AN AUTOMATED DRE BIOMETRIC VOTING SYSTEM WITH VVPAT FEATURE

Fahim Gohar Awan, Muhammad Fahad Ijaz, Suhail Aftab Qureshi, Abdullah Zahid, Muhammad Zain Ali, Anoshka Tariq

Department of Electrical Engineering, UET, Lahore, Pakistan

Contact: fahimgohar@hotmail.com, m.zainali@hotmail.com

ABSTRACT *— The world and specifically Pakistan is facing problems regarding the voting system since long. The questions are always raised about the transparency of the results. There is therefore a need to develop a system which can provide the solution for the problem in the voting system and introduce the automation in the voting system with a means of verification of the voters. This paper demonstrates a system which provides such a solution. This system is based on biometric fingerprint sensor, raspberry pi, a touch screen, a printer and an ID card reader. The system includes central database servers and local database servers. The system comprises of both hardware and software. The system has the capability to produce result during the runtime with advanced security features hence eliminating the risk of tempering with the results. The error rate is less than 10 ppm with acceptable delays. The proposed voting machine is capable of auto-reading the ID card, so a user does not have to type his ID or registration number manually. The proposed machine prints a slip after voting which aids in VVPAT. This machine is operationally made less cumbersome at user end that a voter needs only "three taps" on touchscreen to cast his vote.*

Index Terms — Direct Recording Electronic (DRE), Biometric System, Database System, Verified Voter Paper Audit Trail (VVPAT), Fingerprints.

I. INTRODUCTION

In the world of democracy, for a government to be "by the people" the right to vote of the citizens of a country plays a vital role. The ballots can change the fate of the nations; it can catapult a nation to decades or are enough to drag it back to the age of stones. With the democracy comes the politics and with the politics come the victory and defeat, and those who don't succeed mostly blame the system. This creates a serious problem for a country and nation. The conventional voting systems, mostly involve the human factor. These systems rely on human from the verification of the voter to the compilation of the result. So there is always a possibility of the human error and additionally the loyalty of the authorities can be doubted. The advancement in the technology urged the world to modernize the voting system by means of technology and the idea about the voting machines was put forward. The history of modern electronic voting machine starts in 1960s.

The very first machine used was a punchcard machine which used "votamatic" card and "datavote". In this system the information is obtained by the number of hole on a card. The next voting machine was based on mark sense in which the information of a candidate is preprinted on a paper against a circle, square or rectangle, the voter fills that shape. The paper is then inserted into the computer-tabulating device which then marks the vote using the "dark mark logic" [1]. However these machines still use paper for balloting and there might be a margin of the error. The idea about the first DRE (Direct Recording Electronic) voting machine was presented back in 1890s by Frank S. Wood. A DRE uses a touchscreen, mechanical or opto-electrical switches to mark the vote and can be activated by the voter. This machine had push buttons for voting purpose [2]. The first voting machine used in election was Video Voter in Chicago, Illinois, USA developed by the Frank Thornber Company in Chicago. This Video Voter had a video screen with films of candidate that project the information on video screen. It used phototransistor to check which candidate is to be voted and the corresponding counter was incremented [3].

In 1996, the Brazilian Electoral Justice launched their voting machine for the testing purpose and used it in 2000. These machines are still being used in Brazil for voting purpose. The machine is consisted on two terminals. One terminal is of poll worker and the other is voter's terminal. The poll worker terminal has a numeric keypad and a liquid crystal display. Some of the machines have a biometric sensor. The verification and identification is done on the poll worker's terminal and voter casts his vote on voter terminal [4].

The United States of America adopted the voting machines manufactured by the Diebold Election Systems Inc. For voting, a voter is given a smartcard or a pin after the verification which he can use to access the voting terminal. However analysis and tests made by a team have shown that these machines are not safe as these smartcard does not perform the cryptographic tasks and thus it is possible to create the homebrew smartcards. A person thus can create many such cards and can cast multiple votes. Moreover, a person can create a smartcard that is a replica of that of authority, hence accessing and controlling the machine [5].

Another DRE system that has been used in the world is Indian Electronic Voting Machine (EVM). These machines consist of two units, i.e. Control Unit and Balloting Unit. Both these units run on 6V batteries. Control Unit is with the authority and the Balloting Unit is used by the voter to cast his vote. When a voter is verified manually, the authority presses a button prompting the voter to use his right to vote. This machine however, cannot entertain more than 3840 voter and 64 candidates. A single machine has a capacity to entertain 16 candidates, however, if needed upto four machine can be linked in parallel [6].

However, with the advancement in e-voting, the voter became conscious about the correct selection based on their choice. This lead to the concept of "Verified Voter Paper Audit Trail" (VVPAT) which gives a means to voter to check if the vote has been cast to candidate he selected.

The above mentioned machines served the purpose of voting, but lack the following features which poses serious problems in the voting process:

i. Inability to provide VVPAT.
ii. Manual Verification.(Except in some Brazilian machines)
iii. Manual typing identity number, registration number or pin so there might be a human error.

There was, therefore, a need to design a machine which is good enough and able to take care of the problem in the above discussed machines. Efforts have been made to make such machines. One of the machines is just like the Indian EVMs which lack the ability of biometric verification [7]. The other machines are implemented using biometric fingerprint sensors, which provide a means for verification. There are many possible ways of biometric verification, i.e. fingerprints, facial recognition, iris, finger-vein recognition [8]. Fingerprint biometric verification and identification is however, preferred for the ease, simplicity and more samples per person i.e. upto 10 fingers. Since the idea of this machine is to integrate with the existing system and the database of the registration authority like NADRA in Pakistan. Such database and registration authority keep a record of fingerprints in database so biometric verification based on fingerprints is a better choice.

A biometric voting machine using fingerprint sensor matches the voter's fingerprint with the fingerprints in the database [9]. This provide biometric verification, but identifying a voter on the basis of his fingerprint may work well with less number of voters and cannot serve the purpose in real elections since there can be thousands of voters for a single polling station hence making the process slow. Another biometric machine uses iris verification and after verification the poll worker has to enter the identity number and after that the iris image is captured and matched against the stored image. If verified the voter is prompted to the vote [8]. Another simple biometric machine is based on PIC microcontroller which is interfaced directly with the fingerprint sensor and a 16x2 LCD is used to display the information. This proposed machine, however, does not have any input device besides fingerprint sensor [10]. Another biometric machine is based on Arduino-Mega microcontroller. It uses a keyboard, fingerprint sensor and a 128x64 graphical LCD. This machine identifies the voter on the basis of the fingerprints and then prompts the voter to enter the "code" of the candidate he wishes to vote [11]. This may create serious problem due to human error as the voter may enter the wrong code mistakenly. An ARM9 microcontroller based biometric machine uses a touchscreen and fingerprint sensor. It uses a centralized database hosted by some server. This machine also identifies a voter on the basis of his fingerprints, by comparing his fingerprint with those stored in remote-server. Upon identification and verification it displays the candidates' information on the screen which a voter can use to vote his desired candidate. As soon as the candidate is selected the database in the remote server is updated instantaneously [12]. The use of only central database hosted by remote server is not enough as in the failure of communication the machine will fail to operate.

The above discussed machines can provide biometric verification, however there are some problems with these machines. Almost all machines use fingerprints as an identification means which can slow down the voting process as comparing a fingerprint with fingerprints with those stored in database may take longer time. A 1:1 verification takes less time than 1:N identification and is more reliable. None of the above discussed machines can take care of the problems that have been found in the machines that are being used in the different countries. For example, none of them has a means of VVPAT. So there was still a need of the development of a sophisticated and automated machine which can address the problems and requirements of the desired voting machine. The voting machine discussed in this paper provides a solution against the entire problem mentioned in earlier voting machines. It is automated, user-interactive, sophisticated and easy to use. This machine and the central server with its applications form a voting system.

II. FEATURES

The proposed system has some state of the art features that can help in conducting free and fair elections. The machine has the following features:

a) Automatic identity card reading.
b) Biometric Verification.
c) User Interactive GUI.
d) Ability to hold database in local server.
e) Ability to use database in remote server.
f) Printed slip after voting for VVPAT.

It is however worth mentioning the machine reads the identity card of the citizens, not the smartcard as the voting machines of Diebold Election Systems Inc. do. In Pakistan, this identity card is issued by the National Database and Registration Authority (NADRA). The system also has the following features:

a) Availability of results to authorities during voting.
b) Publishing of results on website as soon as the voting is closed.
c) Fast accumulation of results.
d) Electronic and Paper records of the votes.
e) To check the status of the vote through SMS
f) Polling station Information through SMS.
g) Ease of giving right to vote to overseas citizen.

The information about the vote status is another feature in addition to VVPAT to verify that vote has been cast properly.

III. COMPONENTS AND HARDWARE

This biometric voting system is based on following software components:

a) Voters Database Server.
b) Candidates Database Server.
c) Voter Database Application.
d) Candidate Database Application.
e) Voting Application.
f) Website to display results.

The above mentioned components work as a whole to constitute the voting system and make it effective and less prone to errors.

The voting machine is based on the following hardware:

a) Raspberry Pi 2 [13].
b) 5" Touch Screen [14].
c) GT511C3 Fingerprint Sensor [15].
d) Identity Card Reader (camera) [16].
e) Mini Thermal Receipt Printer [17].
f) 6V Battery

g) Battery Charger

The voting system however uses some extra hardware which is:

a) Server Computer.
b) GSM module
c) GT511C3 Fingerprint Sensor (for Registration)

The hardware block diagram is shown in Figure 1 and gadget top view is shown in the Figure 2 respectively.

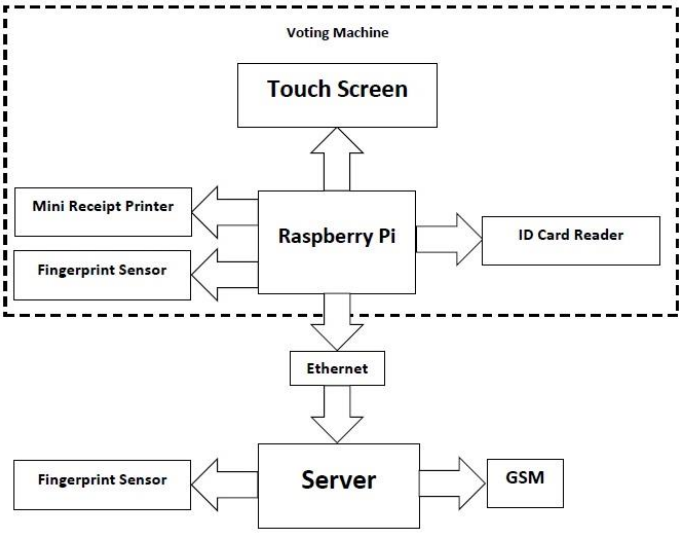

Figure 1: Hardware Block Diagram.

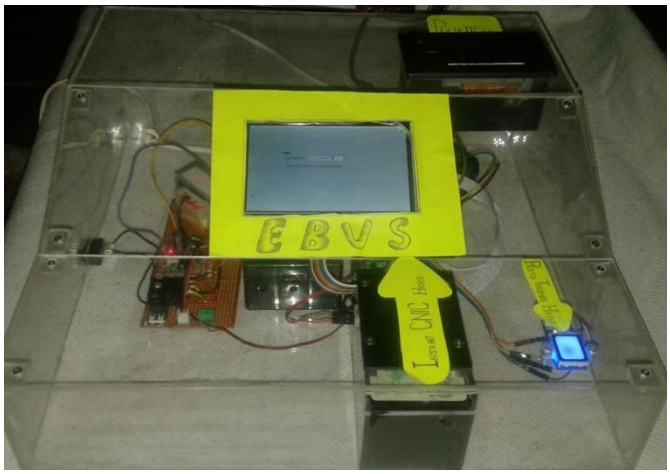

Figure 2: Front view of Voting Machine.

IV. OPERATING SYSTEMS

The voting machine uses the hardware that requires operating system to work. The operating systems used are Raspbian and Windows. Raspbian is a debian based linux operating system installed on raspberry pi which forms the backbone of the voting machine [18]. Application for voting is made on this operating system. Microsoft Windows is used on the server end computer and since the same computer is used to have some applications, which will be discussed later, to manage databases.

V. SOFTWARES

The softwares used in the development of the system are Qt, Microsoft Visual Studio and MySql. Qt is a cross-platform IDE which can be used on multiple systems. Qt Creator is used to write code and design the GUI and Qt uses GCC compiler to compile the C++ codes [19]. This plateform has been used to create Voting Application on Raspberry Pi.

Microsoft Visual Studio is used on Windows system to create Server-end application and for testing some of the hardware. It supports x86 and x64 architectures and use .NET framework for GUI based applications. Almost all languages are supported by Microsoft Visual Studio [20]. However for this project, VB .NET and, to a small extent, C++ was used.

MySql is database management system which can support multiple operating systems and have the ability to create a client-server connection. This connection enables the client to access database remotely hosted by a server. This feature makes it the best choice for the most database related work [21].

VI. WORKING

The voting machine has three access levels, i.e., Authority, Presiding Officer and Voter. A general working of the machine is that a person inserts the CNIC (Computerized National Identity Card) in the box in which camera is housed. The system takes the image of the CNIC and after processing gets the CNIC number of that person, checks for the information in the database and determines the access level of that person. The information is then fed to the machine and asks the person to press his thumb on the finger print sensor. If the impression matches, the system will proceed to respective GUI. At this point it is worth noting that unlike voting machines of the Diebold Election Systems Inc., this machine makes decision on the basis of CNIC, hence eliminating the risk of tempering by the homebrew smartcards.

The working of the system is the combination of following parts:

i. Voter Database Application
ii. Candidates Database Application
iii. Identification and Verification
iv. Machine Settings Phase
v. Voting Phase
vi. Updating of Main Database

Voter Database Application is developed in the main database computer to keep record of the voters. It is developed in VB.NET. This application gets the information of the voter including his thumb prints and stores it in the database.

Candidates Database Application is also developed to keep track of the candidates contesting in the election. This application also shows the results of the elections in different ways. It is also created with VB.NET. The Identification and Verification phase take place on voting machine. The flow chart of this phase is shown in Figure 3. If the person is identified as an authority, the authority GUI will appear. An authorized person can perform following tasks after successfully login: a) set the Constituency, b) download Voter and Candidate Database to Local Database, c) stop

Voting only if it's in progress, and d) clear the machine settings. If the inserted CNIC is found to be of presiding officer, the voting machine will display the GUI for presiding officer. The presiding officer can do the following tasks: a) start voting, b) manually verify a person if, due to any reason, can't be verified by the machine, and c) stop the voting.

It is worth mentioning that the voting can be started and stopped only for once. Once a voting is started and then stopped it can never be started again unless it is reset by the authority. If the person is identified as a voter, the voting machine will display the GUI for voter and goes into voting phase. The flow chart of this phase is shown in Figure 4. After identification and verification, system will get the list of National Assembly candidates and will display it on the touch screen. The voter will select the candidate of his choice. After that, same process will happen for the provincial assembly candidates. After confirmation system will check if main DB is connected. If it is connected then it will update machine database as well as main database, otherwise only machine database will be updated. At the end of this process a slip will be printed confirming the vote has been casted. The slip contains information about the selected candidates.

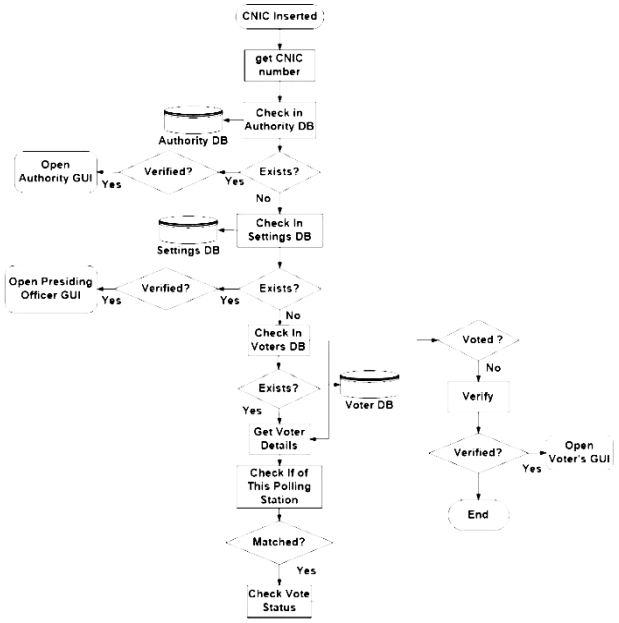

Figure 3: Identification and Verification Phase

The voting machine have local database that is hosted by the machine and if the communication to the remote database server is lost, the machine uses the local database server. There is, however, need to update the remote database server as the communication is restored. The flow chart in Figure 5 shows the process of updating the remote database server. As the communication is established, the system will check the local database and see if any update is needed. If it is needed then it will get list of voters and candidates for update. The system will then update the main Candidate and Voters Database Server and at the same time it will flush away the temporary local server by clearing the candidates and the voters.

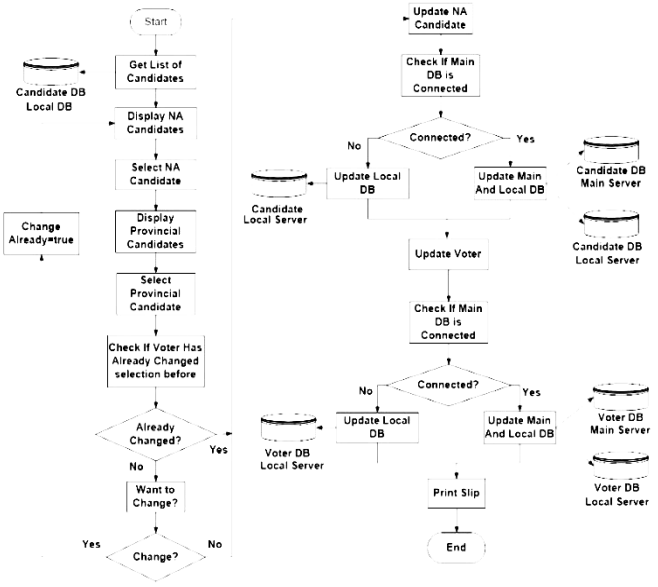

Figure 4: Voting Phase

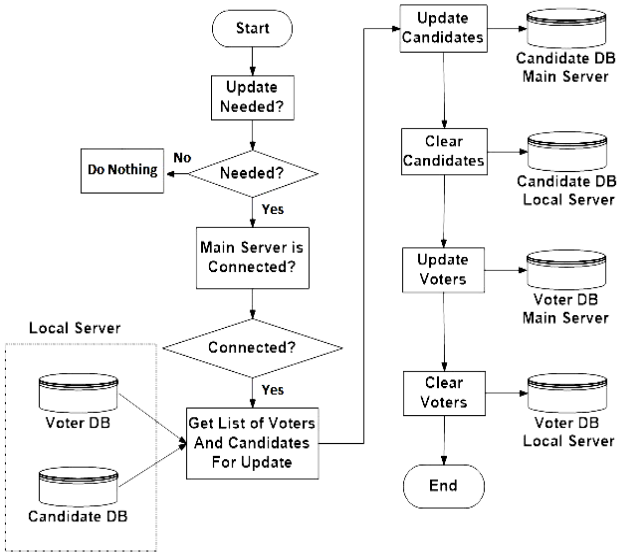

Figure 5: Process of updating the main database.

VII. VOTING FACILITY FOR OVERSEAS CITIZENS

Giving right to vote to the overseas citizens has been a big problem for any country. The authorities face a great problem for this purpose. Since this machine has the ability to use the central database it can assist the overseas citizens to use their right to vote. All governments keep record of their overseas citizens and in Pakistan the overseas citizens have a specially issued ID card that is called NICOP (National Identity Card for Overseas Pakistani) [22]. All that is needed is to set the machine for the overseas voting and keep the device connected to database all the time. The device will communicate with the central database and thus will acquire the detail about the voters and the candidate of their respective constituencies.

VIII. RESULTS

The voting machine and the system were tested by creating a database of voter and fictitious candidates. The machine and system was tested for one polling station. During testing the machine was able to verify 100% voters and recorded the votes of candidates successfully. The fingerprint sensor GT511C3, however, has a false detection rate of 10 per million that is negligible.

IX. CONCLUSION

In this paper, a sophisticated and automated voting system is implemented to regularize and provide a fool proof voting system. The machine is good enough to eliminate the problems in previous voting machines. It has a power backup and can use local database as well as the main database in remote server, thus enables the fast accumulation of the result. The machine is automated and hence removes the factor of human error to a great extent. The machine prints the paper slip after the voting which can be used for VVPAT. The machine has simple user-interactive GUI with a touchscreen which makes it easy to use even for those voters which have little knowledge about the computer and such gadgets.

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