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A Contemporary Approach to Designing and Implementing Electronic Voting Systems (EVS)

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Abstract

This study investigates into the potential of Electronic Voting Systems (EVS) in Ghana, to enhance transparent and trustworthy electoral processes. We presented a comprehensive framework highlighting trust, diaspora engagement, and human factors in voting. The study proposes a robust EVS framework for Ghana, emphasizing trust and accountability, preventing electoral fraud, and encouraging African governments to invest in IT and collaborate with experts in e-government and e-voting systems. We commence with a detailed systems analysis, identifying specific electoral challenges in Ghana. An artifact is designed and developed, and its effectiveness is demonstrated through Design Science Research Methodology (DSRM). We evaluated its alignment with the desired solution for Ghana's electoral issues. We emphasize the potential of EVS to address electoral challenges in Ghana and underscore the importance of proactive government policies, IT investments, and collaboration with IT experts. User performance assessment and acceptance testing were evaluated and achieved a remarkable 98% approval rate, demonstrating the feasibility of implementing EVS at the national level. This research underlines the role of EVS in Ghana and advocates for visionary government policies and investments in IT. These measures can modernize electoral systems, align them with international standards, and promote democratic advancement while preventing electoral fraud in Ghana and other African nations to avoid condemnation and punishment of unconstitutional transfers of power that are being challenged through meticulously planned takeovers in the subregion in recent times.

Keywords: Smart Cities, Software Engineering, E-voting System, Intelligent Agent, Multi-Agent Systems,

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1. Introduction

The idea of using electronic technology in political elections predates the Internet. It originated in the late 1980s with the advent of the Advanced Research Projects Agency Network (ARPANET), the National Science Foundation Network (NSFNET), and the introduction of commercial Internet Service Providers (ISPs) [1]. Voting machines (VM) started emerging globally in the mid-19th century, with advancements in instrumentation, computer science, and Artificial Intelligence (AI) [1] [2]. By the early 20th century, mark-sense scanners were employed for ballot counting, notably the Norden Electronic Vote Tallying System in 1959 [3] [4]. Voting technology took a significant leap in 1965 with Votronic's optical mark vote tabulator [3].

In the mid-20th century, punch-card voting systems (PCVSs) gained popularity but faced some issues [5] [6]. The year 2020 marked a decline in the use of punch card systems, primarily due to their shortcomings during the US presidential elections [5]. The 1970s witnessed the invention of another voting machine (VM), and in 1974, the first direct-recording electronic (DRE) voting machine was used in a legally binding election. The 20th century brought the Internet Revolution, allowing various countries to explore electronic voting technologies [5].

These advances foster the integration of electronic voting systems into smart city infrastructure as a key pillar for the advancement through the Journal of Smart Cities research where e-voting application is evident [7] [8]. It has the potential to provide discussions on the policies and regulations governing e-voting. E-voting systems can be seen as part of this technological ecosystem, and this journal can explore how these systems integrate with other smart city technologies like IoT, data analytics, and digital identity systems [7, 8]. E-voting systems raise important issues related to data security and privacy [8]. The e-voting system ensures the confidentiality and integrity of votes, and how they protect voter information aligns with this Journal [8]. In addition, it plays a pivotal role in raising awareness among the public and stakeholders about the benefits and challenges of e-voting systems and their applications in smart city activities [8].

Electronic voting (e-voting) involves capturing, recording, and processing election data digitally in real-time [5] [6]. It is a formal decision-making process for electing public officials. The efficiency, reliability, and security of e-voting systems (EVS) are crucial for a safe system [6]. Traditional paper-based voting systems have their share of the problems, including lost, stolen, or miscounted ballots [9]. E-voting is changing the perception of voting processes, enabling participation without constraints or political influences [6].
E-voting consists of various methods, from touchscreen kiosks to online voting [6]. It can include punched cards, optical scan systems, specialized kiosks, and even voting via phones or the Internet. E-voting offers real-time results, enhancing accuracy and transparency.

In the proposed EVS, voters cast their ballots online, with strict registration processes supervised by administrators for security [10]. This approach reduces congestion, minimizes errors, and allows for verification. Traditional systems have faced disputes and violence, as seen in the 2020 elections in Ghana and the 2022 Kenyan elections [11] [12].
Global Election Observers have advocated for EVS in Africa to combat vote rigging and ensure accountability [13]. History has shown flaws in traditional voting systems, underscoring the need for EVS [11] [12]. For instance, Kenya's electoral commission struggled to update the voters' register, leading to disputes [12]. Brazil introduced an e-voting system in 1996 to improve accountability and transparency [13] and as a result, e-voting has been used successfully in various countries globally. The government of Ghana should be prepared to implement e-voting in the 2024 elections to ensure free and fair elections. Furthermore, the coup d'états in West Africa, Central Africa, and the Sahel Region are troubling. This frequent phenomenon in the subregion in recent times should serve as a warning to other African leaders to uphold the rule of law and thus seek the ultimate interest of the citizens above personal gains.

EVS can help Africa overcome electoral challenges, such as fraud and violence, as witnessed in Ghana's 2020 election [11] [14]. Voter registration issues and external factors like rain have also affected turnout [14]. Early education can influence voter participation, but traditional systems in Ghana have discouraged voters due to long queues and cumbersome processes.
This study proposes a novel EVS based on Design Science Research Methodology (DSRM). It addresses the limitations of existing systems and aims to improve transparency, reliability, and efficiency. The 2020 election issues in Ghana motivated this project, which focuses on developing a mobile application for voting [15]. The system aims to remind voters, validate eligibility, and ensure fast, accurate result computation.

The paper is structured as follows: Section 2 provides background and defines the problem. Section 3 outlines the DSRM methodology and processes used to develop the EVS. Section 4 discusses the proposed system and outlines system implementation and its related interfaces, Section 5 performs system evaluation in which performance assessment criteria were examined to ascertain that the system meets its requirements and Section 6 concludes the paper and suggests future research directions for enhancing transparency and security [14].

2. Related work

Electronic voting (e-voting), stands as a major transformation to enhance democratic processes. In a world constantly evolving through technological innovation, the traditional paper-based methods of voting have faced challenges and limitations. The integration of electronic systems into voting procedures has offered potential solutions to these challenges, promising greater accessibility, efficiency, and transparency in elections.

We embark on a journey through the evolution of electronic voting systems, spanning from their inception to contemporary trends. These works collectively shed light on the ever-expanding landscape of electronic voting, addressing issues that range from security and privacy to usability and trustworthiness. We read through these papers and investigated the major findings and insights presented by each of them. These findings encompass a wide array of perspectives and considerations, reflecting the multifaceted nature of electronic voting. The authors' research endeavors seek to inform and guide us in the pursuit of more secure, reliable, and accessible voting systems.
We aim to gain a comprehensive understanding of the challenges and opportunities that electronic voting presents in the context of modern democracies. Each paper offers a unique lens through which we can examine the past, present, and future of electronic voting systems, ultimately contributing to the ongoing discourse on the transformation of the electoral process.

The paper [16], offers valuable insights into the use of electronic voting systems in a large-scale educational setting. It focuses on practical experiences and provides useful guidance for educators considering similar implementations. It examines the challenges and successes of this experience, providing key indicators for success. The paper [17] examines the current status of blockchain-based voting research and highlights the advantages of using blockchain technology in electronic voting systems. It identifies privacy protection and transaction speed as major challenges. The paper [18], evaluates previous national electronic voting systems, highlighting their disadvantages before the advent of blockchain technology. It reviews electronic voting systems utilizing blockchain technology, discussing their strengths and weaknesses.

This paper [19], appears to provide a comprehensive review and taxonomy of electronic voting schemes, making it a valuable resource for understanding the landscape of electronic voting. It emphasizes the importance of security requirements and discusses challenges in electronic voting systems. The paper [20] reviews various electronic voting systems, identifies shortcomings, and proposes a novel approach for developing a secured electronic voting system using fingerprint and visual semagram techniques. The paper [21], reviews the evolution of electronic voting systems and their increasing adoption in various elections worldwide. It discusses the challenges posed by complex communication technologies in e-voting, including verifiability, dependability, security, anonymity, and trust. It further explores different views on the adoption of online voting and reports on the role of technology transfer from research to practice.

The author [10], focuses on India's use of Electronic Voting Machines (EVMs) in elections and highlights their simplicity, reliability, and usability. Despite criticism, certain details of the EVMs' design have not been publicly disclosed or rigorously evaluated for security. It examines the effectiveness of EVMs in the Indian electoral system, considering both challenges and opportunities. The paper [22], examines the usability of electronic voting systems, particularly those using touch screens. It reports on usability studies, including expert reviews, observations, field tests, and exit polls. The analysis suggests that electronic voting systems generally work well but have some shortcomings, especially related to voter usability. The paper [23] defines e-voting as any method where a voter's intention is expressed or collected electronically.

The paper [24] provides an overview of global developments in e-voting, with a focus on remote and internet voting. It discusses the interest in e-voting across various sectors and highlights the lessons learned from e-voting tests. The major finding is the increasing attention to e-voting due to its potential to address issues with traditional voting systems. The paper [25], explores the evolution of electronic voting systems, including shifts from paper-based to paperless, manual to technology-driven methods. It discusses the development, legalization, guidelines, vulnerabilities, security, and protection aspects of electronic voting systems over time. The paper [26], discusses the implementation of remote online voting systems suitable for a university setting, allowing students to vote using various electronic devices. It highlights the use of modern technologies, like extensible markup language and extensible style language transformation style sheets, to ensure a consistent voting experience across different devices. It further focuses on achieving "author once, publish to any device" in the context of electronic voting. It discusses the design and implementation of a secure electronic voting system allowing voters to cast their votes using various electronic devices. It further emphasizes the use of technology for enhancing the convenience and integrity of the election process.

The paper [18] discusses the advantages of e-voting over traditional paper voting systems and explores the evolution of electronic voting, particularly with the emergence of blockchain technology. It outlines the strengths and weaknesses of e-voting systems using blockchain. The major finding is the potential for blockchain to enhance the security and transparency of e-voting systems. The paper [27] focuses on Estonia, a country that has made significant strides in deploying Internet voting. It explores the legal, technical, political, and cultural aspects that have contributed to Estonia's successful implementation of Internet voting. The major finding is the in-depth analysis of how Estonia has addressed the challenges and considerations associated with e-voting, providing valuable lessons for other nations. The paper [28] highlights the significance of elections and voting in democratic societies and the increasing interest in e-voting as a means to address the shortcomings of manual voting systems. It reviews common e-voting models, existing election schemes, and essential e-voting terminologies. The major finding here is the growing interest and importance of e-voting in the context of e-government and e-democracy initiatives. The paper [29], compares and integrates the approaches taken by the U.S. and EU regarding e-voting system certification. It suggests that combining high-level guidelines from the EU with field-tested procedures from the U.S. can create a practical certification manual. The major finding is the proposal for an applied methodology that enhances the certification of e-voting systems, ensuring their reliability and security. The systematic review investigates the factors influencing the successful implementation of e-voting, particularly in Namibia and Estonia [30]. The study identifies critical factors such as ICT infrastructure, legal and institutional factors, security, trust, and voter education. The major finding is the identification of these key factors that can shape the successful adoption of e-voting systems, providing valuable insights for policymakers.

The paper [31], outlines the requirements, design, and implementation of electronic voting systems, particularly in a university setting. It emphasizes the separation of data content from presentation to achieve flexibility across different devices. The major finding is the "author once, publish to any device" approach, which simplifies the design and implementation of e-voting systems. The article [32] discusses the importance of voter-verifiable audit trails in electronic voting systems and evaluates the state's criteria for direct-recording electronic (DRE) voting machines equipped with voter-verified paper records (VVPR). It addresses privacy, security, verification, integrity, functionality, and examination issues. The major finding is the potential for VVPR systems to enhance transparency and trust in e-voting. The paper [33], discusses the importance of electronic voting (e-voting) in e-democracy. It acknowledges the controversies, and criticisms surrounding e-voting, including concerns about electoral errors and fraud and further presents a risk assessment framework for e-voting and examines the factors that led to the abandonment of e-voting plans in Ireland in 2004. Thus, emphasizes the need for thorough risk analysis in e-voting implementation. The paper [34] addresses the controversy surrounding e-voting and Internet-based remote voting and discusses the potential benefits of online voting, including increased voter turnout. The paper also highlights security concerns associated with Internet voting and emphasizes the need for a comprehensive approach considering the technical, legal, social, and political aspects of e-voting research. The paper [35] discusses the goals of election reform efforts in various countries, including the U.S. and the U.K. These goals vary, from increasing voter turnout to reducing election fraud and enfranchising underrepresented populations. The overall aim of election reform is to improve the democratic process by making voting more accessible, accurate, and secure to prevent frequent coups in Africa.

The complex history of coups and coup attempts in Africa has been the subject of extensive research and analysis over the years. In recent times, with the backdrop of the COVID-19 pandemic, there is growing concern that the continent may be on the brink of a new wave of political instability in the form of military coups. This review aims to shed light on key scholarly works that investigate this critical issue, offering valuable insights into the factors contributing to coup attempts in Africa and potential strategies for prevention. Hence the comprehensive study of the application of e-voting in national elections in Africa to mitigate coup d'etat is based on these findings:

The author [36], explores the potential for a resurgence of coups in Africa. Major findings are due to the identification of political, economic, or social factors contributing to the risk of coups and increased political instability or dissatisfaction with governance. In [37], the author argued that the impact of the COVID-19 pandemic on coup dynamics in Africa is evidence of how the pandemic exacerbated existing vulnerabilities, potentially leading to an increase in coup attempts and insights into how health crises can strain governance and trigger political unrest. The author [38] conducts a comprehensive historical analysis of coup attempts in Africa covering a considerable timeframe, unveiling observable patterns and trends in such endeavors across various decades. Furthermore, the author evaluates the efficacy of strategies implemented to counteract coups within the African context. The author [39] employs quantitative methodologies to investigate the correlation between military coups and underdevelopment. The study presents statistical evidence that links coup events and diminished economic and social development indicators. The analysis provides perceptions of how coup events can impede development in the affected countries.

In [40] the author concentrates on predictive models for coup attempts in Africa and outlines insightful key variables, and risk factors that facilitate accurate coup prediction. The study provides potential perceptions into the efficacy of early warning systems in preempting coup attempts. The findings underscore the recurrent occurrence of reignited coups in Africa, attributed to the failure of African leaders to recognize warning signs. Moreover, the author [41], discusses emerging threats and vulnerabilities in the context of African military coups and examines the regional conflicts, external influences, or other factors that could heighten the risk of coup attempts and offers potential future scenarios and implications for African stability. Finally, the author [42], also provided specific reasons behind the higher frequency of coups in Africa compared to other regions with an analysis of structural, historical, and cultural factors that make Africa more susceptible to coup attempts and how governance and power dynamics play a role in coup dynamics on the continent.

The historical backgrounds of the coups in Africa leading to the condemnation and punishment of unconstitutional transfers of power are being challenged by meticulously planned takeovers that seem to align with democratic principles and receive widespread popular approval by citizens. The study argued the need for African leaders to allow e-voting to ensure free and fair elections to deepen good governance in the subregion and to avert unnecessary coups for accelerated development of the continent.

3. Methodology

The concept of Design Science Research Methodology (DSRM) originates from engineering and sciences, particularly those focused on artificial artifacts. DSRM is a fundamental problem-solving approach [43], aiming to advance human knowledge by creating innovative artifacts and design knowledge (DK) through creative solutions to real-world challenges [43]. This concept has played a crucial role in enabling research communities and practitioners to develop innovative solutions for complex societal problems. DSRM finds applications in various fields, including engineering, natural sciences, business, and economics. DSRM integration into artificial intelligence and machine learning architectures into system design is suitable for the development of any complex systems. The DSRM Framework serves as the foundation for developing any DSRM architecture and is elaborated in the section below.

3.1 The DSRM Framework

The framework catalyzes comprehending, executing, and evaluating Design Science Research Methodology (DSRM) [43] [44]. Formulating research activities that cater well to the needs of stakeholders, such as citizens or electorates with an interest in e-voting system development, ensures research relevance. Prior research and insights from scholars and practitioners provide robust theoretical support, including theories, frameworks, instruments, constructs, models, methods, and real-world implementations, which are essential for constructing the research study.

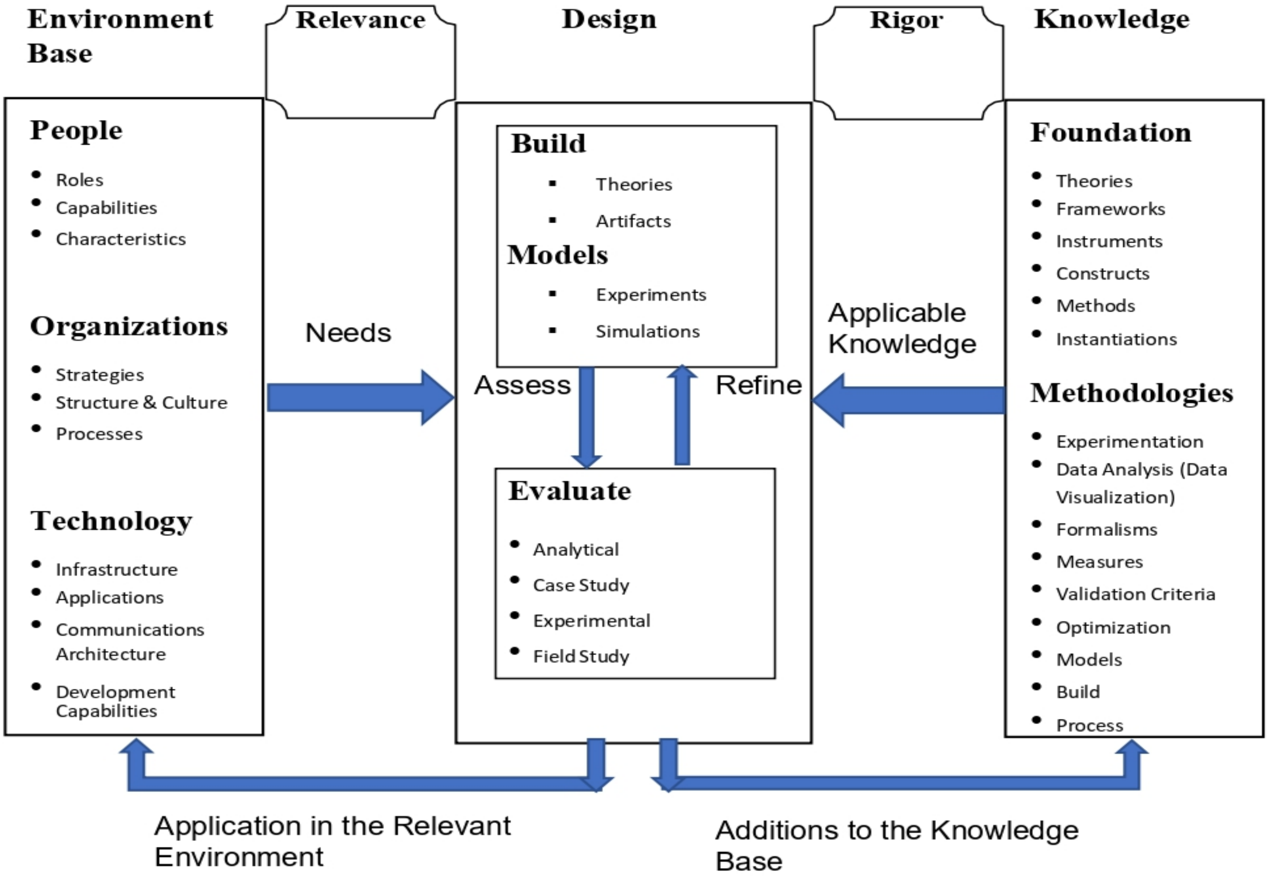

Figure 1: Amplified Framework for Design Science Research Methodology

As depicted in Figure 1 above, DSRM investigates pertinent real-world problems across various application domains. DSRM underscores the importance of furnishing a solution that warrants empirical scrutiny involving researchers, practitioners, and industry collaborators, utilizing specific and pertinent technologies. The central point of DSRM emphasizes conducting thorough systems analysis within the specific real-world context of organizations, institutions, government agencies, companies, etc., to identify the precise issues requiring resolution as the initial step of the DSRM project. However, in scenarios where the specific needs of the problem domain have been previously identified or studied, DSRM would cement those established needs as the starting point. DSRM assesses the existing academic knowledge base to determine the extent to which design knowledge is available to address the identified problem. This academic knowledge may manifest as theories, frameworks, instruments, constructs, models, methods, and instantiations, coupled with methodologies like experimentation, data analysis, formalism, measures, validation criteria, optimization, models, construction, and processes. When this knowledge is deemed necessary to resolve the problem, it can be applied through routine design processes, falling outside the purview of DSRM. DSRM only comes into play when it seeks to create an innovative solution to the problem, typically building upon and modifying existing design knowledge to advance design activities for problem resolution. These design activities consist of 'building' and 'evaluating' components, iterated upon until the problem is effectively addressed. DSRM incorporates diverse research methods, contingent on the established research domain. For instance, in social science research, methods like interviews, surveys, literature reviews, or focus group discussions may be employed, whereas computer science and engineering may favor formal, experimental, building, processing, modeling, and simulation techniques to tackle identified problems.

3.2 DSRM Process

The DSRM projects rely on various process models, as outlined in [43], to tackle different projects in diverse domains. One widely referenced DSRM model is [43] [44]. The DSRM process consists of six stages: problem identification and motivation, defining objectives for the desired solution, design and development, demonstration, evaluation, and communication. Additionally, it encompasses four other entry points, including problem-centered initiative, objective-centered solution, design and development-centered initiation, and client/context initiation. The complete DSRM process is illustrated in Figure 2, providing a concise description on each DSRM activity.

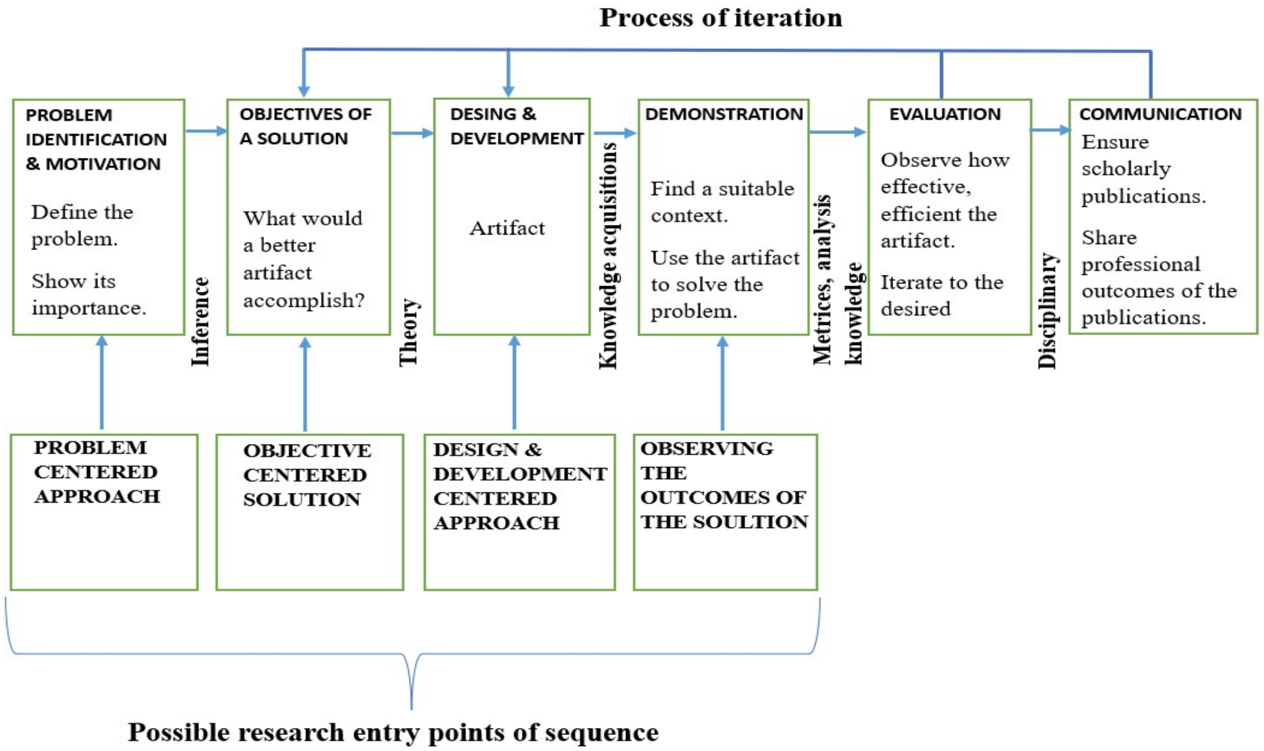

Figure 2: Design Science Research Methodology Process Model

The DSRM processes, from problem identification to evaluation stages, are illustrated with a specific focus on the execution of the e-voting project, from the problem activity stage to the evaluation activity stage, before implementation.

Activity Stage 1. Problem Identification and Motivation: This phase defines the e-voting research problem and justifies the proposed solution. The solution not only motivates researchers but also receives support from stakeholders by demonstrating a deep understanding of the problem. The resources required for this activity are based on the understanding of the problem's state and its solution to support stakeholder needs.

Activity Stage 2. Define the Objective for a Solution: This stage derives specific objectives from the problem definition and knowledge to develop the e-voting system. Objectives can be quantitative (aiming for a better solution than existing systems) or qualitative (explaining how the new artifact description supports problem solutions).

Activity Stage 3. Design and Development: This phase translates the specific objectives derived from the problem definition into a DSRM artifact capable of addressing stakeholder needs and objectives. It also determines the artifact's functionality and architecture based on the e-voting system's objectives.

Activity Stage 4. Demonstration: This stage highlights the significance of the artifact in addressing one or more instances of the problem identified. It involves specific methodologies, such as experimentation, simulation, case studies, proofs, or alternative approaches, to showcase the artifact's effectiveness.

Activity Stage 5. Evaluation: This phase measures how well the artifact aligns with the desired solution for the problem identified in stage one. It involves comparing the proposed solution's objectives to the actual observed results of the e-voting system. The outcomes inform researchers whether the artifact meets its objectives from the problem definition perspective. If not, iterations may be needed for improvements or further communication with stakeholders.

Activity Stage 6. Communication: At this stage, the aspects of the problem and the designed e-voting system are effectively communicated to stakeholders. Stakeholders make an informed decision on whether the e-voting system adequately addresses the outlined problems. This communication extends to a wider audience, including professionals and research communities, to advance knowledge through journal publications.

3.3 UML System Design

The Unified Modeling Language (UML) is a standardized modeling language facilitating the specification, visualization, construction, and documentation of software system artifacts [45] [46] [47]. UML ensures scalability, security, and robustness in software execution. UML plays a crucial role in object-oriented software development.

3.3.1 Use Case

A use case diagram offers a graphical representation of interactions among system elements. It serves as a methodology for system analysis, aiding in the identification, clarification, and organization of system requirements. These diagrams illustrate use cases and the specific roles played by actors within and around the system. Key components of a Use Case diagram include [47] [48]:

Actors: Actors are entities external to the system that interact with it. These can be users, other systems, or even hardware devices. Actors are represented as stick figures or other symbols outside the system boundary.

Use Cases: Use cases represent the specific functionalities or tasks that the system needs to perform their relationships and interactions to fulfill the needs of its users or external entities. Each use case describes a particular interaction between an actor and the system.

System Boundary: The system boundary defines the scope of the system and separates it from its external environment. Use cases and actors are typically placed within this boundary.

Associations: Associations or lines connect actors to use cases, illustrating the relationships and interactions between them. Each association represents a communication path.

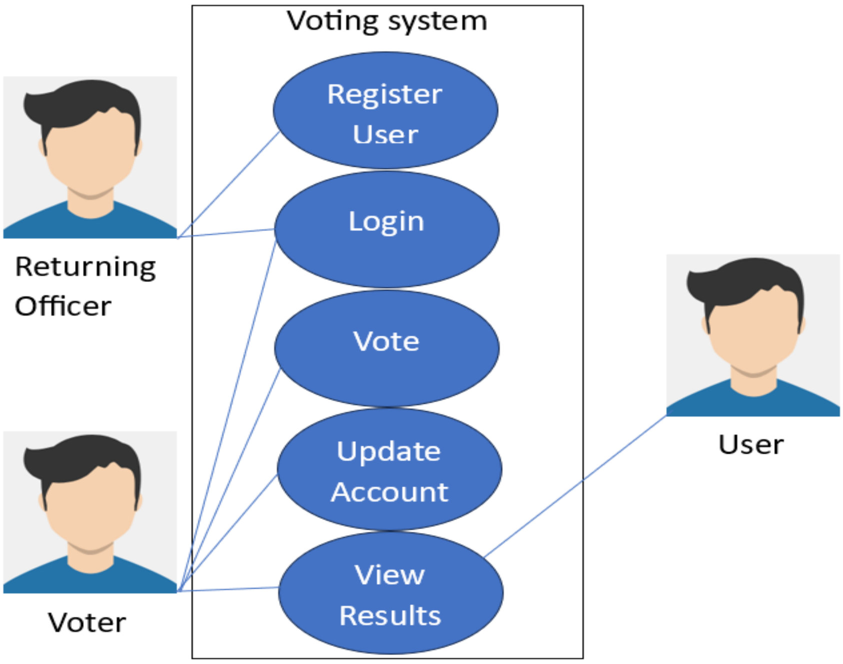

Figure 3: Use Cases of actors within the EVS

3.3.2 Sequence Diagram

A Sequence diagram is a type of interaction diagram in the Unified Modeling Language (UML) that depicts the interactions among objects or components within a system over time [45] [46] [47, 49]. It provides a dynamic view of the system, illustrating the sequence of messages exchanged between different entities and the order in which these interactions occur. Key components of a Sequence diagram include:

Lifelines: Lifelines represent the different entities or objects participating in the sequence of interactions. Each lifeline is depicted as a vertical dashed line, and the length of the line corresponds to the duration of the object's existence during the interaction.

Messages: Messages are depicted as arrows and represent the communication or interaction between lifelines. They indicate the flow of information or control between objects. Messages can be synchronous (i.e. request and wait for a response) or asynchronous (i.e. send a message and continue without waiting for a response).

Activation Boxes: Activation boxes represent the period during which an object is actively processing a message. They appear as a box around the portion of the lifeline where the object is executing a particular task or operation.

Focus of Control: The focus of control, represented by an arrow, indicates the direction of control flow during the execution of a message. It helps visualize the order in which messages are processed.

Return Messages: Return messages illustrate the response sent by an object after processing a received message. They complete the communication loop between the sender and receiver.

Sequence diagrams are valuable for understanding the dynamic behavior of a system, particularly in scenarios where the flow of interactions and the order of message exchanges are crucial for comprehending system behavior over time.

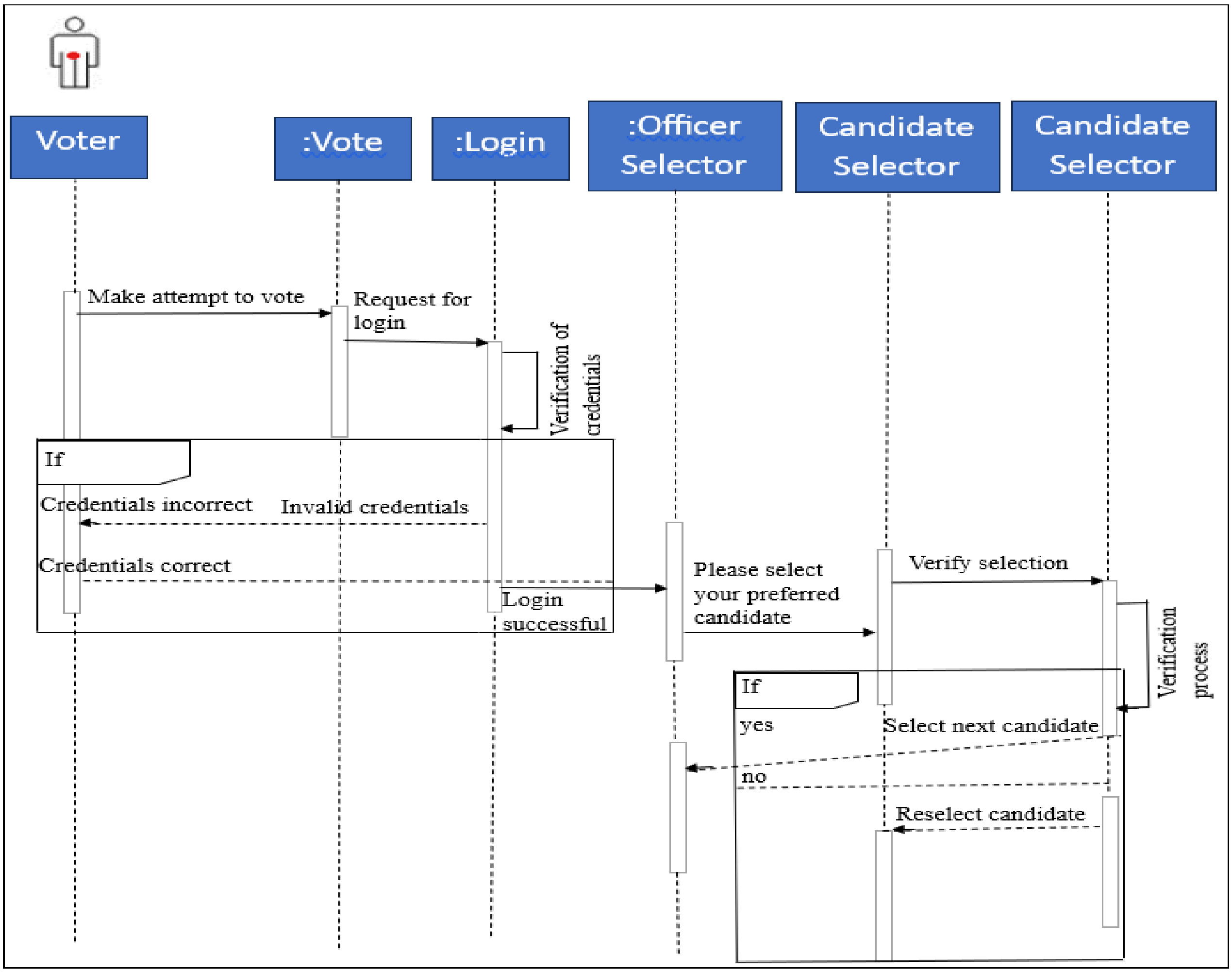

Figure 4: Sequence diagram showing the movement of actors with procedural events

3.3.3 Class Diagram

A class diagram in Unified Modeling Language (UML), is a visual representation that illustrates the structure and relationships of classes within a system [45] [46] [47] [49]. It is a fundamental tool for object-oriented modeling and design, providing a blueprint for the software architecture. The essence of a class diagram lies in its ability to convey key aspects of the system's static structure, including classes, their attributes, methods, and the associations between them. The key elements of a class diagram consist of:

Class: It represents a blueprint for objects, encapsulating data (attributes) and behaviors (methods). Classes are depicted as rectangles with three compartments, showing the class name, attributes, and methods.

Association: It indicates relationships between classes. Associations define how classes interact and can be either uni-directional or bi-directional. Multiplicity notations specify the number of instances participating in the association.

Inheritance (Generalization): It illustrates the relationship between classes, showing inheritance hierarchies. The arrow points from the subclass to the superclass, indicating that the subclass inherits attributes and behaviors from the superclass.

Dependency: It represents a relationship where a change in one class may affect another. It is denoted by a dashed arrow.

Multiplicity: It specifies the number of instances of one class associated with a single instance of another class. It is depicted using numerical values or asterisks.

Class diagrams help developers and stakeholders understand the static structure of a system, facilitating communication and collaboration during the design and development phases of a project. They serve as a foundation for further design decisions, providing a visual guide for creating and maintaining robust, scalable, and well-organized software systems.

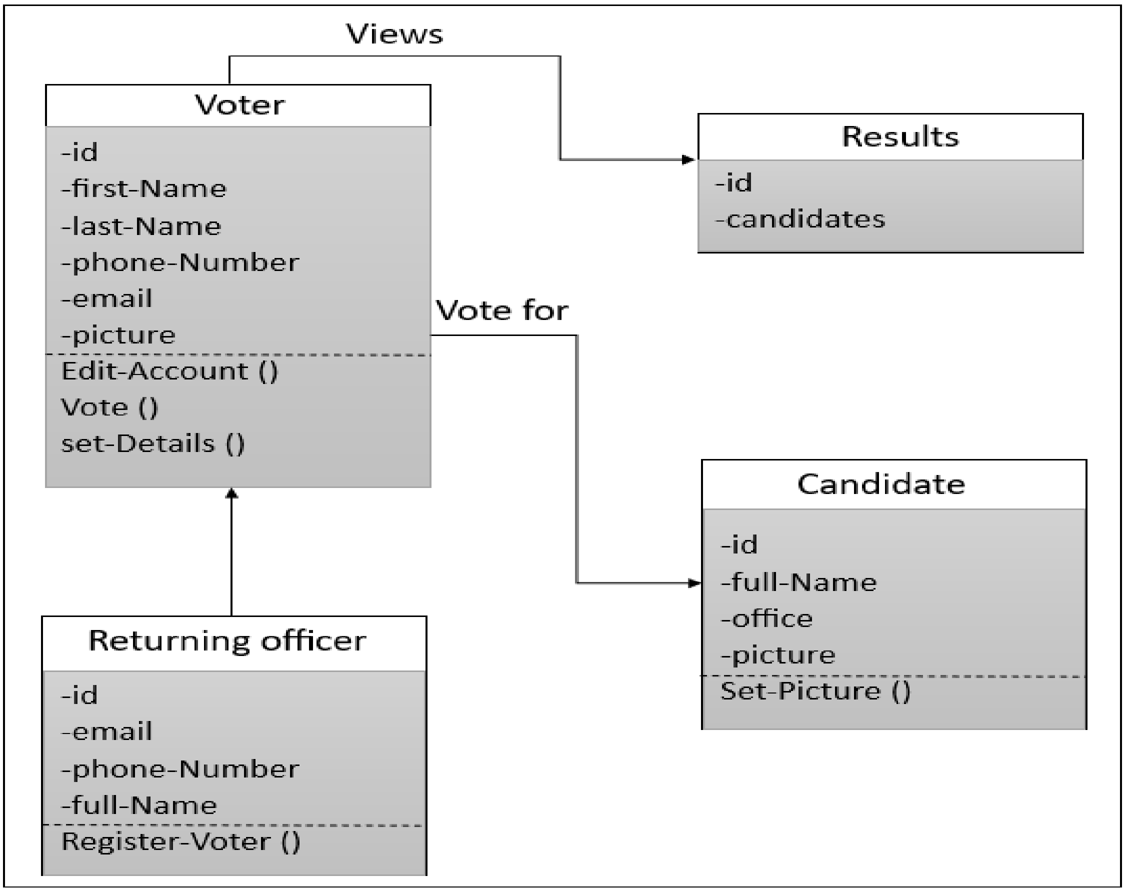

Figure 5: Class diagram of the EVS

3.3.4 Data Flow Representations

A Data Flow Diagram (DFD) in Unified Modeling Language (UML) depicts a graphical representation that illustrates how data flows within a system. It focuses on the transformation of data as it moves through different processes: data stores, and external entities [46] [47] [49]. The essence of a Data Flow Diagram lies in its ability to provide a clear and concise visualization of the flow of information within a system. The key elements of a Data Flow Diagram include:

Processes: These represent activities or transformations that manipulate the data. Processes are depicted as circles or ovals, and they describe the functions or operations performed on the incoming data.

Data Flows: It represents the movement of data between processes, data stores, and external entities. Arrows connecting these elements depict the direction of data flow, emphasizing how information is exchanged within the system.

Data Stores: It represents repositories where data is stored. These can include databases, files, or any other storage mechanism. Data stores are typically represented as rectangles.

External Entities: These represent external entities that interact with the system but are not part of it. These entities can be users, other systems, or external data sources. External entities are usually represented as squares.

Data Annotations: These include data labels that provide additional information about the data being transferred, such as data types or specific attributes.

DFDs are valuable for understanding and communicating the flow of information in a system, helping to identify key processes, data sources, and interactions. They are particularly useful during the early stages of system analysis and design, allowing stakeholders to visualize and validate the information flow before moving into the detailed design and implementation phases. DFD facilitates communication among project team members and stakeholders, aiding in the development of robust and efficient information systems.

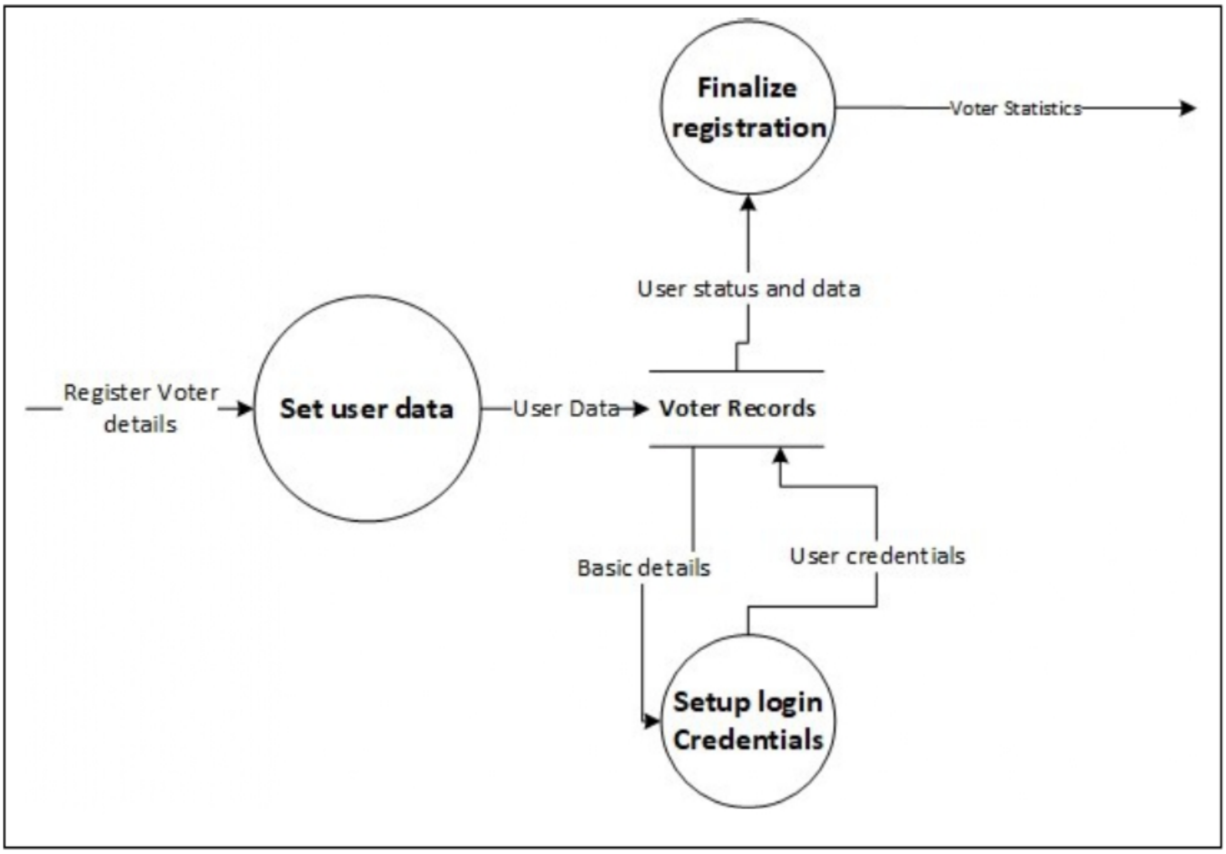

Figure 6: Data flow diagram of EVS

3.3.5 Context Representations

A context diagram in a Unified Modeling Language (UML) is a high-level visual representation that provides an overview of a system and its interactions with external entities [47]. The essence of a context diagram lies in its simplicity and focus on the system's boundaries, showing the relationships between the system and its external environment. The key elements of a context diagram involve:

System Boundary: It represents the scope of the system being modeled. It is typically depicted as a circle or a box, enclosing the system components.

System: It represents the main subject or system under consideration. It could also be a software application, a process, or any entity being analyzed or designed.

External Entities: These represent entities outside the system boundary that interact with the system. These can include users, other systems, or external data sources. External entities are usually depicted as squares or rectangles.

Data Flows: It represents the flow of information between the system and external entities. Arrows connecting the system and external entities show the direction of data flow.

Context diagrams are essential for providing a high-level understanding of a system's context and interactions without investigating detailed internal processes. They serve several purposes:

Clarity: Context diagrams provide a clear and concise view of the system's external interactions, making it easier for stakeholders to grasp the system's overall purpose and connections.

Communication: It facilitates communication between project teams and stakeholders by providing a common understanding of the system's boundaries and external influences.

Scope Definition: Context diagrams help in defining the scope of the system by highlighting what is inside and outside the system boundary.

Project Planning: It serves as a starting point for project planning, helping project teams identify key external elements that need consideration during system analysis and design.

In brief, context diagrams are a valuable tool in the early stages of system development, helping stakeholders establish a shared understanding of the system's context before proceeding with more detailed modeling and design activities.

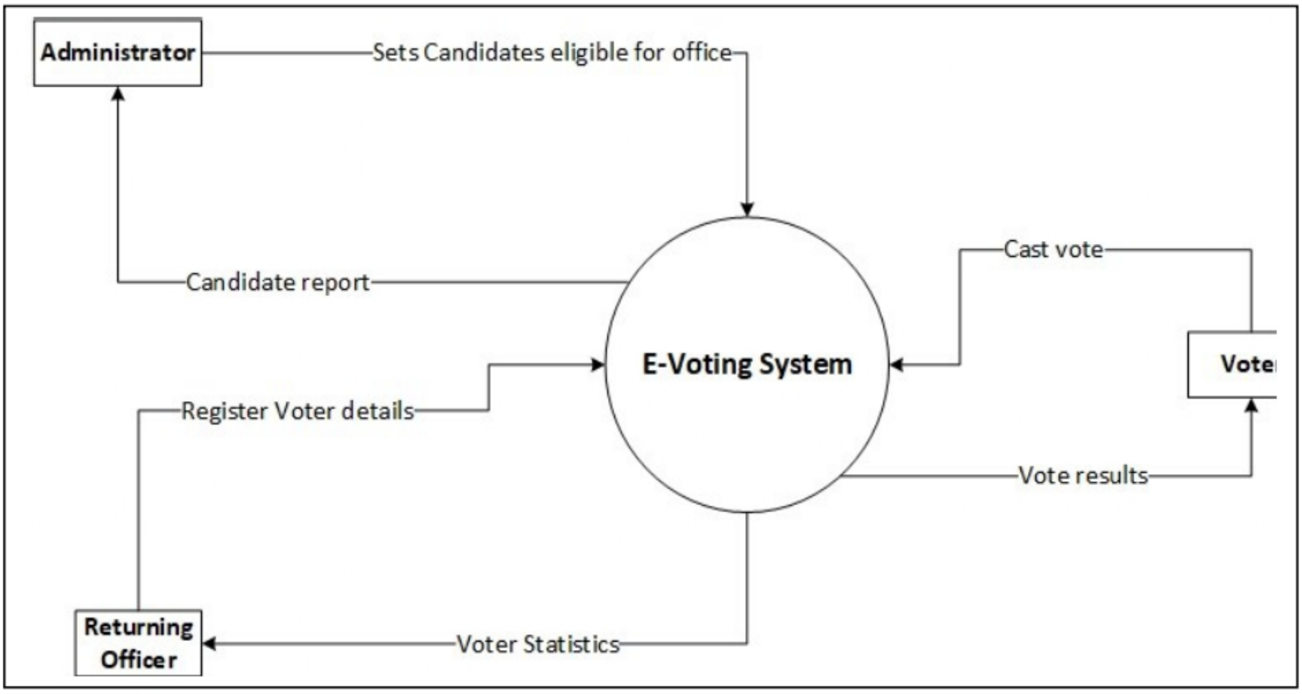

Figure 7: Context diagram of EVS

3.3.6 Flowchart Representations

A flowchart in Unified Modeling Language (UML), uses a diagrammatic representation that illustrates the sequence of steps or activities in a process [50]. While UML itself does not have a specific notation for flowcharts, traditional flowchart symbols and conventions are often used within the broader context of UML modeling. The essence of a flowchart lies in its ability to provide a visual representation of the flow and logic of a process. The key elements of a flowchart include:

Start and End Symbols: These represent the beginning and end points of the process. Typically depicted as ovals or rounded rectangles.

Process Symbols: These represent activities or tasks within the process. Usually depicted as rectangles, with each rectangle containing a description of the task.

Decision Symbols: It indicates points in the process where a decision must be made, leading to different paths. Often represented as diamonds, with branching arrows indicating possible outcomes.

Flow Arrows: They connect symbols to show the flow and sequence of activities. Arrows indicate the direction in which the process is progressing.

Connector Symbols: Used to connect different parts of the flowchart, especially when the process is too complex to fit on a single page.

The essence of a flowchart in UML lies in its utility for process visualization, analysis, and communication. Flowcharts are widely employed in various domains, including software development, business processes, and project management, to represent workflows, decision-making logic, and procedural steps. They serve several purposes:

Clarity: Flowcharts provide a clear and easy-to-understand representation of processes, making it simple for stakeholders to follow the sequence of activities.

Analysis: It aids in analyzing and understanding the logical flow of a process, identifying potential bottlenecks, decision points, and areas for improvement.

Communication: Flowcharts serve as a communication tool between team members, stakeholders, and individuals involved in the process, ensuring a shared understanding of the workflow.

While UML primarily focuses on modeling object-oriented systems, flowcharts, including their symbols and conventions, are a valuable complementary tool for representing procedural aspects and process flows within the broader context of UML-based modeling.

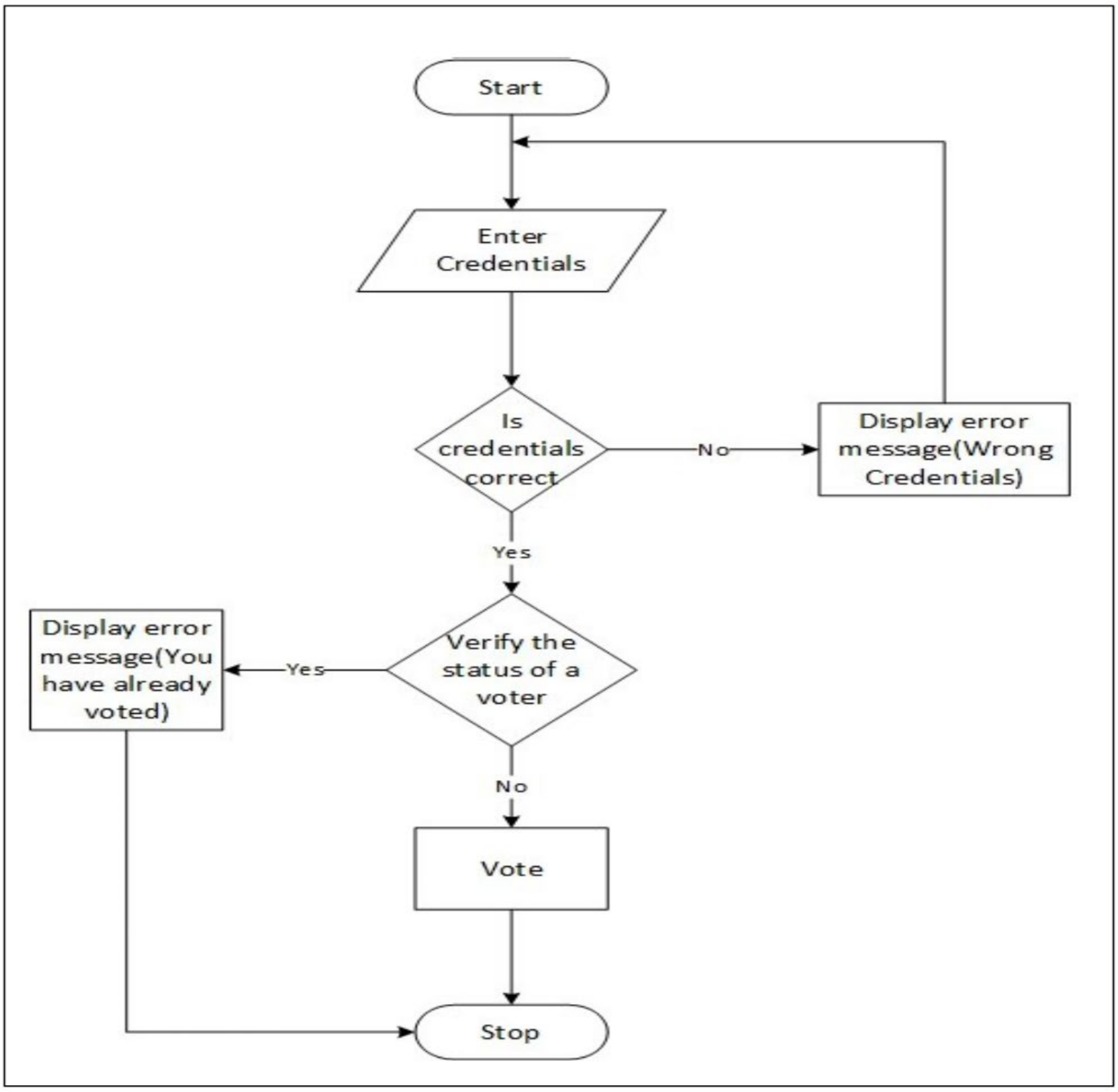

Figure 8: E-voting Systems Flowchart

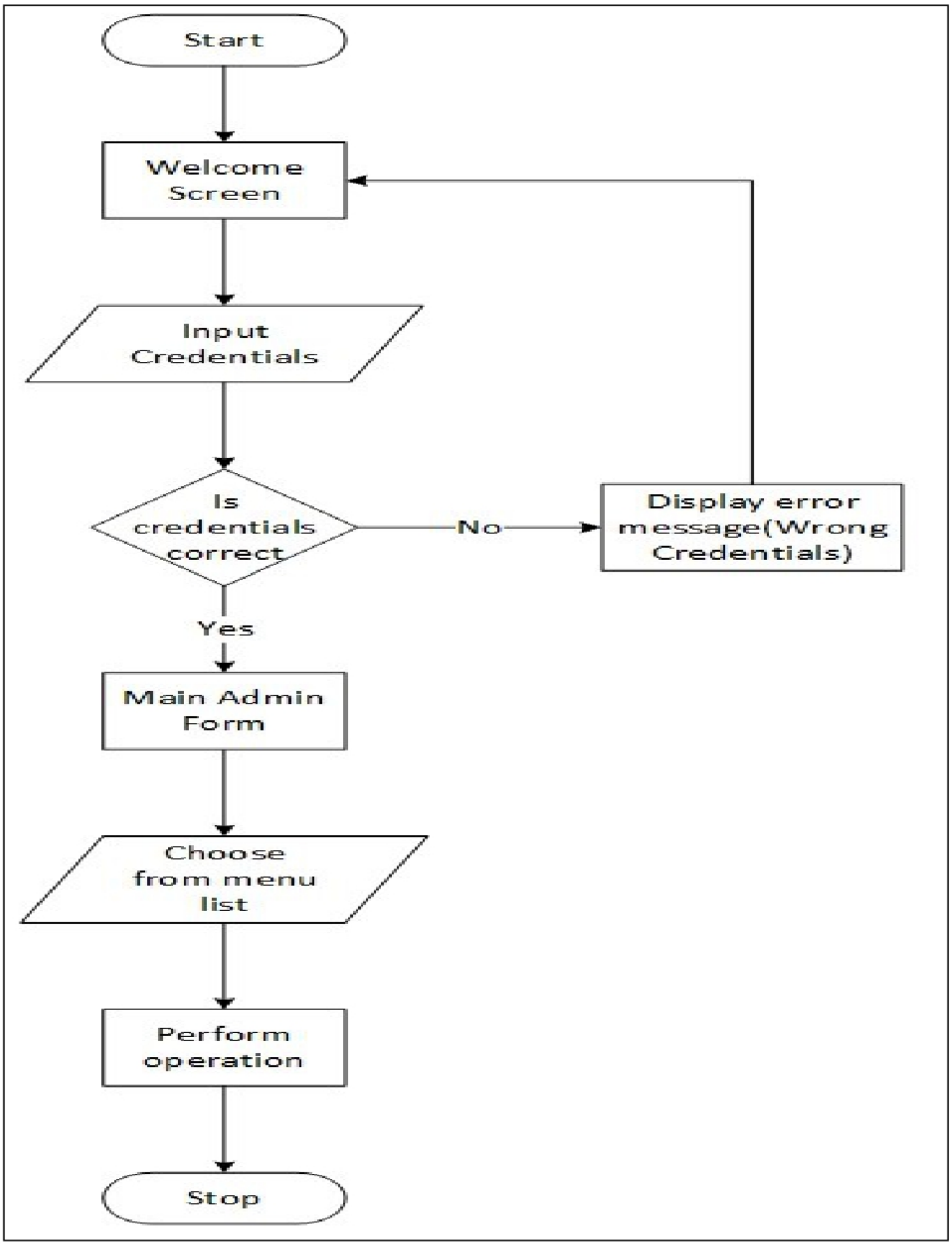

Figure 9: Flowchart Showing the Process of Voting

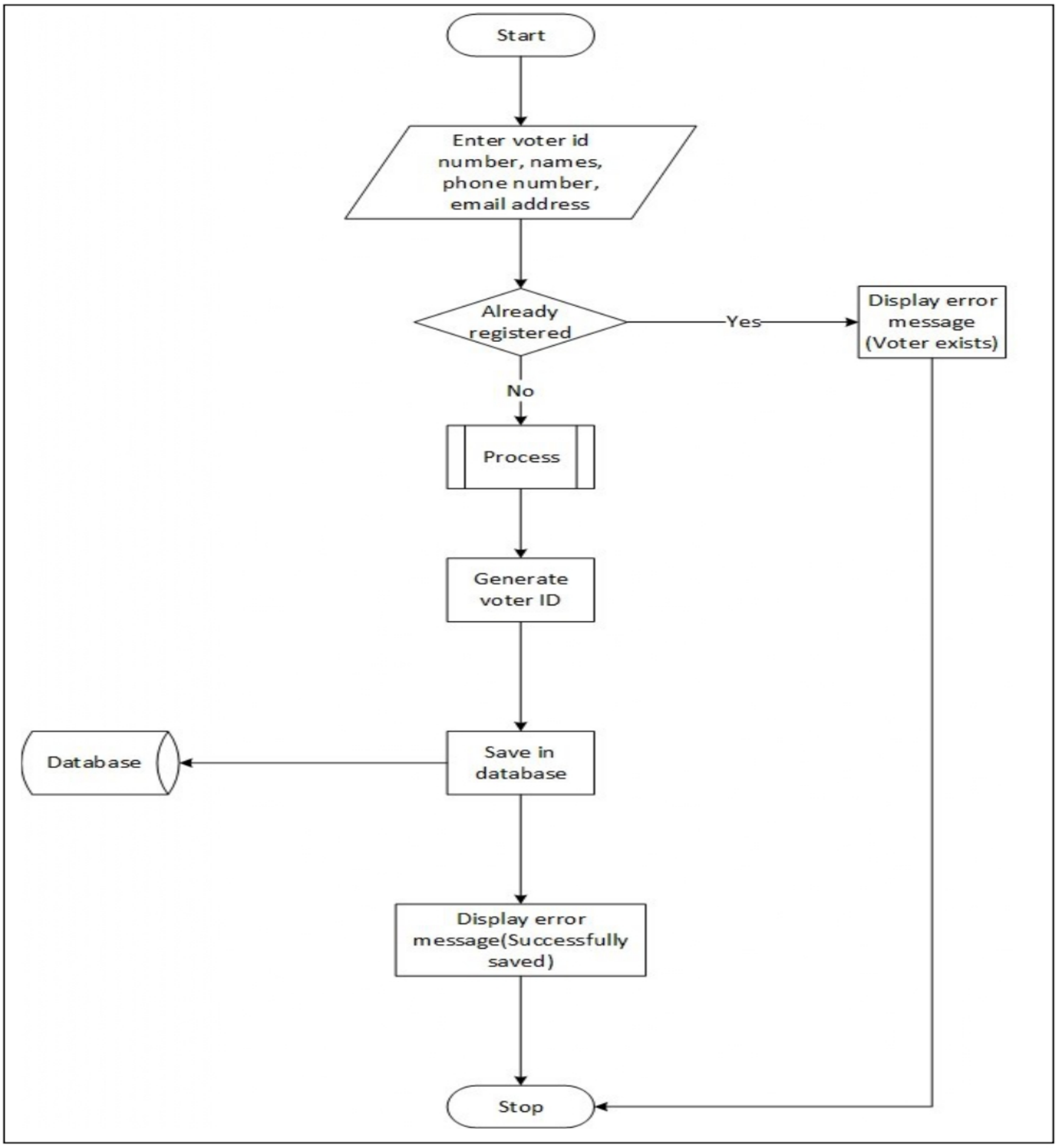

Figure 10: Register Voter Flowchart

4. System Implementation and Interfaces

In this section, we analyze and discuss the practical implementation of the e-voting system, exploring its various interfaces and functionalities.

4.1 Home Interfaces

The Home Interface serves as the initial point of contact for users upon launching the Igbo Students Association (ISA) app. Its primary purpose is to provide information about the Igbo Students Association. Users can access FAQs related to the association, and a menu for navigating the app is accessible through a dedicated button. While the primary focus of the project is the e-voting system within the app. It also doubles as an information hub for both members and non-members of the association. Advertisers can also request to feature their products on this interface for a fee.

4.1.1 Menu Interfaces

The Menu Interface functions include registration, my account, vote, results, and help as the central hub of the ISA app, presenting users with several key options:

Registration: Allows returning officers to register as association members.

My account: Displays the details of the currently logged-in user. If a user isn't logged in, clicking this button prompts them to log in.

Vote: Navigates a registered user to the voting section, where he/she can cast him/her votes.

Results: Provides provisional voting results for a specific session.
Help: Offers information on frequently asked questions about the Igbo Student Association and a means to contact the association.
Registration Interface: This interface is accessed by clicking the "Registration" button. It enables returning officers, who possess the necessary credentials, to register new eligible voters of the association. Information collected during registration includes first and last names, ID numbers, email, gender, phone number, and a default password set by the returning officer. Users are required to read and accept the terms and conditions before the returning officer proceeds with registration.
My Account Interface: To access this interface, voters must log in using the information provided or given by the returning officer. They are required to change their password, ensuring it meets the security requirements. Additionally, users can update their details here.
Voter Interface: After verifying login credentials, users are directed to the Voter Interface when attempting to cast their votes. In this situation, they can select their preferred candidates, starting from the president and proceeding down the list. Upon completing their vote, clicking the "Finish" button stores their choices in the database. Each office category opens a view for the voter to choose their preferred candidate from the options provided.
Results Interface: This interface displays election results and serves as an information source for the votes cast. It presents candidate names and the number of votes they've received, with color codes explained at the bottom of the system.
Selected Candidate Interface: Once a category (e.g., president) is selected, this interface allows users to choose their preferred candidate for that position. Users simply select one option from the provided choices. A final confirmation is prompted to ensure the user's intent. If confirmed, the user's choice is saved, and they can continue voting for other offices. If denied, they can return to the selected preferred candidate page to make a different selection.
Login Interface: Before casting a vote, users must log in to ensure that only eligible voters participate and prevent fake votes. Users enter a username and password. Only those with the correct credentials are allowed to access the voting system.
Contact Us Interface: In this interface, users have the option to call the association by clicking the "Call" button or send an email directly through their mail application. If users choose the email option, they are prompted to enter their full name and compose a message.
About US Interface: The About Us interface offers users relevant information about the application, their voting rights, and the governing body responsible for the app's usage.

Figure 11: Menu interface

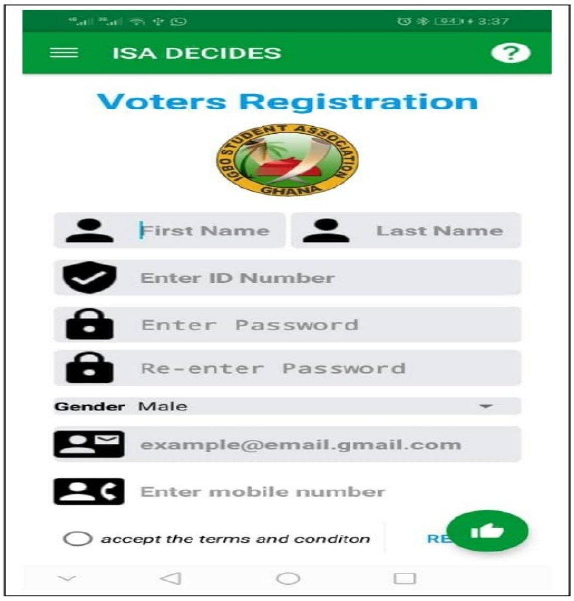

Figure 12: Voter Registration Page

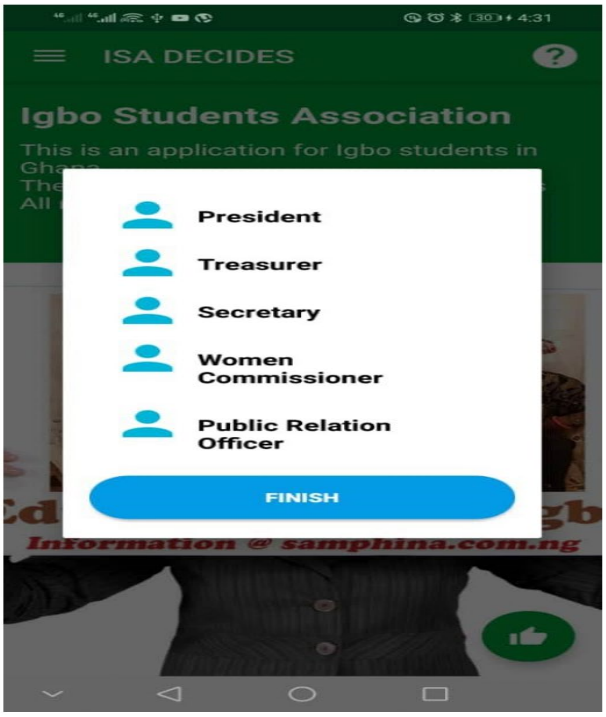

Figure 13: Candidate Voting Page

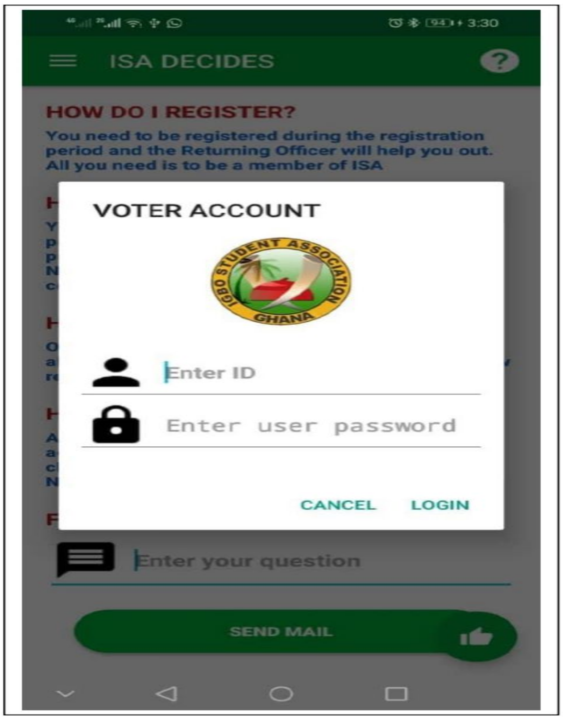

Figure 14: Login Page

5. System Evaluation: Performance Assessment Criteria

Acceptance testing is a process used in software development to determine if a system or application meets specified requirements. The criteria used in the survey are (strongly agree, agree, somewhat agree, and disagree). They are commonly used in survey-based assessments and can be applied to evaluate various aspects of the acceptance test. The brief discussion for each criterion for the survey is as follows:

Strongly Agree:

The user or tester strongly believes that the system or application has met the specified requirement.

The implication indicates a high level of confidence in the successful completion of the acceptance test.

The user is satisfied that the software meets their expectations fully.

Agree:

The user or tester believes that the system or application has generally met the specified requirement.

Its implication indicates a positive assessment, with the user being generally satisfied with the performance of the software. Minor issues may exist, but they are not significant enough to undermine the overall satisfaction.

Somewhat Agree:

The user or tester is leaning towards an agreement but has reservations or concerns about certain aspects.

The implication suggests that while there may be some satisfaction, there are noticeable issues or concerns that need attention. It indicates a level of uncertainty or a need for further investigation into specific areas.

Disagree:

The user or tester believes that the system or application has not met the specified requirement.

Its implication signals a clear dissatisfaction with the performance or functionality of the software. These requirements could be due to major issues, critical bugs, or a failure to meet essential requirements. These criteria are subjective and depend on the perspective of the user or tester. They are useful in gathering feedback and assessing the overall success of the acceptance test. The goal is to ensure that the software aligns with the user's expectations and fulfills the agreed-upon requirements.

System evaluation and testing have been conducted to ensure accuracy and correctness. User acceptance tests align the system with user requirements, and it has achieved a 98% acceptance rate. The user responses are summarized in Table 1.

The Evaluation Criterion

Criterion	Strongly Agree (8-10)	Agree (5-7)	Somewhat Agree (2-4)	Disagree (0-1)
System Accuracy	314 (98%)			
Ease of use	314 (98%)			
System Validation	314 (98%)			
Transparency	314 (98%)			
Convenience		314 (98%)		
Authentication	314 (98%)			
Reliability	314 (98%)			
Non-coercibility	314 (98%)			
Integrity	314 (98%)			
Certifiability	314 (98%)			
Cost-effectiveness		314 (98%)		
Uniqueness	314 (98%)			
Auditability	314 (98%)			
Secrecy	314 (98%)			

Table 1: User acceptance test and performance evaluation criterion

5.1 Discussion on Each Criterion For Assessment Test

Table 1 presents an evaluation of various criteria related to the e-voting systems based on the responses of individuals. We evaluate each criterion below:

System Accuracy: Strongly Agree (8-10) has 314 responses, representing 98%, and indicates a high level of confidence in the system's accuracy among the respondents. It demonstrates the extent to which the system produces correct and reliable results. High accuracy is crucial, especially in applications where precision is essential.

Ease of Use: Strongly Agree (8-10) receives 314 responses with 98% acceptance suggesting the system is perceived as user-friendly. It explains how user-friendly and intuitive the system is for end-users. An easy-to-use system improves user adoption, reduces training costs, and enhances overall user satisfaction.

System Validation: Strongly Agree (8-10) similarly has 314 responses which represent 98% with strong agreement, indicating trust in the system's validation processes. The process confirms that the system meets the specified requirements. System validation ensures that the software performs as intended and meets the user's expectations.

Transparency: Strongly Agree (8-10) representing 314 respondents with 98% indicating a high agreement to suggests that respondents perceive the system as transparent. The degree to which the system's operations and decision-making processes are visible and understandable. Transparency is essential for building trust and understanding how the system works, particularly in critical applications such as e-voting systems.

Convenience: Agree (5-7) with 314 respondents representing agreement of 98% to indicate that respondents find the system convenient to use. It demonstrates how easily and comfortably, users can interact with the system. A convenient system enhances user experience and encourages regular use.

Authentication: Strongly Agree (8-10) which is 314 respondents, indicating strong agreement of 98% to suggests that respondents trust the system's authentication mechanisms. The process of verifying the identity of users or entities accessing the system. Strong authentication is crucial for security, preventing unauthorized access to sensitive information.

Reliability: Strongly Agree (8-10) with 314 respondents representing a high agreement of 98% indicates that respondents consider the system to be reliable in its performance. The ability of the system to consistently perform as expected without failures. Reliable systems are crucial, especially in mission-critical applications, to ensure consistent performance and availability.

Non-coercibility: Strongly Agree (8-10) representing 314 respondents with a strong agreement of 98% to indicate confidence that the system cannot be coerced or manipulated. The system should not force or coerce users into taking certain actions against their will. It demonstrates high ethical considerations and user autonomy, particularly in systems dealing with personal information or decision-making.

Integrity: Strongly Agree (8-10) which has 314 respondents with high agreement of 98% to suggest that respondents perceive the system as maintaining its integrity. The assurance that data and information within the system are accurate and unaltered. Data integrity is vital for maintaining the trustworthiness of information and preventing unauthorized tampering.

Certifiability: Strongly Agree (8-10) indicating 314 respondents with 98% indicating that respondents believe the system is certifiable, meeting necessary standards. The system's adherence to relevant standards and certifications. Certifiability is important in regulated industries and ensures that the system complies with established norms.

Cost-effectiveness: Agree (5-7) which receives 314 respondents, indicating agreement of 98% to suggest that it provides value for money. The efficiency of the system in delivering value relative to its cost. A cost-effective system maximizes benefits while minimizing expenses, contributing to overall organizational efficiency.

Uniqueness: Strongly Agree (8-10) which has 314 respondents suggesting strong agreement of 98% to indicate that respondents perceive the system as unique or innovative. The distinctiveness of the system's features or capabilities compared to alternatives. Uniqueness can provide a competitive advantage and attract users looking for specific functionalities.

Auditability: Strongly Agree (8-10) which consists of 314 respondents with a high agreement of 98% suggests that respondents believe the system is auditable, allowing for scrutiny and verification of results. The ability to track and review system activities for accountability and compliance. Auditability is crucial for regulatory compliance and internal monitoring of system behavior.

Secrecy: Strongly Agree (8-10) which receives 314 respondents, representing high agreement of 98% indicates that respondents believe the system maintains the secrecy of votes. The protection of sensitive information from unauthorized access. The implication implies secrecy is crucial in systems handling confidential data to prevent data breaches and maintain privacy.

The evaluation across all criteria indicates strong agreement (98%) from respondents, suggesting high levels of confidence in the system's accuracy, usability, security, transparency, and other essential attributes. This overwhelmingly positive feedback indicates that the system is well-perceived and meets the expectations of users in various aspects, making it a reliable and trustworthy system for its intended purpose as an e-voting system.

5.2 Performance Assessment

In this section, we explain the meaning of the criterion used for the performance assessment and how it relates to EVS development. Each of these criteria plays a vital role in assessing the performance, usability, security, and overall effectiveness of a system in its intended context and how the survey evaluation process was done immediately after casting the votes. The evaluation process was meticulously organized to gather input from a targeted group of 320 individual students. Below is a detailed breakdown of the evaluation process.

The evaluation aimed to include the participation of 320 individual students. The selection of these individuals involved stakeholders, users, or relevant participants with adequate interest in the subject matter under evaluation.

Voter turnout: The expected voter turnout was 320 voters. However, only 314 individuals actively voted successfully and subsequently completed the survey to cast votes immediately to evaluate the system's performance.

Percentage of voters who voted: To calculate the percentage of voters who participated, we divided the 314 voters who cast votes by the 320 total number of voters expected and then multiplied by 100.

$$\text{Actual voters} = \left(\frac{314}{320}\right) \text{ x } 100 = 98.125\% \quad (1)$$

Therefore, the percentage of voters who voted successfully was approximately 98.13%

To calculate the percentage of voters who did not participate, subtract the 314 number of voters from the 320 expected total number of voters and multiply by 100.

$$\text{Voters absent} = \left(\frac{320-314}{320}\right) \text{ x } 100$$

$$= \left(\frac{6}{320}\right) \text{ x } 100 = 1.875\% \quad (2)$$

Therefore, the percentage of voters who did not turn out to vote was approximately 1.8%. In brief, the evaluation process targeted the participation of 320 voters, but 314 individual students actively participated resulting in a high voter turnout of approximately 98.13%. The remaining 6 individual students who did not vote represent 1.88%. This information provides insight into the engagement level and participation rate in the evaluation process indicating the robustness of the EVS.

SECTION A: SOCIO-DEMOGRAPHIC DATA					
No	**Questions**	**User / (Voter)**	**%**	**Returning Officer**	**%**
Q1	**Gender**				
	Male	147	46.8	10	3.2
	Female	I51	48.1	6	1.9
Q2	**Age groups**				
	18-28	179	57	5	1.6
	29-38	68	21.7	7	2.2
	39-48	51	16.2	4	1.3
	49-58				
	59+				

Q3	**Marital status**				
	Single	278	88.5	12	3.8
	Married	20	6.4	4	1.3
Q4	**Highest education**				
	SHS	263	84.0	6	2
	Diploma	22	7.0	3	1
	Degree	10	3.2	3	1
	Masters	3	1	2	0.6
	PhDs				
	Other				
Q5	**Designated University/Technical University**				
	University of Ghana, Accra-Public	27	8.6	5	1.6
	University of Cape Coast (UCC)- Public	13	4.1		
	University of Education, Winneba- Public	2	0.6		
	Nkrumah University of Science and Technology, Kumasi- Public	23	7.3	4	1.3
	University of Mines & Technology, Tarkwa-Public	4	1.3		
	University of Professional Studies, Accra- Public	11	3.5		
	University of Development Studies, Tamale- Public	3	1		
	Ghana Communication Technology University (GCTU), Accra- Public	15	4.8	1	0.3
	Regional Maritime University, Accra- Public	13	4.1		
	Ashesi University, Accra-Private	14	4.5	1	0.3
	Central University	15	4.8	1	0.3
	All Nations University	14	4.5	1	0.3
	Methodist University	14	4.5	2	0.6
	Presbyterian University				
	Islamic University College, Ghana (Accra)	4	1.3		
	Ghana Institute of Management and Public Administration (GIMPA), Accra.	11	3.5		
	Christian Service University College, Kumasi				
	Catholic University of Ghana (CUG), Sunyani	3	11		
	Accra Institute of Technology, Accra	5	1.6		
	Regent University College of Science and Technology, Accra	14	4.5	1	0.3
	Knutsford University College, Accra	5	1.6		
	Garden City University College, Kumasi				
	Wisconsin International University College, Ghana (Accra)	11	3.5		
	Academic City University College, (Accra)	12	3.8		
	Radford University College (Accra)				
	Evangelical Presbyterian University College (Ho)	3	1		
	African University College of Communication (AUCC), Accra	5	1.6		
	Kaaf University College	6	2		
	University of Energy and Natural Resources	3	1		
	Zenith University College, Accra	9	2.9		
	Accra Technical University	7	2.2		
	Kumasi Technical University	7	2.2		
	Ho Technical University	6	2		
	Takoradi Technical University	5	1.6		
	Koforidua Technical University	9	2.9		
	Cape Coast Technical University	5	1.6		
SECTION B: DIGITAL LITERACY AND ACCESSIBILITY OF USING E-VOTING SYSTEMS					
Q1	**To what extent do you feel digitally literate to use the e-voting system for this election? (**Please, **INDICATE** your digital literacy and accessibility of using E-voting systems in the box provided based on a scale of 1-5 where **1 is Very low** and **5 is Very high** where possible.**)**				
	Very low	2	0.6		
	Low	11	3.5		
	Don't know/not sure	12	3.8		
	High	108	34.4		
	Very high	181	57.6		
Q2	**What challenges do you foresee for students with limited digital literacy in using e-voting systems?**				
	Limited Understanding of Technology	16	5.1		
	Difficulty in Using Electronic Devices	3	1		
	Concerns About Security and Privacy	71	22.6		

	Risk of Making Errors During Voting	36	11.5		
	Difficulty in Verifying Votes	92	29.3		
	Limited Access to Information	21	6.7		
	Digital Exclusion and Inequality	11	3.5		
	Potential for Coercion or Manipulation	13	4.1		
	Difficulty in Troubleshooting Technical Issues	51	16.2		
Q3	**Are you aware of any resources or support services available to enhance digital literacy by using e-voting systems?**				
	Yes	197	62.7		
	No	76	24.2		
	Maybe	41	13.1		
Q4	**In your opinion, how would you rate the following digital literacy initiatives to improve and ensure broader accessibility to e-voting platforms?**				
	Tailored Training Programs	57	18.2		
	Online Tutorials and Resources	12	3.8		
	Community Workshops and Outreach	27	8.6		
	Multilingual Support	23	7.3		
	Incorporate User-Friendly Design	56	17.8		
	Collaboration with Educational Institutions	36	11.5		
	Public Awareness Campaigns	53	16.9		
	Accessible Learning Platforms	15	4.8		
	Continuous Support and Feedback Mechanisms	35	11.1		
Q5	**Do you believe that e-voting systems are user-friendly for individuals of varying levels of digital literacy?**				
	Yes	253	80.6		
	No	51	16.2		
	Maybe	10	3.2		
Q6	**To what degree does your perception of your digital literacy influence your willingness to adopt e-voting in elections?** (Please, **INDICATE** your digital literacy and accessibility of using E-voting systems in the box provided based on a scale of 1-5 where **1 is Very low** and **5 is Very high** where possible.**)**				
	Very low	3	1		
	Low	36	11.5		
	Don't know/not sure	7	2.2		
	High	101	32.2		
	Very high	167	53.1		
Q7	**How would you rate your level of digital literacy in terms of using technology, including e-voting systems?** (Please, **INDICATE** your digital literacy and accessibility of using E-voting systems in the box provided based on a scale of 1-5 where **1 is Very low** and **5 is Very high** where possible.**)**				
	Very low	4	1.3		
	Low	15	4.8		
	Don't know/not sure	3	1		
	High	91	28.9		
	Very high	201	64.0		
Q8	**What challenges do you anticipate for individuals with limited digital literacy in utilizing e-voting systems?**				
	Difficulty in Navigating Electronic Interfaces	61	19.4		
	Lack of Familiarity with Technology	23	7.3		
	Concerns About Security and Privacy	37	11.8		
	Difficulty in Verifying Votes	61	19.4		
	Limited Access to Information	13	4.1		
	Potential for Coercion or Manipulation	24	7.6		
	Difficulty in Troubleshooting Technical Issues	25	8.0		
	Risk of Making Errors During Voting	40	12.7		
	Digital Exclusion and Inequality	30	9.6		

Table 2: Analysis of survey data to assess the effectiveness of the e-voting system

5.3 Discussion on Performance Assessment

To evaluate the data provided in Table 2, we analyze various aspects such as socio-demographic characteristics and attitudes toward e-voting systems. The evaluation has been broken down into sections below:

Section A: Socio-demographic Data

- **Gender distribution:** The data shows that 46.8% of respondents are male, while 48.1% are female. There is a slight imbalance favoring females. It is noteworthy that a significant portion of 3.2% Returning Officers are male while 1.9 % are female).
- **Age group:** The majority of respondents 57% within the 18-28 group indicating a younger demographic.
- **Marital status:** A vast majority 88.5% of respondents are single, suggesting potential differences in voting behavior compared to married individuals.
- **Highest education:** The majority have completed Senior High School (SHS), indicating a relatively high level of education among respondents.
- **Designated university/Technical university:** The data provides insights into the distribution of respondents across different educational institutions, which could be valuable for targeting awareness campaigns or training programs.

Section B: Digital literacy and accessibility of using E-voting systems

- **Digital literacy:** We had 57.6% significant majority feel very highly about using the e-voting systems, while 34.4% rate their literacy as high. Only a small percentage of 4.1% feel very low or low digital literacy, which is promising for e-voting adoption.
- **Challenges faced by students with limited digital literacy:** Concerns about security, privacy, and difficulty in verifying votes are the most significant challenges identified, indicating areas for improvement in e-voting system design and education.
- **Awareness of resources for digital literacy enhancement:** A majority of 62.7% are aware of resources or support services available to enhance digital literacy by using e-voting systems, suggesting a positive inclination toward learning.
- **Perception of digital literacy initiatives:** Tailored training programs, user-friendly design, and public awareness campaigns are perceived positively, indicating potential areas of focus for improving digital literacy.
- **User-friendliness of e-voting systems:** A large majority of 80.6% believe e-voting systems are user-friendly for individuals of varying levels of digital literacy, which is crucial for adoption.
- **Impact of digital literacy adoption:** A significant majority of 85.3% have a high or very high perception of their digital literacy, which positively influences their willingness to adopt e-voting systems.
- **Challenges for individuals with limited digital literacy:** Difficulty in navigating interfaces, verifying votes, and troubleshooting technical issues are the primary challenges anticipated, highlighting areas for improvement in system usability and support.

In general, the data suggests a generally positive towards e-voting systems, with a majority expressing confidence in their digital literacy and user-friendliness of such systems. However, there are still concerns regarding security, privacy, and potential technical challenges, especially among individuals with limited digital literacy. Targeted efforts in education, training, and system design are essential to address these concerns and ensure broader accessibility and acceptance of e-voting systems among diverse demographics.

6. Conclusion and Future Work

The e-voting system (EVS) has received widespread endorsement in the African continent, particularly following attempts at election rigging by a few presidential candidates. Electoral fraud, or the manipulation of election results, is a prevalent issue in many African countries. In recent times, some African countries have seen coup d'etats due to many factors: popular dissatisfaction, institutional weakness, historical precedents, authoritarian regimes, military discontent, and economic crisis. One major pillar to preventing coup d'etats in Africa is building a strong institution to make independent decisions without any political influences.

Challenges to implementing EVS at the national level in countries like Ghana include high illiteracy rates. However, its successful implementation in tertiary institutions, as demonstrated by a 98% user acceptance rate, can serve as a model for broader adoption. As these educated students graduate, they will educate the nation about the benefits of EVS over traditional systems, fostering transparency and trust in electoral systems across Africa.

African leaders should invest in Information Technology to develop robust e-government and e-voting applications. Collaboration between IT experts and government is crucial for timely implementation. Recent advancements in e-government in Ghana exemplify progress in this direction. It is advisable to implement e-voting systems in the 2024 general elections to ensure transparent, auditable, and trustworthy electoral processes in Ghana.

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