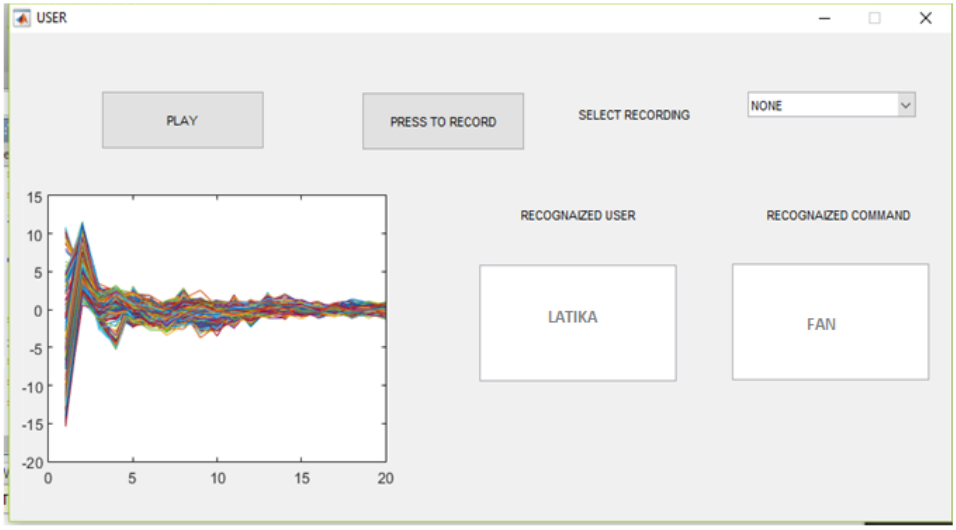
5.Testing Phase : Once all the steps are deployed successfully in real time, testing phase commences. In testing phase a random voice command is selected from Test Database or voice command is recorded in real time. The system calculates the MFCC of the test voice sample and compares it with MFCC vectors present in the database. If a match is found with greater than 80 percent threshold , the user is granted rights to control devices and the voice command is listed for conversion into action. The recognized voice command is sent by MATLAB to simulation environment in PROTEUS ISIS. The Arduino UNO microcontroller receives the command and actuates LED pins accordingly.

III. RESULTS AND DISCUSSION

The developed graphical user interface is shown in Fig 3.1(a). A random input command can be selected by pop up menu or real time sample can be recorded by pressing 'PLAY TO RECORD' button. To hear the recoding PLAY button is pressed. The calculated MFCC vectors are displayed graphically in GUI. Fig 3.1(b) shows the recognised user and voice command. Fig3.2 shows the PROTEUS ISIS simulation. The received voice command by PROTEUS ISIS and the action taken by Arduino UNO microcontroller is shown in Fig 3.2.



(a)



(b)

Fig 3.1(a) Developed GUI in MATLAB (b) Recognised User and voice command

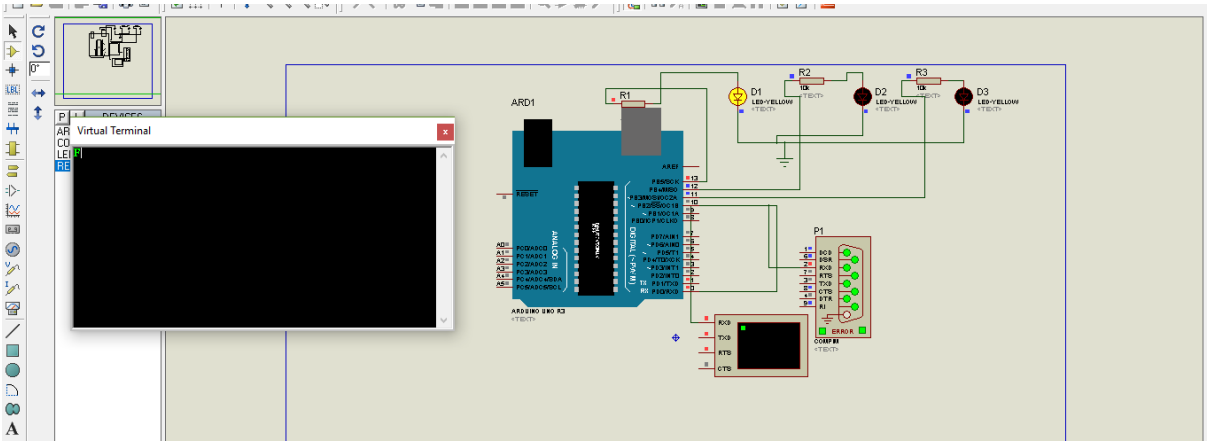


Fig 3.2: Developed Home Automation Simulation in PROTEUS ISIS

The efficiency of the system is evaluated by False Acceptance Rate (FAR) and False Rejection Rate(FRR).These rates are defined in equations 5.1-5.3. In our model combined FAR of 0.1, FRR of 0.1 and success rate of 92% is obtained.

$$\text{False Acceptance Rate(FAR)} = \frac{\text{Total number of falsely accepted commands}}{\text{Total Test Attempts}} \quad 3.1$$

$$\text{False Rejection Rate(FRR)} = \frac{\text{Total number of falsely rejected commands}}{\text{Total Test Attempts}} \quad 3.2$$

$$\text{Success Rate(SR)} = \frac{\text{Total number of recognaised commands}}{\text{Total Test Attempts}} \quad 3.3$$

IV. CONCLUSION

The proposed algorithm for secure home automation by MFCC and DTW is secure and efficient. The algorithm is able to differentiate between authorized and unauthorized user with minimum false acceptance and rejection rate. The proposed algorithm is also recognize the voice commands of an authentic user at a good success rate and takes action accordingly. Thus the proposed algorithm is well suited for deployment in home automation environment.

V. FUTURE SCOPE

In future more voice commands can be included. The proposed algorithm can be combined with wireless technologies such as Bluetooth and Internet of Things. Security factor can be further enhanced by machine learning algorithms.

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