UNIVERSITY FOR DEVELOPMENT STUDIES

BIOMETRIC ELECTRONIC VOTING SOFTWARE FOR GHANA

YINYEH MHAANEEH OPHELIUS

Thesis submitted to the Department of Mathematics, Faculty of Mathematical Sciences, University for Development Studies in Partial Fulfillment of the Requirement for the Award of Master of Science Degree in Computational Mathematics

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BY

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(UDS/MM/0009/11)

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OCTOBER, 2013

DECLARATION

Student

I hereby declare that this thesis is the result of my own original work and that no part of it (has been presented for another degree in this university or elsewhere) except where due acknowledgement has been made in the form of citations.

Candidate's Signature:..... Date: 07/11/2013

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Supervisor

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies:

Supervisor's Signature:..... Date: 07/11/2013

Name: PROF. KAZEEM A. GBOLAGADE

ABSTRACT

This thesis presents the development of Biometric Electronic Voting System Software (BEVSS) for Ghana. To achieve an acceptable design and a successful implementation of Biometric Electronic Voting System, several local languages were taken into consideration during the development process to cater for the over forty (40%) percent of the population who are illiterates. These local languages were further recorded in audio format to aid the visually impaired to use the software in the electioneering process. This is to widen access, comprehension and to reduce the possibility of disenfranchising citizens who are illiterates or visually impaired. Many African countries have proposed electronic voting system for their national elections, this project as a case study for Ghana would be a pivotal reference to speeding up their implementation. Microsoft Visual Basic 2010 was used to develop the BEVSS at the front end and SQL Server Database at the backend. The BEVSS is integrated with a biometric fingerprint machine to scan the finger print of eligible voters during the registration process and for the authentication or verification on Election Day. The BEVSS would be implemented on personal computers over a Local Area Network at each polling station. The software was implemented for the Computer Science Students Association Election, and was successful.

ACKNOWLEDGEMENT

I would like to register my profound gratitude and appreciation to my supervisor, Prof. K. A Gbolagade for his mentorship, unflinching support and guidance throughout the entire research work, to the entire post graduate class for their contributions and criticisms that fine tuned the ideas in putting up this thesis.

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Finally to my Parents Mr. and Mrs. Maurice B. Yinyeh, for their financial support and parental guidance throughout my education to this level

DEDICATION

This thesis is dedicated to the Yinyeh and the Opoku-kyeremeh families.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

BACKGROUND TO THE RESEARCH PROBLEM

1.1 Introduction

The republic of Ghana gained independence on the 6th of March 1957. It comprises of ten (10) Regions and two hundred and seventy five (275) constituencies. The country is located in West Africa and shares land borders with the Republic of Togo in the East, Cote d' ivore in the West, Gulf of Guinea in the South and Burkina Faso in the North. In Ghana, general elections are carried out every four (4) years where the head of state (the President) and The Members of Parliament of the various constituencies are elected. The Parliament is made up of 275 members representing respective constituencies.

The electoral commission of Ghana since its inception, despite the latest advancements in technology, still use paper based methods during voting; this system is characterized by thumb printing ballot papers to choose leaders, this has led to an excessive number of mistakes leading to wrong number of votes cast, hence leading to confusion at the time of announcing election results. The main advantage of paper-based systems is that ballot papers are easily human auditable. The disadvantages outweigh the advantages for instance the need to print ballot papers is a slow, expensive, inflexible, environmentally hostile process and last minute changes to the voter register are difficult to accommodate among others.

Over the last few years, there have been a number of stakeholders who have suggested electoral reforms to introduce electronic voting at State and Local

Government election processes. Biometric Electronic voting would be cheaper for the long term than the present paper based arrangement David (2006).

Throughout history, election fraud has occurred in many electoral processes from which experience shows that the manual voting process is a major source of such vices and violence in many democratic countries.

Ghana's elections in December 2012 marked the sixth consecutive Presidential and Parliamentary elections since Ghana returned to democratic rule in 1992. Like has been the case in the past election years, stakeholders and various organizations worked hard to defend democratic gains by developing strategic interventions to promote free, credible, acceptable and violent free elections. Against this backdrop was the introduction of the Biometric Voter Registration and Verification System, which was to minimize the occurrence of election tension that usually triggers from issues such as multiple registration and voting, bloated voters' registers and disputed polling station results. However this technical intervention could only do so much to ensure peaceful elections. The rest still boils down to the human factor which includes responsible engagement and dialogue between and amongst presidential and parliamentary aspirants, the lack of inflammatory radio discussions, the willingness of the police to act decisively in arresting and prosecuting perpetrators of electoral offences and instigators of electoral violence and the empowerment of the youth and youth organizations through information and skills aimed at reducing their vulnerability to the selfish and cancerous manipulation of politicians.

Election is one of the most acceptable means of selecting representatives in a democratic setting. Leaders are selected by majority of the populace and not by a "powerful" few who may not represent the overall interest and aspirations of the people, Jegede et al. (2009).

In recent times, democracy has become an important part of people's lives, and to achieve democracy we must meet several conditions. The heart of democracy is voting. The heart of voting is trust that each vote is recorded and tallied with accuracy and impartiality. The accuracy and impartiality are tallied in high rate with biometric system. Among these biometric signs, fingerprint has been researched the longest period of time, and shows the most promising future in real-world applications. Because of their uniqueness and consistency over the years, fingerprints have been used for identification over time, (Sobia & Ummer, 2011).

Voting theory began formally in the 18th century and many proposals for voting systems have been made ever since (Sobia & Ummer, 2011). There have been several studies on using electronic technologies to improve elections. When designing an electronic voting system, it is essential to consider ways in which the voting tasks can be performed electronically without sacrificing voter privacy or introducing opportunities for fraud.

An electronic voting system defines rules for valid voting and gives an efficient method of counting votes, which are aggregated to yield a final result.

Moreover, electronic voting systems can improve voter identification process by utilizing biometric recognition. Biometrics is becoming an essential component of personal identification solutions, since biometric identifiers cannot be shared or

misplaced and they represent an individual's identity. Biometric recognition refers to the use of iris, fingerprint, face, palm and speech characteristics, called biometric identifiers. Fingerprint matching is a significant part of this process, Avarez et al. (2008). It is an extremely difficult problem, due to variations in different impressions of the same finger. Fingerprints are unique to each individual and they do not change over time (Sobia & Ummer, 2011).

Many people use the paper ballot to choose their representatives through the traditional (paper ballot) voting system. This method has been used since independence. This method requires the presence of the person to the polling station, at the time specified, stands in the booth and vote to choose one of the candidates in confidence and then put the paper in the ballot box. However, the method has several disadvantages, for example the voters must go to the voting point and wait in a queue to cast his vote and in some cases the voter is subjected to harassment by some officials. Again, is easily susceptible to fraud and changing of votes, due to the human factor in the tallying and counting of votes. Furthermore, it is very cumbersome to collect the ballot boxes and transport them to the various polling centers because of the limited time on election day and most importantly, the error that may occur during the counting of votes. In some cases, security problems may affect the functioning of the electoral process. For example, threat to the polling stations, voters and the electoral officials may negatively affect entire election. All these reasons and many others necessitate serious research to the introduction of biometric electronic voting system in Ghana.

Elections are necessary for the establishment of a functional democracy; but elections can also result in flash-points and catalysts for further violence, particularly when fraud occurs or is believed to have occurred. Pre-mature victory claims and non-acceptance of election losses even when the results are affirmed or verified by neutral third-party, missions and the exacerbation of pre-election tensions, David et al. (2006)

A study conducted in 2013, accepted the hypothesis that the electronic voting system will help eradicate rigging in Ghana and that the e-voting will encourage people to vote more and the best results of candidates might be achieved, Yeboah et al. (2013).

1.2 Problem Statement

The inefficiency in Ghana's current voting system is due to four factors: The difficulties in managing and tallying paper ballots, the probability of human error in the tallying and coalition process, alleged ballot stuffing as well as spoilt ballots are the problems that bedevil almost every election since independence. The effects of rigging and stuffing of ballot paper has led to political crisis in many African countries. Kenya lost more than half a million population through electoral manipulation. Rwanda experienced the worst human degradation through election rigging, Ivory Coast nearly disintegrated as a result of electoral malpractices. With a biometric electronic voting system the votes can be managed and tallied electronically, reducing the time involved in this process and eliminating ballot stuffing, double registration and voting.

1.3 Research Questions

i) How can we reduce double registration or voting?

ii) How can biometric electronic voting system ensure political stability in Ghana?

iii) How would the visually impaired be able to use this system to vote?

iv) How can this voting system support the vast majority of the voting population who are illiterates and do not know how to use the software?

1.4 Objectives of the research

i) To develop biometric electronic voting software that would prevent double registration and double voting.

ii) To develop an electronic voting system that would tally votes by candidates and their positions as well as their vote's percentages.

iii) To develop a voting system in about ten (10) Ghanaian languages both in text and in audio.

1.5 Significance of the Project

Biometric Electronic voting will speed up the voting process, especially where advance voting is concerned (voting earlier than the election date). After voting in the polling booth, voters would not have to go back and drop their ballot into the ballot box and go for another ballot because, electronic ballot would be issued to each voter on the screen on the voting machine. Similarly, on election day voters do not have to wait for their ballots to be stamped or drop them into the ballot box.

Biometric Electronic voting will also increase the security and reliability of elections. An electronic vote is transported safely, reliably and fast into the centralized database. Electronic voting makes possible to vote at any polling station, regardless of domicile, even on election day.

Further, in biometric electronic voting it is not possible to make voting errors by mistake, because the identification information of the chosen candidate will appear on the screen before the vote is confirmed.

Another advantage for the voter and the candidates as well as the parties is that, there is no ambiguity in interpreting an electronic vote. When current paper ballots are used, unclear thumbprint, numbers, pictures or symbols may sometimes cause problems.

Biometric Electronic voting reduces and simplifies the work of the electoral commission significantly. Biometric Electronic voting leads to notable cost savings for the nation through reduced personnel in the long run. For instance the following functions are no longer needed in electronic voting:

i) stamping the ballot and sealing or folding the ballot in the election envelope
ii) making or marking the entries in the voting register
iii) sending the voting documents to the Regional, District and Polling station
iv) examining the documents at the Regional and National Office of the electoral commission
v) transportation of the election materials to the constituency electoral areas

vi) opening the ballot box and counting the votes

Electronic voting will deliver also other cost savings. For example various envelopes, forms and documents are no longer needed.

Electronic votes can be counted fast and reliably, and the result of the vote will be ready almost immediately.

To the political parties and independent candidates participating in the elections are assured of all votes cast in their favor without having to deploy personnel to the various voting centers to monitor elections.

Research institutions, political analyst and Judicial System would have a primary source of data and reference for future research and arbitration of electoral disputes.

1.6 Definition of Terms

Electronic voting: Electronic voting refers to the use of computers and telecommunication systems to handle an entire or certain aspect of an electoral process.

Voter's registration: The voter's registration is a phase that facilitates the collection of data of prospective voters and the subsequent transfer of such data into the computerized system.

Authentication: The authentication is a phase that verifies the voters access rights and franchise.

Voting and votes saving: The voting and vote saving is a phase where eligible voters cast votes and e-voting system saves the votes cast by voters.

Vote management: The vote management is a phase, in which votes are organized, sorted and prepared for counting.

Vote counting: The phase where votes are decrypted and arithmetically added and to output the final tally.

Auditing: The auditing is a phase that ensures that eligible voters were able to vote and their votes count in the computation of final tally (Sobia & Ummer, 2011)

1.7 Operational Definition of Terms

Current Voting System: A paper ballot with candidates pictures for a voter to make a choice by thumb printing against the candidates of choice.

Traditional voting: Using paper ballot in a legal system for making democratic choices

Electronic Tally: Counting by the computer without the assistance of humans.

Electronic Ballot: A softcopy of candidates pictures for a voter to make a choices.

Be-voting: Biometric Electronic Voting system, this encompasses registration of voters by scanning their fingerprint and verified by the finger print on Election Day before voting through electronic ballot in the computer.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Irrespective of how attractive and laudable the traditional electoral process seems, it has been a great challenge for developing countries of Africa, Asia and Latin America to conduct reliable elections whose results are generally accepted by the populace, Jegede et al. (2009).

This has led to wide protests, which has culminated in loss of lives and wanton destruction of properties. Many promising democracies in these countries have been truncated because of crises that arouse due to electoral disputes. Some of these countries have been plunged into serious political unrest, which in some cases culminated in civil wars with the attendant security, social, economic and humanitarian problems. For instance the political unrest that followed the 1964 elections in Nigeria led to military takeover on January 15, 1966 and the counter coup of July 29, 1966 which triggered a chain of events which culminated in the civil war of 1967-1970. The political crisis which engulfed the Western part of Nigeria in 1983 also left death and loss of properties on it trail. Some other countries of Africa also have their tales of electoral woes. In 1998, the political and economic stability hitherto enjoyed by Kenya and Zimbabwe was disrupted by series of violent protests because of disagreements over the presidential elections, which took place in these countries during the year, Jegede et al. (2009).

2.2 Design of Electronic Voting

(Compuware Corporation, 2003), proposed a web-based voting system using fingerprint in order to provide a high performance with high security to the voting system. In this paper the system was developed using C#. It is remarkable to note that in this system the research failed to make the system accessible to the visually impaired.

After a careful study of the electoral commission of Ghana and the processes involved in the organization of elections, (Ofori-Dwumfuo & Paatey, 2011) put forward an on-line voting system (OVIS). This system was to phase out the paper ballot system in Ghana. (Ofori-Dwumfuo & Paatey, 2011) concluded however that not all voters may be able to enter their voter identification numbers and passwords. Clearly, this indicates that there is the need for a better way of authentication for voters to solve that problem. In addition (Ofori-Dwumfuo & Paatey, 2011) admitted in their paper that hackers and fraudsters, including system administrators was a threat to the system.

Compuware Corporation (2003) revealed the need to incorporate biometric identification to electronic voting system, taking into consideration previous development. The characteristics and performance of the biometric recognition system was analyzed before incorporating it into the electronic voting system and it proved successful to the Universidad Nacional de La Plata (UNLP)

David (2006) identified the most popular and widely researched and widely used biometric recognition system successfully implemented. The fingerprint biometric recognition system in this paper was designed and implemented in restricted area. In

this paper, the authors found that the fingerprint image may not always be of very high quality. These images may sometimes be degraded due to variation of skin, impression conditions and the type of working conditions of some individuals. The paper therefore proposed a minutiae image enhancement before matching of the images.

Kumar et al. (2011), designed an electronic voting system using fingerprint using Gabor technique to enhance the fingerprints for electronic voting system to correct poor images scanned and for verification.

In an Offline e-voting process, authentication can be done using facial recognition, finger vein sensing and RFID (smart cards) which enables the electronic ballot reset for allowing voters to cast their votes. The main goal of a secure e-voting is to ensure the privacy of the voters and accuracy of the votes. A secured e-voting system satisfies the following requirements,

Eligibility: only votes of legitimate voters shall be taken into account;

Unreusability: each voter is allowed to cast one vote.

Anonymity: votes are set secret.

Accuracy: ballot cast cannot be altered. Therefore, it must not be possible to delete ballots nor to add ballots, once the election has been closed;

Fairness: partial tabulation is impossible; *Vote and go*: once a voter has casted their vote, no further action prior to the end of the election;

Public verifiability: anyone should be able to readily check the validity of the whole voting process (Alaguvel & Gnanavel, 2013).

If the Nigerians' Electoral Commission is determined to conduct a credible poll in the future elections, then electronic voting should be seen as a veritable option to achieve its aim. Electronic voting also known as biometric voting has been effectively implemented in some countries in Africa with Mozambique taking the lead. As the most reliable solution to electoral fraud and malpractice, Nigeria has been Africans largest needs to follow suit in order to overcome the problems of mass thumb printing of ballot papers by an individual, ballot stuffing, snatching of ballot boxes, impersonation of voters, errors due to manual collation of results and multiple registration, Security Criteria for Electronic Voting (1993).

Some of the minimum requirements of a democratic election procedure proposed are;

i) That those wishing to cast a vote are positively identified as eligible voters and that no voter is able to cast more than a single ballot in a given election;

ii) That safeguards against personating are maintained;

iii) That the free exercise of the vote is safeguarded, both in terms of the opportunity to cast a ballot and that voters are free from duress and unlawful undue influence;

iv) That secrecy regarding how an individual elector has, or has not, voted is preserved save in the face of a proper order of a competent Court;

v) That the voting process is protected against tampering after any vote or votes have been cast;

vi) That the counting procedure is verifiable, transparent and open to scrutiny, and accurate Bob (2002).

In the design of any electronic voting system, authentication is a very crucial part of the whole voting system which ensures that the voter is authenticated to vote; if there is a loophole in the authentication process then a voting system is not secure and results will not be acceptable and if a government comes in power by any illegal means like electoral fraud that affects the electoral processes and the legitimacy of the elected government. Developing country like India which have one of the largest democracy in the world are continuously trying to improve on their voting system, (Saurabh & Ajay, 2013)

2.3 Security of Electronic Voting

Stewart et al. (2010), in their research bemoaned the security vulnerabilities of paperless voting systems. Citing insider threats and poor cryptographic implementation as well as network vulnerabilities

Ferars (2011) introduces an electronic voting system based on username and password. In this paper, security was their objective and to achieve that, prospective voters were issued with username and a corresponding password to access the system to vote.

Hari et al. (2010) in their paper concluded that, India electronic voting machine (EVM) was vulnerable to serious attacks that can alter election results and violate the secrecy of the ballot.

This refers to issues related to voters for instance eligibility, privacy protection, anonymity and secrecy of voters, Alvarez et al. (2009).

Mercuri (2003) presents a very interesting scheme, whereby voters could get receipts for their votes. This receipt would allow them to know if their votes were included in

the final tally or not, and to prove that they voted without revealing any information about how they voted. The security of this scheme depends on visual cryptography developed by Naor and Shamir, and on voters randomly choosing one of two pieces of paper, Mercuri (2002).

In 2003, concerns around the quality of voting equipment standards and certification were reaffirmed when one voting system vendor, Diebold Election Systems, accidentally disclosed the source code for the software used in its AccuVote-TS voting system to the public (Science Applications International Corporation, 2003).

This story exploded into the press with the public release by several of us Rubin, Wallach (2005) of a report documenting serious security flaws in that software (the Hopkins/Rice report), Kohno et al. (2004).

Although the vendor has strenuously denied the significance of these flaws (Security Criteria for Electronic Voting, 1993) subsequent reports commissioned by the state of Maryland from Science Applications International Corporation (SAIC) (Science Applications International Corporation, 2003) and RABA, Technologies Kohno et al. (2004) and by the state of Ohio from InfoSentry, (Ashok & Sariba, 2011), Begum and Compuware (Science Applications International Corporation, 2003), substantially confirm all the major security flaws identified in the Hopkins/Rice report. The InfoSentry and Compuware reports additionally considered systems made by Election Systems and Software, Hart InterCivic, and Sequoia (which, with Diebold, collectively dominate the marketplace for voting equipment); every system had significant flaws.

A new model called KBEVS has been proposed which uses concept of Kerberos. In this model, electorates have to download an application on their mobile, with the help of this application they can vote without knowing the background processes that are taking place.

This model of electronic voting system enhances the security features, prevention against malicious attacks and gives flexibility. Finally this model can be used along with other existing electronic voting systems as an option, depending upon the electorates whatever option he may choose. The option may include by going to the voting centre or by simply the place where you are, with the help of your mobile device, Virendra et al. (2012).

A two-factor-based self-authentication and deniable authentication schemes were proposed in which, firstly, each user has to perform self-authentication by something he knows (password) and something he is (biometrics), and then he can accomplish the transaction, e.g., e-commerce. Security analysis shows that the proposed schemes can overcome the security pitfalls of the previous schemes and are secure, reliable and practicable with high potential to be used in the electronic world Muhammad (2009).

The Kwame Nkrumah University Information Technology Services in collaboration with the office of the Dean of Students embarked on a Biometric Data Collection for all students of the Kwame Nkrumah University for Science and Technology (KNUST). The exercise was towards Students Representative Council (SRC) elections. It was anticipated that, to safeguard and to bring more transparency into electoral processes towards Student leadership.

The decision was arrived at when the university was brought to notice some students' motivation to rigging elections through the ballot paper. In reviewing the procedures for elections, ballot papers were printed to which the security was not fully guaranteed. The results motivated the Office of the Dean of Students to liaise with the Electoral Commissioner of the SRC to implement a more secure way of conducting elections on campus Kwame Nkrumah University of Science and Technology (KNUST, 2012).

2.4 Accuracy of Electronic Voting

A very important expectation of e-voting systems is improved accuracy and elimination of spoiled votes De (2007). In any election, there exists a set of requirements among which voters should receive assurance that their intent was correctly captured and that all eligible votes were correctly tallied. On the other hand, the election system as a whole should ensure that voter coercion is unlikely. These conflicting requirements present a significant challenge: how can voters receive enough assurance to trust the election result, but not so much that they can prove to a potential coercer how they voted.

The challenge of changing the traditional paper based voting methods used in many developing countries into electronic voting raises a set of functional and constitutional requirements. These requirements are governed by the country in which they operate and are usually not limited to privacy, authentication, fairness, transparency and integrity Anne-Marie et al. (2009).

The attributes that makes an e-voting model acceptable is its ability to properly authenticate voters and provide a secure means through which a voter can express

his/her franchise. Adopting biometrics authentication is regarded as an effective method for automatically recognizing, with a high confidence, a person's identity Virendra et al. (2012).

An electronic voting system provides increased transparency to the public and verification for the individual voters regarding the tallying of their respective votes. A voting record can be made available electronically, thereby eliminating the need to provide a voter with a paper ballot (Robert & David, 2010).

2.4.0 Non-Technical Consideration

Boulus-Rodje (2000) took into consideration the non-technical dimensions of implementation, including the socio-cultural, organizational and political dimensions. They added that, e-voting technologies are imagined as having the capacity to do a wide range of things: increasing overall voter turnout, efficiency and accuracy of the electoral process as well as reducing waiting time and cost.

(Davide & Anil, 2009) also discovered that, e-voting was expected to improve accessibility for all voters (Disabled voters, elderly people and illiterates) Anne-Marie et al. (2009) established that policy makers hold the believe that; e-voting has unintended effects by excluding large groups of citizens from participating in the democratic process for those who are not familial with computers.

E-voting may increase greater political participation through increased transparency of the electoral process, improved accessibility for all voters as well as increased voter turnout, Shamos (1993).

Electronic voting technology can speed the counting of ballots and can provide improved accessibility for disabled voters. The user authentication process of the

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Electronic voting technology can speed the counting of ballots and can provide improved accessibility for disabled voters. The user authentication process of the

system is improved by adding both face recognition and password security. The recognition portion of the system is secured by the cover image. This system will preclude the illegal practices like rigging. Thus, the citizens can be sure that they alone can choose their leaders, thus exercising their right in the democracy Kaliyamurthie, et al. (2005).

The Indian Election Commission ensured success through massive training and awareness campaigns. The innovations are an 'unqualified success' and have been well received by parties, candidates and staff, according to the Indian Government. More than 95 per cent of the voters welcomed the use of EVMs in 1999 (Centre for the Study of Developing Societies, 1999) Cesar (2013).

2.4.1 Trust of Electronic Voting

Although technical dimensions are indeed important, trust in the e-voting system is more important than the technical characteristics, Alvarez et al. (2009).

Trust and confidence have been defined that the election produces fair outcomes and that the ballots were counted accurately, Ashraf (2011).

Another definition of trust from, Besselaar et al. (2003) is the very mechanisms of democracy, the actual electoral machinery and the process that records and counts votes accurately, Fischer (2003).

People tend to be more confident if they vote using the technology they like, Stewart et al. (2010).

2.4.2 Effects of Electronic Voting

Compuware Corporation (2003) investigated the effects of e-voting (internet) and the media. Their investigations will also inform developers about design and use of internet technologies for political processes.

2.5 Biometric Identification

Automated fingerprint verification: is a closely related technique used in applications such as attendance and access control systems. On a technical level, verification systems verify a claimed identity (a user might claim to be Joseph by presenting his PIN or ID card and verify his identity using his fingerprint), whereas identification systems determine identity based solely on fingerprints . A large number of computer algorithms have been developed to automatically process digital fingerprint images. These algorithms have greatly improved the operational productivity. Minutiae filter and Gabor filter are part of these algorithms; all these algorithms use the following steps in Figure 2.1 to do the automated fingerprint identification Mercuri (2003).

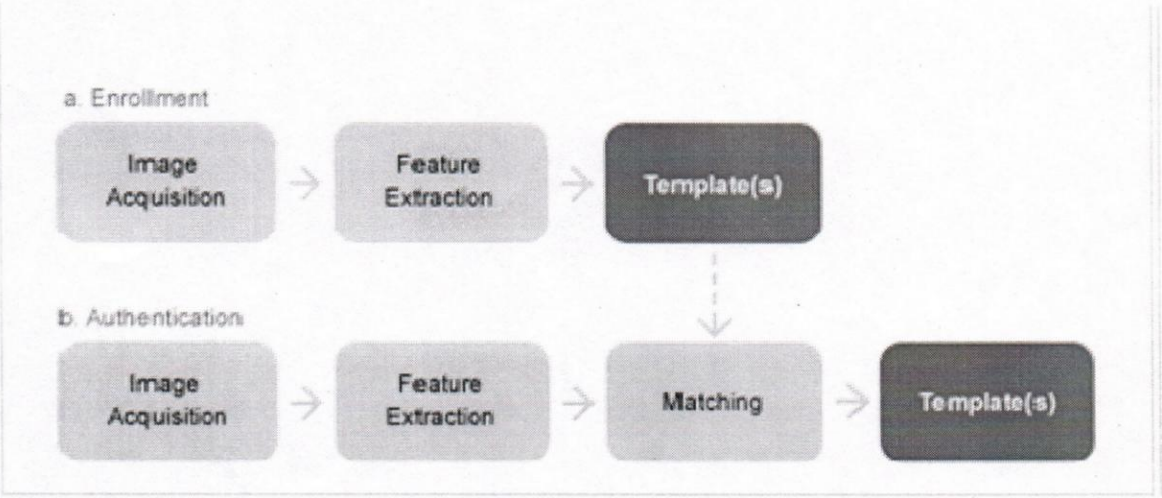


Figure 2.1: Fingerprint Identification Process Mercuri (2003).

Security Criteria for Electronic Voting, (1993) gives a list of suggestions for "generic voting criteria" which suggests that a voting system should be so hard to tamper with and so resistant to failure that no commercial system is likely to ever meet the requirements, and developing a suitable custom system would be extremely difficult and prohibitively expensive.

The introduction of electronic voting in Ghana is both feasible and desirable and that, information on the technology must, henceforth be opened to deeper and wider public scrutiny and understanding.

On Tuesday, 12 May 2009, the Electoral Commission and seven political parties including the National Democratic Congress (NDC), the New Patriotic Party (NPP), the Conventions People Party (CPP) and the Peoples National Convention (PNC) through the Inter-Party Advisory Committee (IPAC) endorsed the compilation of a new voter register based on biometric technology as the solution to multiple registration and other electoral defects associated with voter registration in Ghana.

While a biometric voter register can resolve the illegal practice of multiple registrations, it will, nevertheless, not arrest entirely the problems confronting our voting system, including multiple voting due to the normal expectation of non-100% voter turnout and the anticipated absence of an electronic biometric data identification/verification system for individual voters at the polling station on voting day.

Our electoral system will be more democratic, credible, less costly, and free from errors, delays, violence, fraud, intimidation and other electoral malpractices that frequently undermine the credibility and general public acceptance of our elections, if we institute a biometric registration and electronic voting system in Ghana, Danquah Institute (2010).

To prevent any future electoral disputes, The flag bearer of the United Front Party (UFP), Akwasi Addai Odike suggested that the nation (Ghana) invests in a fully electronic voting process, 'whatever it takes' to remove the human element which could manipulate the out outcome of polls.

The aftermath of the December 7 and 8, 2012 general elections in Ghana make this research more pronounced and begging for solutions and further research.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The voting system requires software that will allow the voter to cast their vote securely and anonymously. The biometric electronic voting software needs to be scalable, robust and most of all secure. In order to create this software in a systematic and timely manner an evaluation of available software development models was made. The project requires a model that allows quick progress, simultaneous work in different tasks and produces documentation.

Iterative waterfall Model of the Software Development Life Cycle was used.

Diagrammatically it is shown in Figure 3.1.

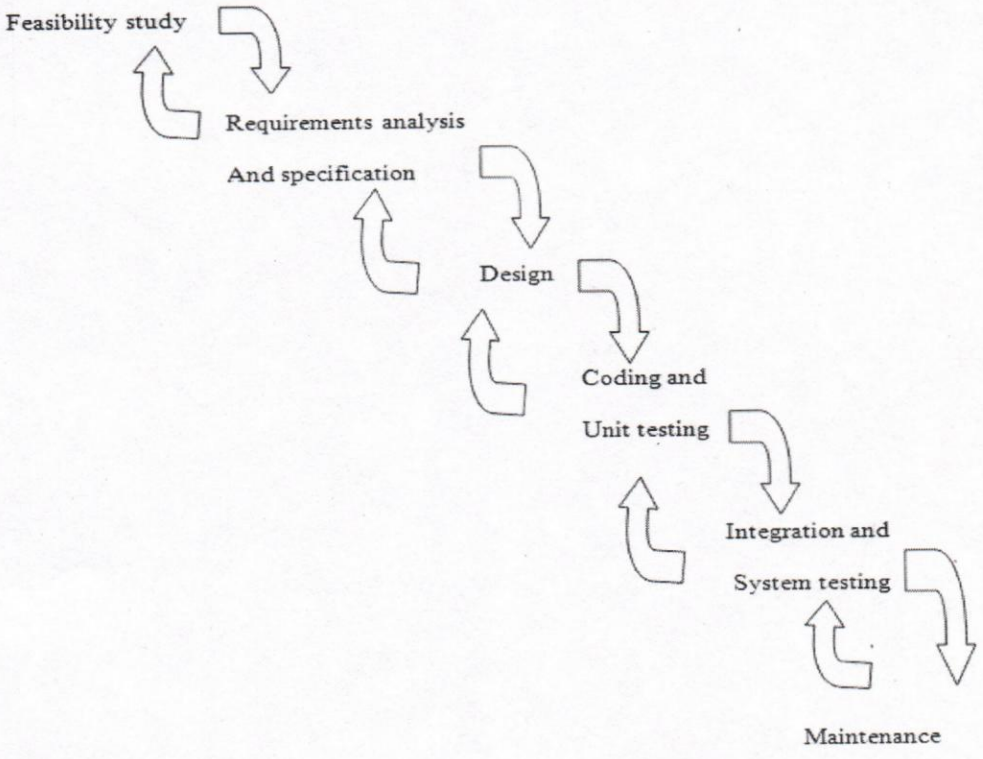


Figure 3.1 Iterative waterfall model

The development of the software adopted the life cycle model of software development. A software life cycle or process is a series of identified stages that a software product undergoes during its lifetime. The development of every software usually starts from with a feasibility study stage, and requirements analysis and specification stage, design, coding, testing and maintenance are undertaken. The above phases or stages are the life phases, (Rakesh & Naresh, 2012).

The software life cycle model is a descriptive and diagrammatic representation of a software life cycle. This identifies all the activities required to develop and maintain the software product. As mentioned earlier on the Iterative waterfall model method have been employed for the development of the software primarily because this method does not assume an ideal system development process since errors or bugs in the development of such sophisticated systems are inevitable.

3.2 Feasibility Study Phase

The main aim here is to ascertain whether the development of the product is financially as well as technically feasible. After a careful collection of data concerning the inputs as well as the expected output compared with current paper voting system, it was clear that the new system (Biometric electronic voting software) will be feasible both financially and technically. Technically, the system can be programmed in visual basic 2010 which is very comfortable to program with, taking Navrongo and Wa campuses as a case study.

3.3 Requirements Analysis and Specification

The requirement analysis and specification phase aims at understanding the exact requirement of the system and to document them properly. In this phase, requirements were obtained from the United States Department for elections; some of the requirements that a good electronic voting should possess includes the following;

The system must be robust, tamper free, easy to use with a good user interface, support and enable the disable to vote, must accurately calculate and tabulate the results or votes cast, must be economical, easy to implement and use among others.

Aside these requirements from the United States Department for elections requirements and specification were gathered from the Electoral commission of Ghana as well as UDS Navrongo and Wa Campuses Electoral commission to help build a befitting system. A document is then prepared after the analysis of the requirements and specification called the software requirement and specification (SRS) document. The software requirement and specification (SRS) document is the final product of this phase.

3.4 Design of Electronic Voting

At the design phase, the important task is to transform the requirements documented during the requirement analysis and specification stage from the software requirements and specification (SRS) document in a structure that can be implemented in a particular programming language. Object oriented design approach have been adopted because it is relatively new design technique and can be used in the realization of the design of the system. In this technique, various objects that occur in the problem are first identified the different relationship also clearly identified; in that, the various votes which is one of the object is identified taking into consideration its relationship with the various candidates vying for the positions. It's worthwhile mentioning that this technique is easy to maintain. This is because, when a system is developed using the objects as well as identifying their relationships can easily be modified using those objects.

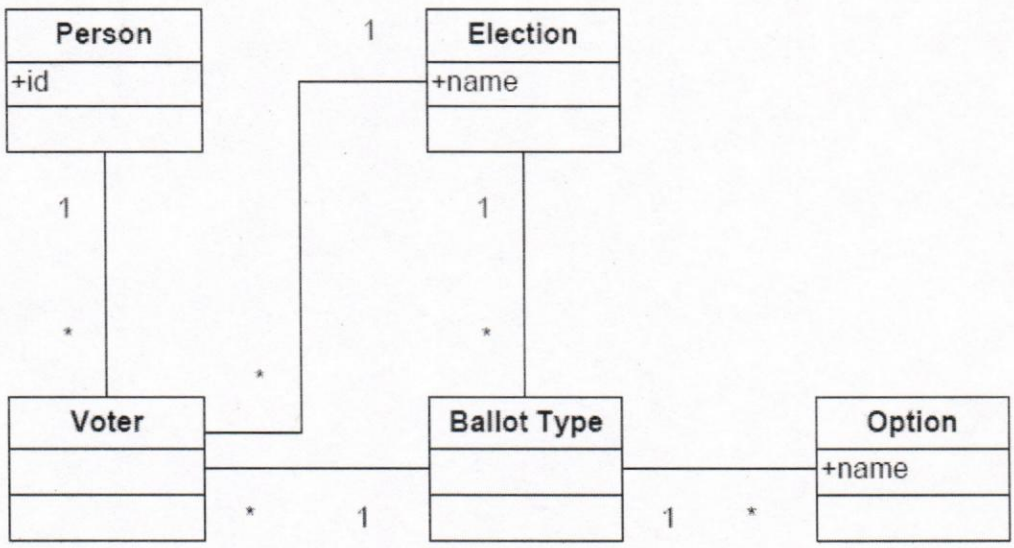


Figure 3.2 Main model of the design

Person; Any person that may participate in an election. The assumption that each person has unique identifier (Voter ID and Fingerprint).

Election; The assumption is that elections are identified by a unique name.

Voter; A person participating in an election. Many voters can participate in election. Each person can be a voter in many elections. Voter is identified by a person's Identifier and name of the election

Ballot Type; Different voters can be presented with different ballot types at the election with the same candidates for that portfolio. Ballot type consists of some number of options amongst which a voter will have to select one during the registration process.

Option; One option belonging to some ballot type, Options are identified by Names, Option names are unique within corresponding ballot type

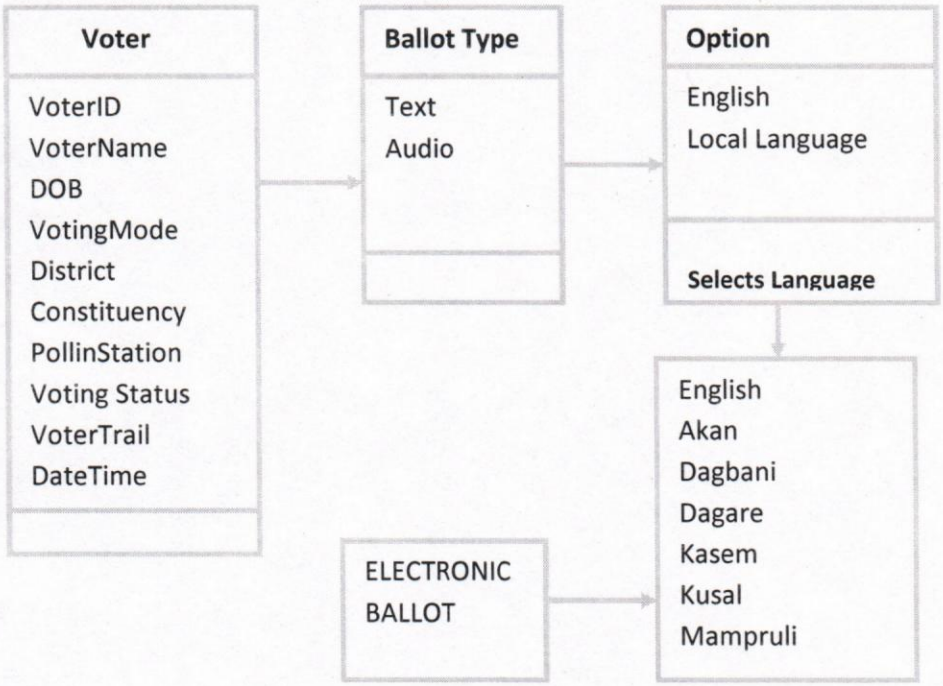


Figure 3.3 Diagram of voter and ballot selection

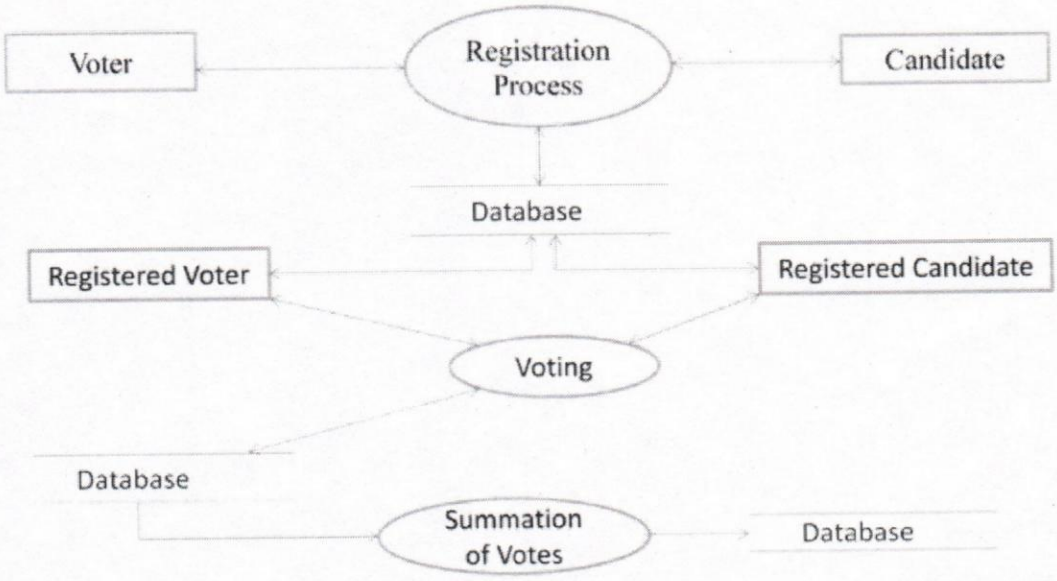


Figure 3.4 Data flow diagram of the software

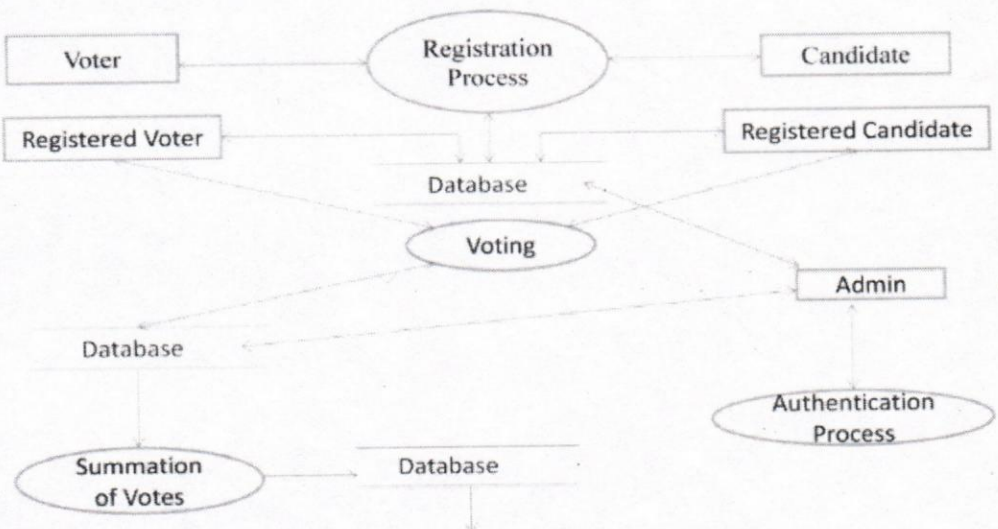


Figure 3.5 Second level data flow diagram of the software

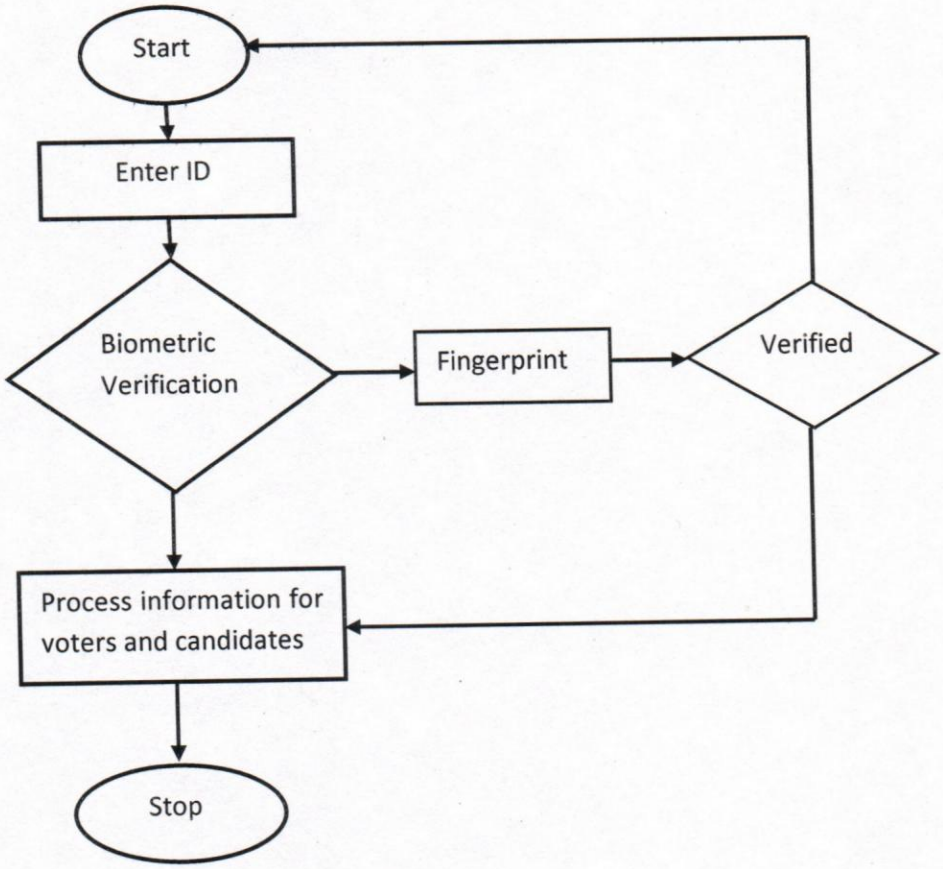


Figure 3.6 System administrator login

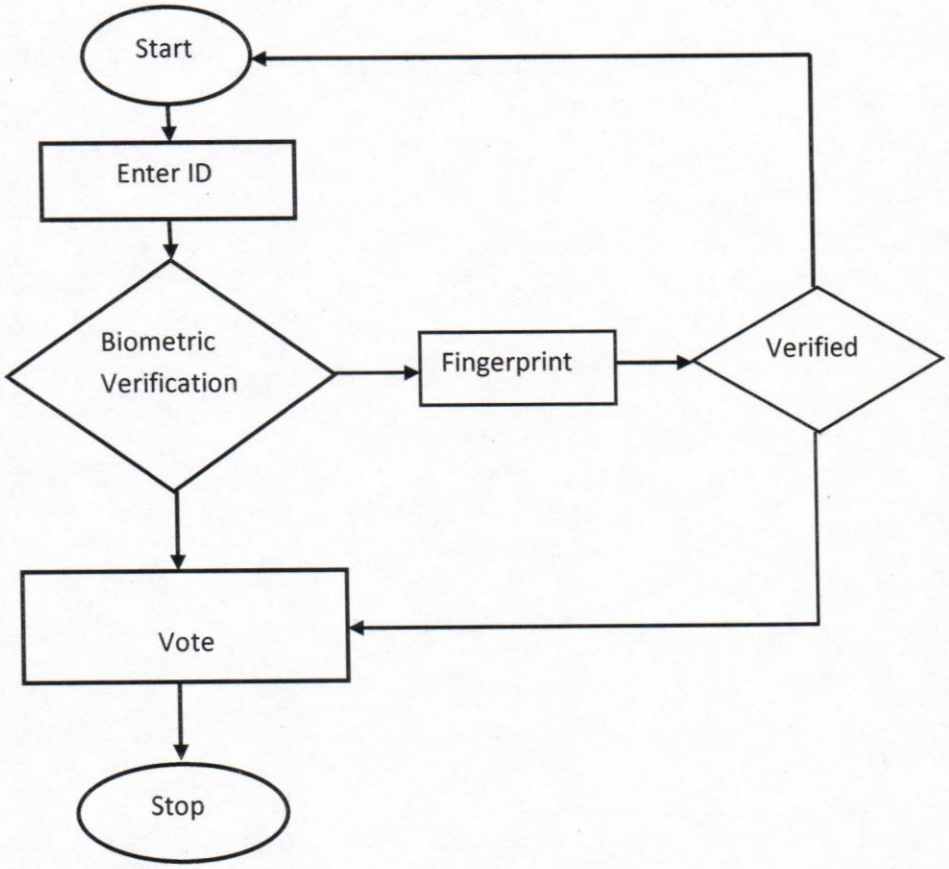


Figure 3.7 Voters login

3.5 Coding and Unit Testing

This phase (Implementation phase) is to translate the software design into source code. Each component is implemented as a model and each model is tested separately, debugged, and documented. The end-product of the implementation phase is a set of program modules that have been individually tested.

Problems that were detected in each model were corrected before testing the next module separately.

3.6 Integration and System Testing

In this phase, the various modules are integrated in a planned manner. The different modules are integrated in steps at the end of each step the integrated part is tested before the next part or step is integrated, that is the main form for the verification was integrated with that of the form for the presidential candidates and tested before integrating that of the database. The goal of system testing is to ensure that the developed system functions according to the requirements as specified in the software Requirements Specification (SRS) document. System testing usually consists of three different kinds of testing activities namely;

α –testing; this testing is done by the developer or the engineer. The system is vigorously tested to make sure that it is functioning as required.

β –testing; this type of testing is performed by close friends or organizations, groups of the engineers or developers. This is to further scrutinize the resilience and robustness as well as the functionality of the product.

Acceptance testing; finally the product is tested by the intended user(s) to either accept or reject the system based on the functional requirements of the SRS document.

3.7 Maintenance of the Software

There are three types of maintenance;

i) Corrective maintenance: correcting errors that are not discovered during the development phase.

ii) Perfective maintenance: improving the implantation of the system and enhancing the functions of the system according to the requirements.

iii) Adaptive Maintenance: porting the software to a new environment for instance to a new computer.

3.8 Tools (Software) Employed

i) Visual Basic 2010

ii) Microsoft SQL Server 2005

iii) Futronic Fingerprint Scanner and Drivers

Since the choice of a programming language is very important, Microsoft Visual Basic 2010 was used. This software is very robust and maintainable and also meets the requirement of the project. For the database system of the project, Microsoft SQL Server 2005 database was used primarily because; it is one of the most powerful database systems used in software developments.

It has many inbuilt functions for construction, retrieving and the overall management of the database.

3.9 Research Instrument

Computer: A computer is an electronic device that manipulates information, or "data." It has the ability to store, retrieve, and process data. This instrument is used for the development of the software.

Fingerprint Scanner: Finger scanning, also called fingerprint scanning, is the process of electronically obtaining and storing human fingerprints. The digital image obtained by such scanning is called a finger image. In some texts, the terms fingerprinting and fingerprint are used, but technically, these terms refer to traditional ink-and-paper processes and images.

Finger scanning is a biometric process, because it involves the automated capture, analysis, and comparison of a specific characteristic of the human body. There are several different ways in which an instrument can bring out the details in the pattern of raised areas (called ridges) and branches (called bifurcations) in a human finger image. The most common methods are optical, thermal, and tactile. They work using visible light analysis, heat-emission analysis, and pressure analysis, respectively, Kohno et al. (2004).

Visual Studio 2010: Software developers need a solid environment to work in that will help bring their applications to life. And collaboration is more important than ever before, as today's development projects expand in complexity and scope. The Visual Studio development system is a comprehensive suite of tools designed to help software developers create innovative, next-generation applications. This instrument is used to design the user interface of the software and the source codes used to interact with the hardware components of the computer.

SQL Server: SQL Server is a relational database management system (RDBMS) from Microsoft that's designed for the enterprise environment. SQL Server runs on T-SQL (Transact -SQL), a set of programming extensions from Sybase and Microsoft that add several features to standard SQL, including transaction control, exception and error handling, row processing, and declared variables. This is the instrument used to store the voters and candidates information as well as their biometric finger prints (De, 2007).

Web Camera: A webcam, or web camera, is the loosely used term for any camera that generates images that can be accessed by and displayed on the World Wide Web through a server. A webcam is essentially just a camera that is connected to a computer, either directly or wirelessly, and gathers a series of images for remote display elsewhere. Webcam technology is widely used by all sorts of people for all sorts of different reasons.

This instrument is used to take snap shot of voters and candidates pictures during registration for elections Scala Inc (2012).

CHAPTER FOUR

DATABASE

4.1 Introduction

Microsoft SQL Server Database was used primarily because it is resilient and easy to manipulate or manage efficiently. Again, it is supported by the programming language that is Microsoft Visual BASIC 2010 and can fit very well with the requirements of the system. Some of the tables designed and used in the product are shown below.

Table 4.1 Definition view of the presidential candidates

Column Name	Data Type	Allow Nulls
PartyName	varchar(50)	☐
CandidatesName	nvarchar(50)	☐
Votes	int	☐
Percentages	nvarchar(50)	☐
Position	int	☐

Table 4.2 Data view of the presidential candidates

PartyName	CandidatesName	Votes	Percentages	Position
NDC	JOHN DRAMANI MAHAMA	0	0	1
GCPP	HENRY LARTEY	0	0	1
NPP	NANA ADDO DANKWA AKUFO-ADDO	0	0	1
PPP	PAPA KWASI ENDOOM	0	0	1
DFP	KWASI ADDAI ODIKE	0	0	1
PNC	HASSAN AYARIGA	0	0	1
CPP	ABU SAKARA	0	0	1
INDEP	JACOB OSEI YABOAH	0	0	1

Table 4.3 Definition view of the voters

Column Name	Data Type	Allow Nulls
VoterID	nvarchar(50)	☐
VoterName	nvarchar(50)	☐
DOB	date	☐
VotingMode	nvarchar(MAX)	☐
District	nvarchar(50)	☐
Costituency	nvarchar(50)	☐
PollingStation	nvarchar(50)	☐
VotingStatus	nvarchar(50)	☐
VoterTrail	nvarchar(50)	☐
DateTime	datetime	☐

Table 4.4 Data view of the voters

VoterName	DOB	VotingMode	District	Costituency	PollingStation	VotingStatus
OPHELIUS	7/29/2013	English Audio	TAMALE	TAMALE SOUTH	SHS	Not Voted
Hillary	7/30/1987	English Audio	NAVRONGO	NAVRONGO	UDS NAVRONGO	Not Voted
MARCEL	7/30/1973	Ewe Audio	BOLGA	BOLGA CENTRAL	BOLGA GIRLS	Not Voted
MUBARAK	7/30/1986	English Audio	NAVRONGO	NAVRONGO CE...	UDS	Not Voted
ALHASSAN	7/30/1978	English Audio	TAMALE	TAMALE CENT...	MARKET	Not Voted
RICHARD	7/30/1982	Frafra Audio	NANDOM	NANDOM	MARKET	Not Voted
OMARY	7/30/1978	Akan Audio	kumasi	bantama	market	Not Voted

4.2 Interface of the Software

Figure 4.1 below shows the main form of the software as it's launched from the computer. This is the first point of contact of the biometric electronic voting system software and the administrator (Electoral commission staff). Prospective voters would be registered (Enrolled) as well as verify from this interface. Other administrative functions such as deleting users or voters from the database when an error occurs are also possible from this page.

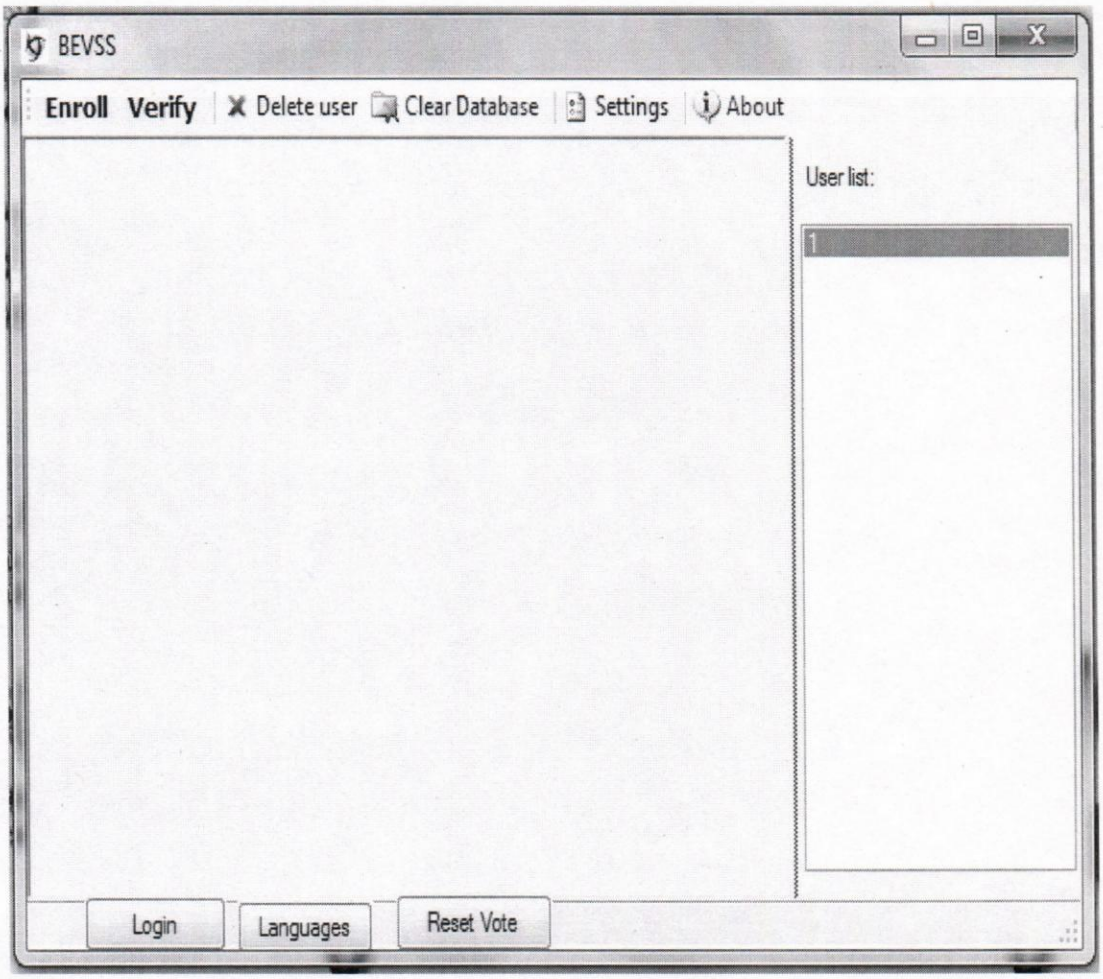


Figure 4.1 Main window of the software

Figure 4.2 shows the enrollment (Registration) form for voters. All prospective voters would be registered from this interface including their biometric finger print and their passport sized photograph.

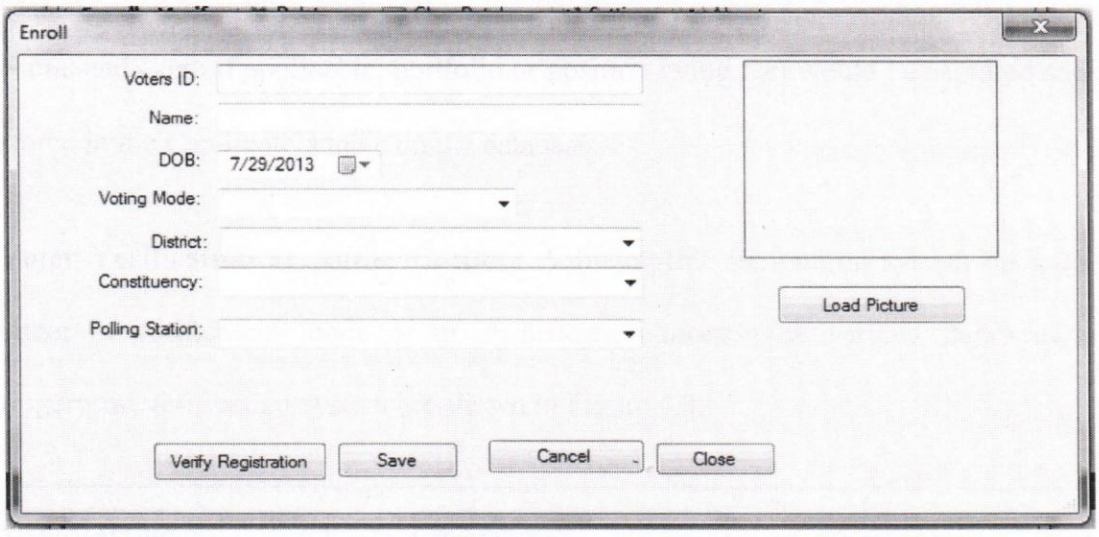


Figure 4.2 Registration form

Biometric Registration of voters: This involves the process of capturing an eligible (18 years of age or above, with a sound mind, a national and resident in the country) voter's personal information (Name, Date of Birth, Home town, Language, Address, Family, Passport. photograph, etc), including fingerprints using the fingerprint machine to scan the fingers and stored to the voters database to be used for authentication or verification on election day.

Fingerprints are formed in the womb at around five months and remain constant even after death of an individual. Empirically, it can be noted that no one has found identical prints, not even identical twins, Wagadre et al. (2013).

Candidates Registration: Each political party or Independent Candidate after passing all the requirements of the electoral processes required for contesting in the election would then be registered to the software after going through the ballot position balloting. Each candidate's personal information (Name of Candidate, Party Name and Logo if applicable, portfolio or position vying for) would be captured and stored in the Candidate's table on the database.

Voter Verification or Authentication: A fingerprint recognition system operates either in verification mode or in identification mode. The various stages in a fingerprint verification system are shown in Figure 4.3.

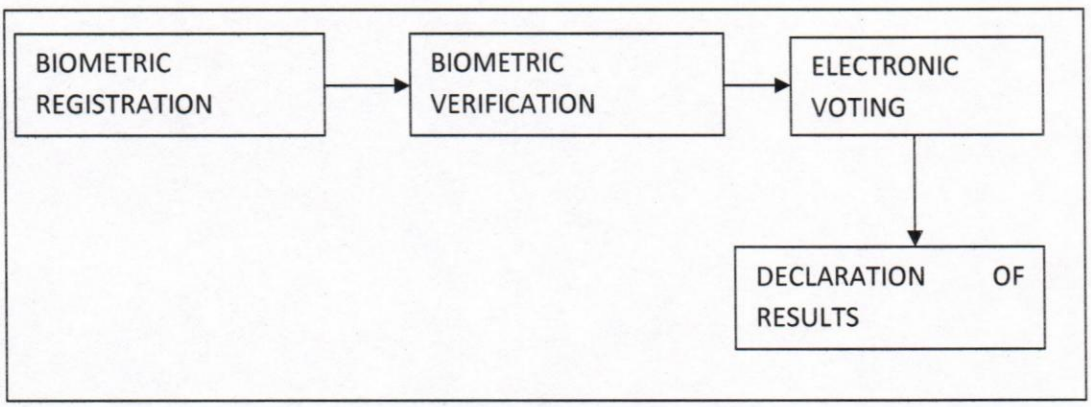


Figure 4.3 Biometric electronic voting Architecture

After going through authentication or verification through fingerprint, an electronic ballot is served to each voter as shown in Figure 4.4, a voter is expected to touch or click on **Vote** button or any part of the candidate's name, passport size photograph, party logo or picture to cast his/her ballot. A caution message will be shown from which the voter either accepts (Yes button) or reject (No button) the choice made.

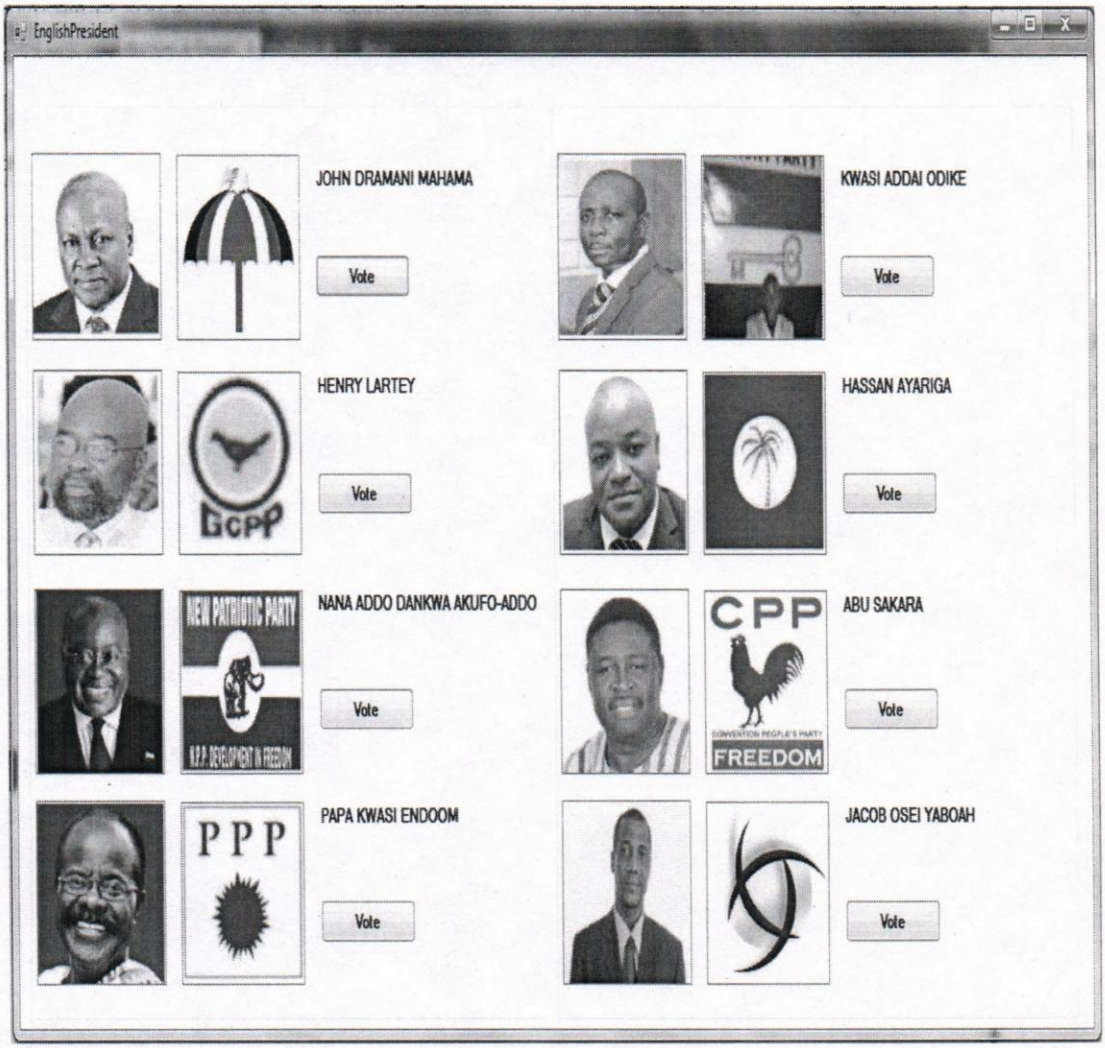
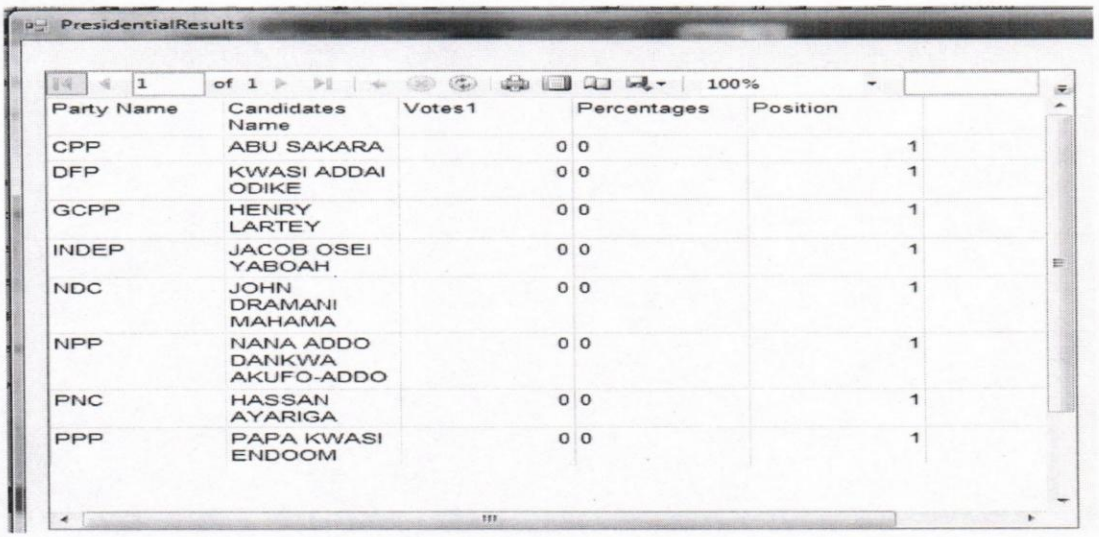


Figure 4.4 Electronic ballot

Results of the Election The software will make it possible to display the results after the elections by the electoral official as shown in Figure 4.5. The results page displays the name of the candidate and the acronym of the party, the passport photograph of the candidate, the total votes for each candidate, and the percentage of votes per candidate as well as the positions of each candidate.



Party Name	Candidates Name	Votes1	Percentages	Position
CPP	ABU SAKARA	0	0	1
DFP	KWASI ADDAI ODIKE	0	0	1
GCPP	HENRY LARTEY	0	0	1
INDEP	JACOB OSEI YABOAH	0	0	1
NDC	JOHN DRAMANI MAHAMA	0	0	1
NPP	NANA ADDO DANKWA AKUFO-ADDO	0	0	1
PNC	HASSAN AYARIGA	0	0	1
PPP	PAPA KWASI ENDOOM	0	0	1

Figure 4.5 Election Results

The first stage is the data acquisition stage in which a fingerprint image is obtained from an individual by using a sensor. The next stage is the pre-processing stage in which the input fingerprint is processed with some standard image processing algorithms for noise removal and smoothening. The pre-processed fingerprint image is then enhanced using specifically designed enhancement algorithms which exploit the periodic and directional nature of the ridges. The enhanced image is then used to extract salient features in the feature extraction stage. Finally, the extracted features are used for matching in the matching stage.

Electronic Voting: The term electronic voting and also known as e-voting is a term inclusive of many systems and methods of voting. This includes booths equipped with electronic devices, software, peripherals, processing systems, equipment, tools and screens, networks and means of communication, etc.

Vote Counting and Collation of Results: While voting is in progress, the software would tally each candidate's votes as and when an eligible voter selects the candidate by clicking or touching the passport size photograph, Name of the candidate or the logo if applicable. The percentage of vote cast by each candidate is calculated and their respective positions determined as soon as polls closes.

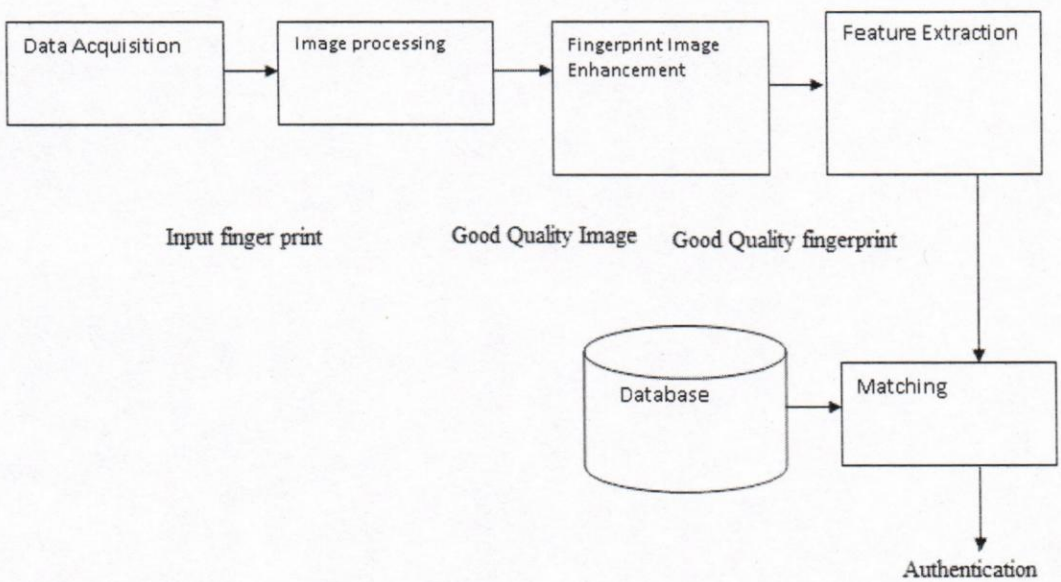


Figure 4.6 Architecture of Fingerprint Verification System

4.3 Testing of the Software

A test run or implementation of the software was carried out by conducting the election for the Computer Science Association and subsequently the Statistics Students Association of Ghana all in the Navrongo Campus of the University for Development Studies. Both elections were successful and all parties and stakeholders were satisfied with the performance of the software.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This thesis developed Biometric electronic voting software for Ghana. The software is in 10 Ghanaian languages in both text and audio. The software collates and calculates the percentages of votes as well as positions for each candidate. Biometric registration and verification is incorporated to reduce double registration and voting and is implemented at polling station level.

5.2 Summary

In this research, biometric electronic voting software has been developed for Ghana, a careful study of the electoral processes and the functioning of the electoral commission of Ghana was observed. An overview of biometric electronic voting software was conducted by reviewing literature in chapter two. It was clear from literature that biometric electronic voting carries with it numerous advantages that outweighs the disadvantages and was worth an option for consideration for future elections. A well fashioned out plan for the development of the biometric electronic voting software is presented in chapter three. After thorough examination of the software development lifecycle models, the iterative waterfall model was employed in the development process and Microsoft visual basic 2010 for the design of the forms and the source codes. In chapter four, snapshots of the design view and the data view of some of the tables designed from Microsoft SQL database is presented. The main window of the software, biometric electronic registration form, biometric

voting architecture, electronic ballot, architecture of the fingerprint verification system as well as the results report are discussed. Finally this work presents a software developed with biometric fingerprint registration and verification system coupled with electronic voting for Ghana.

5.3 Recommendations

It is recommended that, the maintenance of the software should be done regularly and taken very seriously to maintain the functionality and up to date requirements of the electoral processes.

Again, all institutions and the nation as whole should consider adopting the automated system to minimize and eventually eliminating the difficulties that engulf the current electoral processes.

Students of the Faculty and the other Campuses should be encouraged to take interest in implementing biometric electronic voting system in their SRC/NUGS elections.

Polling station based implementation of this software is recommended since this would be cheaper and more reliable than a centralized system that requires a fiber optic backbone which is currently not in place to run the system.

5.4 Major Contributions

This thesis amongst other things has contributed to;

i) Debate on major electoral reforms in Ghana electioneering process

ii) Maiden Biometric Electronic Voting System Software for Ghana, to eradicate electoral disputes in Ghana.

iii) Audio format of instructions in Native Ghanaian Languages for illiterates in Ghana.

iv) Text instructions in Native Ghanaian Language for voters who have non-formal education in their mother tongue.

v) A coalition system devoid of arithmetic errors for coalition of electoral results

vi) Reference for future researchers in this area

5.5 Future work

Multiple biometric registration and verification system could be incorporated in this work to eliminate any unforeseen occurrence of hardware failure (finger print device).

A countrywide implementation of the biometric electronic voting system software over a Wide Area Network (WAN) over a fiber optic backbone of the country with a centralized database system should be carried out.

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APPENDIX

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