ENGINEERING

ISSN (Print): 24490954
ISSN (Online): 26364972

DEVELOPMENT OF A DOOR LOCK SECURITY SYSTEM BASED ON AUTOMATIC SPEECH RECOGNITION

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Manuscript received: 10/06/2018 Accepted: 27/06/18 Published: December 2018

ABSTRACT

The security of homes and properties are of utmost importance and various methods have been employed by researchers to achieve this aim. This work developed a door lock security system based on automatic speech recognition. The developed system was programmed to recognize certain users and give a particular user access to a door. In training the system, MFCC feature extraction technique was used to extract appropriate features from five different individual's speech signal and Vector Quantization using LBG algorithm (VQLBG) was done to recognize a speaker. A prototype door was designed and implemented to test the developed system. Euclidean distance was used in calculating the parametric representation of individual speech signal to be recognized and an accuracy of 75% was obtained by calculating the Word Error Rate (WER). Results show that the developed system is more reliable in securing door lock in homes than traditional method.

Key Words: *security, speech recognition, vector quantization, Euclidean distance*

INTRODUCTION

Conventional mode of door lock in homes, schools, offices, and buildings is mechanical and the rate of access by unauthorized people in these places has drastically increased, hence, this led to the introduction of automatic door control systems. Automatic door control systems are widely used to prevent manual opening and closing of doors as well as to ensure security of lives and properties by preventing unauthorized access in a place (Yang *et al.*, 2013). Research shows that existing door lock security systems have some drawbacks. For example, Facial recognition based security system is affected by change in lighting and facial problem (Gowsalya *et al.*, 2014; Satti, *et al.,* 2015), fingerprint based door lock security system requires high resolution scanner (Nafi *et al.*, 2012) and Password Based door lock security systems have the inability to change password during power failure (Oke *et al.,* 2013). Hence, this research developed a door lock security system based on speech recognition. Speech recognition is referred to as a method by which speech signal is converted to a sequence of words by an algorithm which is implemented as a program known as Automatic speech recognition (ASR) (Upase, 2016 and Joshi, 2016). ASR system involves two phases; training phase and recognition phase. At the training phase, known speech is recorded and parametric representation of the speech is extracted and stored in the speech database while the recognition phase extracts and compares the features of an input signal to the reference templates to recognize a speaker. Speech recognition algorithm consists of several stages in which feature extraction and classification are mainly important. The performance of speech recognition systems is usually measured based on speed and accuracy. Speed is measured with the real time factor while accuracy is measured in terms of performance accuracy which is usually rated with Word Error Rate (WER) or Word Recognition Rate (Maier *et al.,* 2010). Therefore, the performance of the developed system was measured using Word Recognition Rate.

Various methods have been employed in developing automatic door lock security systems. The methods include: password-based, Radio Frequency Identification (RFID)-based and biometric-based such as: fingerprint recognition and facial recognition. A password-based security system is one that employs certain American Standard Code for Information Interchange (ASCII) characters in securing a place. Sur (2013), developed a system which unlocks a door by using pre-decided password. The significance of the work is that, if the user forgets the both passwords, the system has the flexibility of allowing users change or reset the password. This automatic password based lock system enable users secure their doors. In addition, Mishra *et al.*, (2014),developed a password based security lock system which uses keypad to enter a password. The system gives the flexibility of allowing users enter a password thrice before finally preventing accessing to the door. Also, a Liquid Crystal Display (LCD) module is also used in the design to display messages to the user. In addition, a Field Programmable Gate Array (FPGA) and Global System for Mobile Communication (GSM) based advanced digital locker system was developed by (Gaikwad, 2013). While closing the door of office/home, the user presses the “0” key available on the hex keypad. The developed system communicates owner of the office or house whenever an unauthorized person tries to intrude via the GSM module.

Verma and Tripathi, (2010) developed a digital security system using the Radio Frequency Identification (RFID) technology. The technology employs RFID tags in ensuring that only authorized users gain entrance through a door. In order to gain access through the door, the user places the tag in contact with the RFID detector and the system was designed to work in real time. Mishra (2015) developed an RFID based door lock security system based on Arduino. When the card is swiped on the RFID module, it peruses the data and matches with the data stored in the program memory to validate an entry. Furthermore, Kamelia (2014), developed an android door lock system for indoor and outdoor access based on Bluetooth technology. The work aimed at controlling the door condition using an Android phone which is Bluetooth-enabled via Bluetooth HC-05. Nafi *et al.,* (2012) developed a biometric based security door system using the finger print recognition based technology. The system takes an image of the palmtop then partition and processes it in order to verify an authorized person. Also, facial recognition based security door was developed by Al-shebani (2014). An efficient door access control system was obtained using a Field Programmable Gate Array (FPGA) device, because it operates at a higher speed and can be re-programmed. Recently, the fast based principal component analysis approach was proposed by (Yugashini *et al.,* 2013). The image was captured by the web camera and it gets matched with the image stored in the database. Advancement in technology introduced door lock security systems which are based on the pattern of the human iris which gives a higher level of security (Gowsalya *et al.,* 2014). Kharka *et al.,* (2015), designed a voice controlled wheel chair for the physically handicapped persons where the voice command controls the movements of the wheel chair. Voice Recognition Kit (HM2007 Module) was used to recognize the voice command which was later converted to binary numbers and sent to the Arduino board for the control of the wheel chair. Upase and Joshi, (2016) designed a speech recognition based wheelchair. When the user speaks into the microphone, the Raspberry pi B follows the commands and perform the operations on the Dc motor. The designed project enable people with limited control over their limbs navigate using voice commands.

MATERIALS AND METHODS

In this work, the automatic speech recognition based door lock system was developed and a prototype was designed. The developed system was tested by five users. The result gotten was recorded. Word Recognition Rate was used in evaluating the performance of the system (Maier *et al.,* 2010).
. Figure 1 illustrates the block diagram of the system.

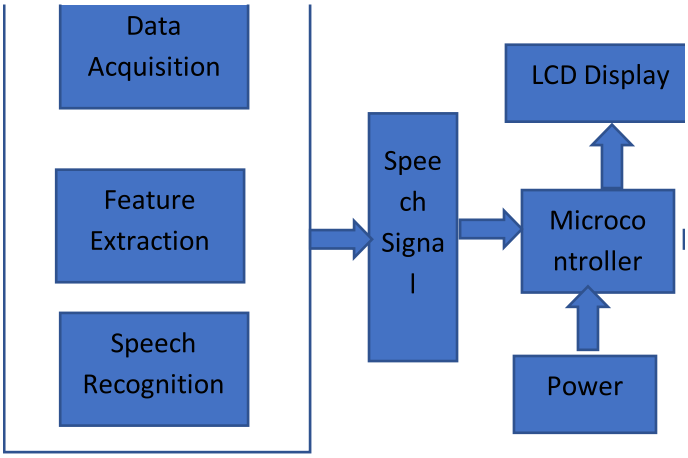

Figure 1: Architecture of the developed speech recognition-based door lock security system

The software design phase include: Data acquisition and pre-processing stage, Feature extraction and data storage and Recognition using Vector Quantization Linde Buzo Gray (VQLBG) algorithm.

1. ***Data acquisition and pre-processing:*** in this stage, data is acquired by the use of analogue microphone using some recommended properties such as; Sound ID (to represent the speech signal), Duration of recording in seconds (3 seconds recommended), Sampling frequency (22050 Hz recommended) and Number of bits per sample (8 bits recommended). After data acquisition, noise filter is used to remove unwanted signals from actual signals needed and Analogue to Digital Converters (ADC) help to convert the signal from analogue form received from microphone to digital process-able signal.

2. ***Feature extraction and Data storage:*** After pre-processing, some features of the vocal characteristics of the speech are extracted from the speech signal and the speech in form of SOUND ID is stored in the speech system database. The Mel Frequency Cepstral Coeficients (MFCC) feature extraction technique is used for the extraction of features.

3. ***Speaker recognition using VQLBG algorithm and access control:*** The speaker's identity is recognized by comparing the features of the input speech to those in the database. VQLBG algorithm is used to match the inputted speech signal to a speech signal in the database based on the closeness of the parametric distance (Euclidean distance).

The hardware components used in the design of the work include: the PIC18F1X20 microcontroller to receive signal from the speech recognition system, the L293D H-bridge driver used in opening and closing the model house door, Liquid Crystal Display (LCD), relay drive circuit, and door drive circuits. The circuit diagram of the work is shown in Figure 2.

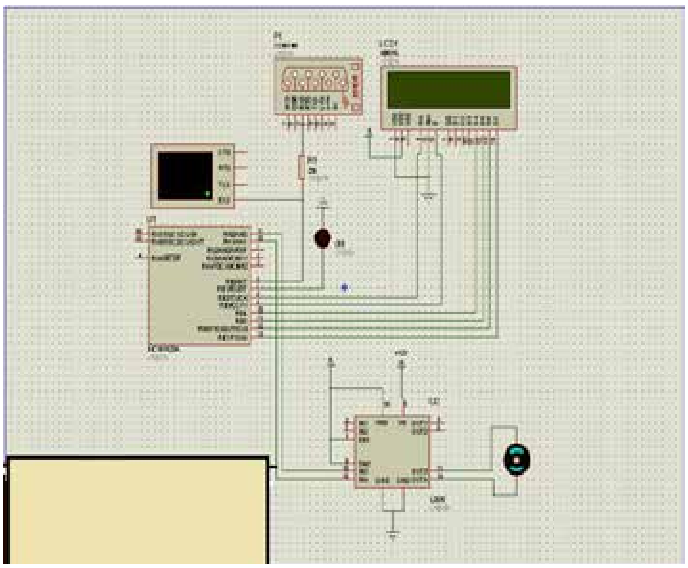

Figure 2: Schematics of the hardware door control circuit

From figure 2, a slider mechanism with slide gear fixed with a motor is used to slide the door opened and close in response to signal from the microcontroller. The microcontroller PIC18F1X20 receives the signal through the RS232 cable and sends a signal to the motor for the door to be opened. The H-bridge driver controls the forward and backward movement of the door. A 4MHz crystal oscillator provides speed for the microcontroller and is connected to two 30uF capacitor connected in parallel. Rectifying diodes are provided for full wave rectification (1N4001 rectifying diode (4)) and the rectified power of the Alternating Current (AC) which will still have some ripples becomes a pulsating Direct Current (DC). The voltage is then sent to the condenser microphone, a 2200 uF capacitor which takes away the ripples making it smooth to get the pure DC voltage at 9 V. It is the 9 V that is fed into the 3 pin regulator (a 5 V regulator with path number LM7805). To recover the voltage after it has passed through the regulator, a 100 uF capacitor is used because it acts as a storage that always makes 5V available to the microcontroller at any time. A 0.1 uF capacitor is recommended as a noise filter for every I C (one for the microcontroller and the other for the H-bridge). A 10 k resistor is used to provide the contrast for the LCD while a 10 K pull-up resistor is used for the microcontroller to provide the missing filter when the port is in a high state. There are resistors connected at the base of the transistor that serves as a buffer, the pull-up and series resistors from the RS232 port form a buffering unit for the RS232 signal that is coming into the Programmable Interface Controller (PIC), it provides the voltage level that the PIC needs to communicate with the PC. Lastly, the transformer, an AC transformer, can take in up to 220 V and give out 9 V. The diagram showing the interconnection of components on the Printed Circuit Board (PCB) is shown in Figure 3.

Figure 3: Diagram showing the interconnection of components on PCB board.

Subjects were used in testing the developed system. Speech signals were collected from these subjects using analogue microphone with some recommended properties such as; Sound ID (to represent the speech signal), Duration of recording, Sampling frequency (22050 Hz recommended) and Number of bits per sample (8 bits recommended). Data acquisition was done under a conducive environment to prevent acquisition of unwanted signals that may have effect on the speech system. After data acquisition, noise filter was used to remove unwanted signals from actual signals and ADC converts the signal received from microphone to digital form. Some features were extracted from the speech signal using MFCC feature extraction technique and stored in the database. Figure 4 shows the addition of speech signal (of the first respondent) in the database. It was represented as “SOUND ID: 1” with sampling frequency of 22050 Hz at 8 bits per sample and a recording rate of 3 seconds. These values were taken constant for subsequent speech signals to be added to the database (Maier *et al.,* 2010).

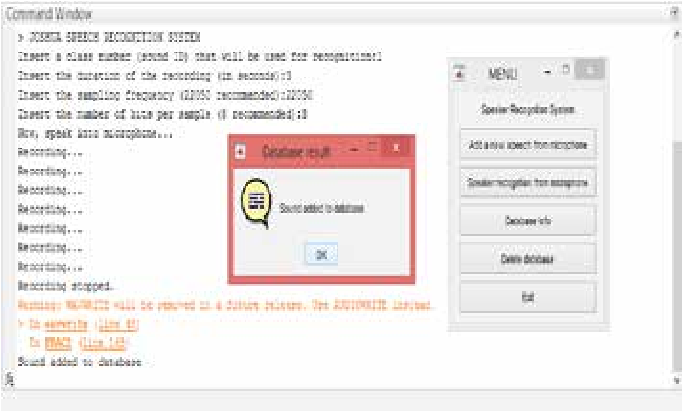

Figure 4: Acquisition of Speech Data “Sound Id: 1”

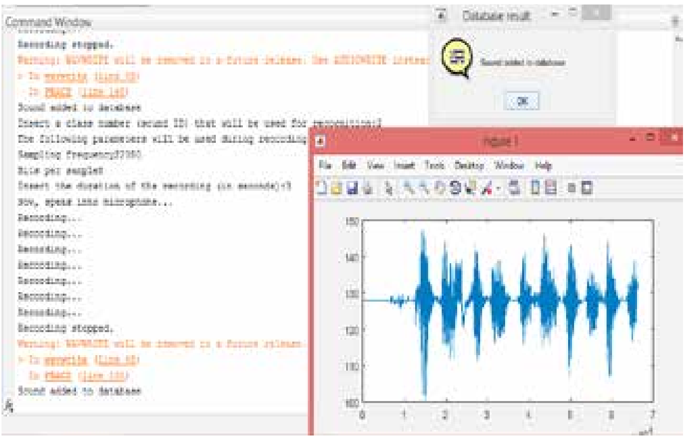

Figure 5: Acquisition of Speech Data “Sound ID: 2”

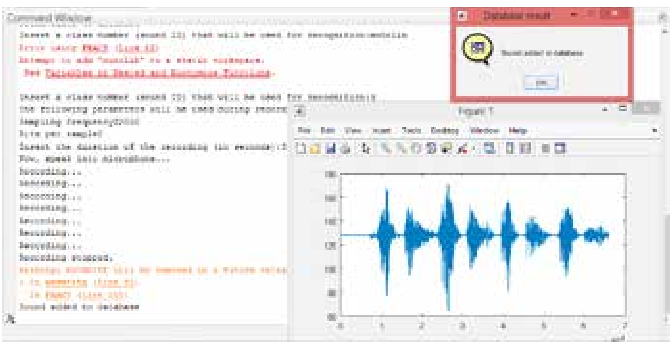

Figure 6: Acquisition of speech data “sound ID: 3”

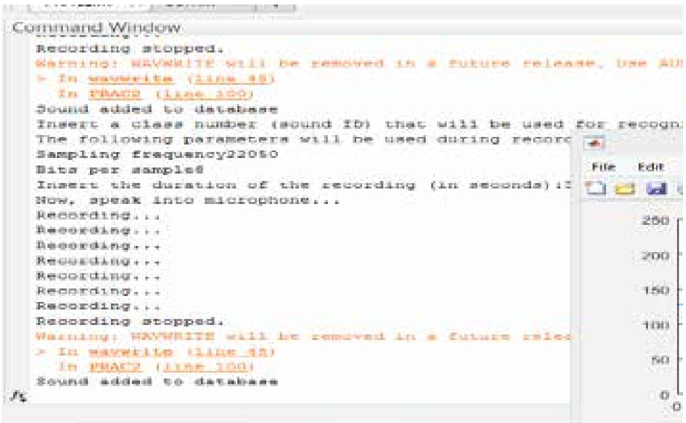

Figure 7: Acquisition of speech data "sound ID: 4"

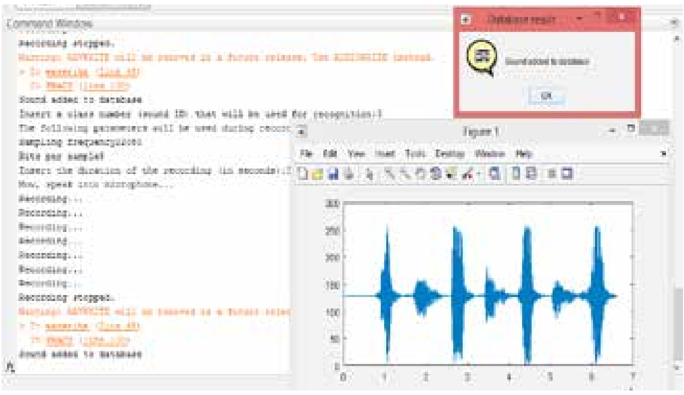

Figure 8: Acquisition of speech data "sound ID: 5"

Figures 4 to 8 represent speech signals from five (5) different individuals tagged as sound ID 1 to sound ID 5, collected during the acquisition stage and stored in the speech database.

RESULTS AND DISCUSSION

Results gotten after comparing the features of the input speech to those in the database using VQLBG algorithm were recorded. The algorithm matches the inputted speech signal to those in the database and the speech signal which is closest to the parametric distance (Euclidean distance) is referred to as the speech of the authorized user and this activates the opening of the door. On insertion of the first speech signal, the system performs MFCC coefficient and VQ codebook training and after the processing, recognition was done by matching the speech signal to the User ID which is the closest to the Euclidean distance. Speaker 4 was recognized with Euclidean distance of 5.8837. Users 1,2,3 and 5 Euclidean distances are 6.4123, 7.4592, 6.8146, and 6.0719 respectively. This is shown in figure 9.

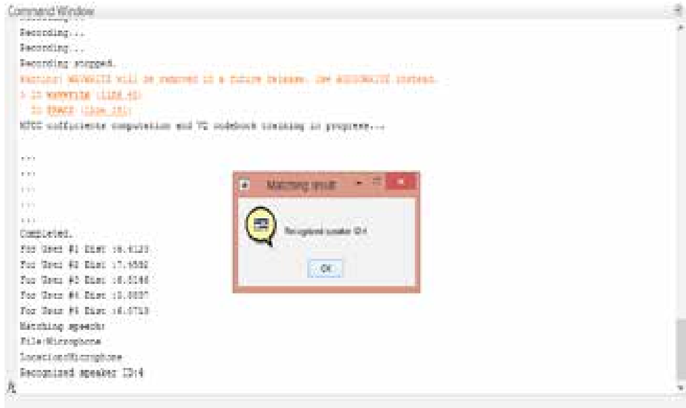

Figure 9: Recognized speaker "sound ID: 4"

From Figure 10, it is shown that speaker ID: 3 was recognized with Euclidean distance of 5.8837. Users 1, 2, 3 and 5 Euclidean distances are 6.4123, 7.4592, 6.8146, and 6.0719 respectively.

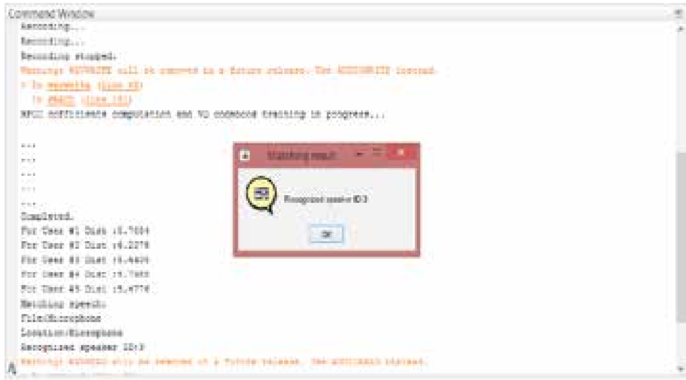

Figure 10: Recognized speaker "sound ID: 3"

From Figure 11, speaker ID: 5 was recognized with Euclidean distance of 5.2299. Users 1, 2 ,3 and 4 Euclidean distances are 5.3781, 5.6809, 5.7985, and 5.2595 respectively.

Figure 11: Recognized speaker "sound ID: 5"

In figure 12, the system recognizes the speaker as user 1and configured it as the authorized user to gain access to the door.

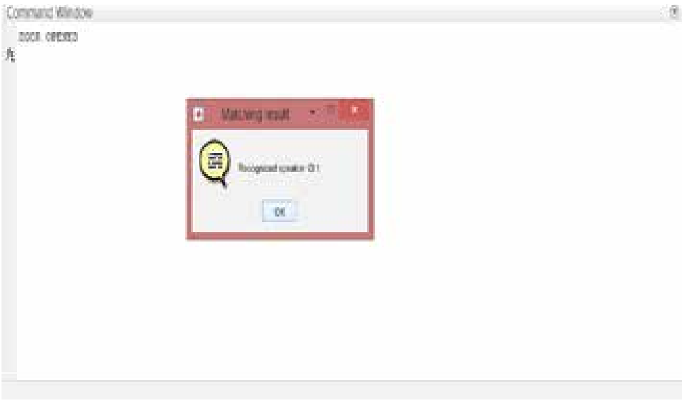

Figure 12: Recognized speaker "sound ID: 1", the authorized user

From Figure 13, it is shown that speaker ID: 2 was recognized with Euclidean distance of 7.3367. Users 1, 3, 4 and 5 Euclidean distances are 67.4469, 7.785, 8.2049, and 7.777 respectively.

Figure 13: Recognized Speaker "Sound Id: 2"

Summary of results from figures 9 to 13 were recorded in table 1. Speaker with sound ID 1 has the shortest feature distance and was recognized as the authorized user. When this speaker was recognized, the door automatically opens for 5 seconds and closed after the period of time. Figure 14 shows a prototype of the developed automatic speech recognition based model Door model.

Table 1: Parametric Representation of Recognition Process of Five Users.

Users in Database	**Speakers to be recognized using the individual Euclidean distance of features extracted to the features of data stored in the speech system database.**				
	Distance to User-1	Distance to User-2	Distance to User-3	Distance to User-4	Distance to User-5
User-1	5.1527	7.4469	5.7684	6.4123	5.3781
User-2	5.8374	7.3367	6.2278	7.4592	5.6809
User-3	6.1213	7.7850	5.4405	6.8146	5.2595
User-4	5.3778	8.2049	5.7985	5.8837	5.6317
User-5	6.1183	7.7770	5.4776	6.0719	5.2299

Figure 14: Prototype of automatic speech recognition based model Door

The developed system was evaluated using accuracy metric by calculating the Word Recognition Rate (WRR) (Maier *et al.,* 2010).

Word Recognition Rate (WRR) = S/H X 100%;

where S is number of success in H number of recognition trials (Majer *et al.,* 2009).

WRR = 15/20 X 100%; 0.75 X 100%, 75% accuracy.

Therefore, the percentage accuracy of the system based on Word Recognition Rate (WRR) is 75.

CONCLUSION

A security door lock system was developed in this work based on automatic speech recognition. An unknown speaker was recognized from a number of registered speakers and Euclidean distance was calculated for each signal to be recognized. The user having the shortest feature distance is matched to a user stored in the database of the speech system and recognized as the authorized user. The functionality of developed system was tested using a model door. The effectiveness of the work was determined using the accuracy metric and results show that the developed system is seventy five percent accurate.

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