Improving Accessibility: A Novel E-Voting Approach for Enhanced Privacy and Security, Empowering Visually Impaired Voters through Advanced Security Techniques

Blessing Nwala
Department of Computer Science
Bowling Green State University
Bowling Green, Ohio, USA
unwala@bgsu.edu

***Abstract*—Ensuring active participation in electoral processes is crucial for democratic societies. However, traditional voting systems often fail to accommodate the needs of visually impaired individuals, challenging their ability to vote independently and securely. Our work introduces an advanced electronic voting system tailored specifically for visually impaired voters, enhancing e-voting security, privacy, and accessibility. By incorporating a dual authentication mechanism using fingerprint verification and password entry via a Braille keyboard, our system enables voters to cast their votes securely from remote locations, ensuring privacy and autonomy. Our system uses cutting-edge technologies such as RSA encryption and salted hashing to protect voter data against malicious attacks, thereby strengthening data integrity and security. Developed using the Python programming language and following the waterfall Software Development Life Cycle (SDLC), Our approach significantly improves accessibility and inclusion in electoral processes for visually impaired persons and offers enhanced security and data protection compared to existing e-voting systems.**

***Index Terms*—E-Voting, RSA Algorithm, Salting, Advanced hashing techniques, Fingerprint Scanning, Braille Keyboard Authentication.**

I. Introduction

EVERY individual in a democratic society should have equal access and the freedom to participate in e-voting processes, which is a core principle of electoral equality.Traditional voting methods, however, have placed visually impaired individuals at a disadvantage by complicating their participation in democratic rights exercises. These challenges are due not only to inaccessible voting technology but also to physical barriers at polling stations, which deter a significant portion of the electorate. Our work is a new e-voting system designed to cater to the unique needs of visually impaired voters. We aim to resolve longstanding issues of accessibility, security, and privacy in electoral processes. Our system integrates state-of-the-art technologies, including fingerprint authentication and a Braille keyboard for secure password entry, establishing a robust two-factor authentication framework that ensures the security and straightforwardness of remote voting. This approach not only enhances security through precise biometric verification but also protects voter privacy. A cornerstone of our system is our sophisticated dual authentication mechanism that combines fingerprint scanning with password entry through a Braille keyboard, enabling highly secure and user-friendly voting. The use of RSA encryption ensures the confidentiality of transmitted data, while the application of salted hashing techniques secures the data against unauthorized access and manipulation. Developed in accordance with the waterfall SDLC model and programmed in Python, our system is designed to undergo rigorous testing at each development phase. By thoroughly comparing our system's effectiveness and performance with existing e-voting systems, our system aims to demonstrate superior functionality and security, setting a new standard for accessible voting technologies. This initiative not only promises to enhance democratic participation among visually impaired individuals but also upholds the highest standards of election security and data integrity, promoting greater inclusivity and trust in electoral systems.

II. Related Work

A. Introduction

Electronic voting systems have included many ways to improve accessibility, security, and privacy for individuals with visual impairments. Also, several researchers have examined the use of various cutting-edge technologies, such as blockchain, biometrics, deep learning, and encryption, to overcome the challenges of electronic voting. Each of the paper we reviewed offers a distinct addition to the field of e-voting for individuals with visual impairment, focusing on various aspects of the design and security of electronic voting systems for people with visual impairment. Dema et al.[2] in 2022 designed and developed an electronic system for individuals with visual impairment that makes use of the Arduino AT Mega 2560. To assist visually impaired voters, navigate the ballot while maintaining vote integrity, their design placed a high priority on accessibility and the privacy of the electoral process. They also included a function that uses audio to identify candidates. However, even with distinct ballot and control units intended to reduce tampering, their system remained vulnerable to voice impersonation and insider attacks. On the other hand, our method greatly increases security by strengthening user authentication by combining fingerprint scanning with inputs password from Braille keyboard. Additionally, the use of RSA encryption protects voter data from malevolent insider attack, and our system guarantees data integrity by integrating salting and hashing techniques. H.N. Odikwa et al.[3] in 2020 catered to the underprivileged demographic in Sub-Saharan Africa by installing an e-voting system accessible via a web-based platform that allowed speech authentication where a voter uses their voice for authentication. However, relying on speech authentication makes the system vulnerable to security flaws such as voice impersonation. Our system improves on their work by bridging the security vulnerability of voice impersonation, we integrate the use of fingerprint and braille keyboard for voter's password creation for system authentication hereby optimizing security and user privacy, we also use salting and hashing techniques for data integrity to prevents reverse engineering attack and use of precomputed tables attack. RSA encryption and decryption significantly improves the voting process's security of our system. Ruba et al.[4] designed a voice authentication system to help visually impaired voters register and vote independently. While it improved accessibility, the system was vulnerable to security breaches. In contrast, our system uses fingerprint authentication and a Braille keyboard for creating passwords, enhancing security with RSA encryption, salting, and hashing to protect voter information more effectively. While many studies have sought to improve electronic voting systems, they frequently fail to fully address the accessibility needs of visually impaired voters. Our system breaks through these barriers by providing a secure, private, and user-friendly voting experience. With dual-factor authentication and advanced data security measures, we promote an e-voting process that enables visually impaired people to be more inclusive and anonymous when they participate in e-voting process. Our system is a specialized system that not only strengthens the foundation of electronic voting systems but also supports the active engagement of visually impaired voters, ensuring they can vote independently and receive any needed assistance remotely.

III. System Methodology and Approach

Our work focuses on the specific needs of visually impaired voters by incorporating multiple security techniques and dual authentication into the electronic voting system. This section outlines our system's architecture, flowchart, ER diagrams, and use case design and approach, explaining how it addresses the challenges faced by visually impaired voters regarding security, data integrity, and privacy. Prior to election day, visually impaired voters are required to register during the designated registration phase.We also list the method and materials used to collect our data, analyze data, and elaborate on our software development life cycle process. This preliminary step ensures that our system can effectively and efficiently authenticate all registered users.

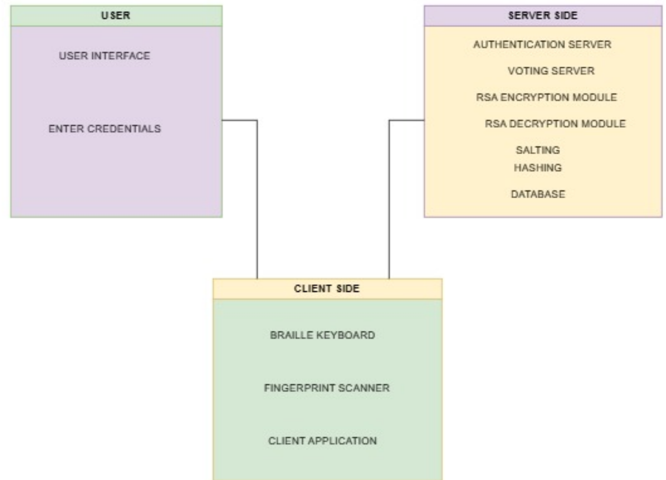


Fig. 1. System Architecture

A. System Architecture

1) User: Our system's target users are individuals with visual impairments. They use the E-voting interface, which is designed for accessibility, allowing them to enter credentials independently, primarily using a Braille keyboard for password creation and fingerprint scanner for dual authentication.

2) Client Side: On the client side of our system, visually impaired voters have access to:

a) Visually impaired voters interface: This is an interface that adapts to the needs of visually impaired users, enabling them to register and engage in the e-voting process with autonomy.

b) Braille Keyboard: The braille keyboard is a special kind of keyboard device that is used by individuals with visual impairment, we integrate braille keyboard to our system for use by visually impaired voters to create unique passwords, providing an accessible way to input secure credentials.

c) Fingerprint scanner: As part of our system dual-authentication mechanism, the fingerprint scanner is used to capture and verify voters' biometric data, enhancing the security of voter identification.

d) Client Application: The client application is used to process the input from the Braille keyboard and fingerprint scanner, facilitating secure communication with the server side.

3) Server side: The server side of our system manages the core processes of the voting system and is made up of:

a) Authentication Server: Our authentication server is used to verify the voter's identity using the credentials and fingerprint data received from the client application.

b) Voting Server: Our voting server is used to control the voting process, including ballot creation, encryption, and storage.

c) RSA Encryption Module: RSA encryption module is used to encrypt sensitive data before data is stored in the database. It makes use of public key generated by RSA key to encrypt plain text into cipher text. Here each voter has a pair of public-private keys, the vote is encrypted with the public key before it is sent.

d) RSA Decryption Module: Authorized personnel use a private key to decrypt stored data for vote tallying. When authorized users need to access stored data, this module is used to decrypt and count votes.

e) Salting: Salting would be used when storing a voter's information and votes. It is used to add more layers of security. It includes random strings of characters called (salt) to each vote before hashing. This makes it hard for attackers to make use of precomputed tables (rainbow tables) to perform reverse engineering to the original vote from its hash.

f) Hashing: Hashing is used to enhance security by appending a unique salt to each visually impaired voters' password and then hashing it, preventing attackers from reversing the hash to discover the original password.

g) Database: Our secure database is where all voter data, including the encrypted credentials from the Braille keyboard inputs and fingerprint data, are stored. Our system architecture ensures that each visually impaired voter can interact with our system securely and independently while maintaining their privacy and the integrity of their vote.

B. System Entity-Relationship Architecture

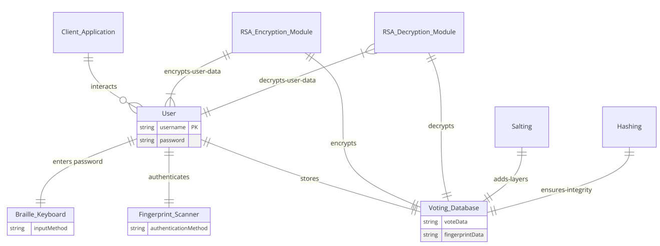


Fig. 2. Entity-Relationship Architecture

We also represented our system with an ER diagram, the entity-relationship diagram in our work is used to visualize how different components of our E-Voting system are connected, the ER diagram delineates the flow of data between components and ensures that each aspect of the voting process is secured and interrelated.

1) Braille Keyboard:

a) Input Method: The input method is used to enable visually impaired users to enter their password using Braille, which enhances the accessibility of the voting system.

2) Fingerprint Scanner:

a) Authentication Method: The authentication method is used to capture the visually impaired voter's fingerprint to provide a secure and unique form of identification.

3) User:

a) Username (PK): This is a primary identifier for each user, it is unique for every visually impaired voter.

b) Password: The password is the secret key entered by each visually impaired voter via the Braille Keyboard, contributing to the two-factor authentication process.

4) Voting Database:

a) Vote Data: This is the Visually impaired voters encrypted data related to the votes cast by users, this ensures the confidentiality of each vote

b) Fingerprint Data: This is the visually impaired voter's encrypted biometric data obtained from the Fingerprint Scanner, this is used to validate the voter's authenticity.

C. System Flow Chart Architecture

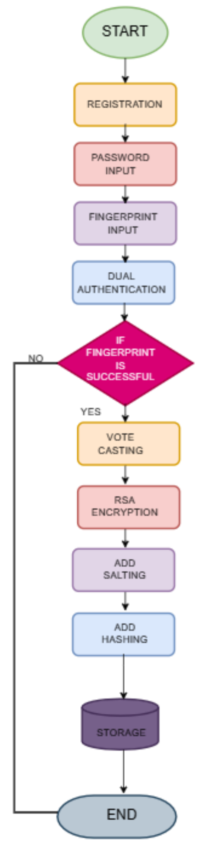


Fig. 3. System Flow chart diagram

Our system flowchart is used to outline the process for visually impaired voters using our electronic voting system.

a) Start: This is the first stage of system initialization. At this stage the E-voting process begins.

b) Registration: Each visually impaired Voter must register first on our system, entering their data into the system.

c) Password Input: Utilizing our Braille keyboard, each visually impaired voter creates their secure passwords.

d) Fingerprint Input: Each visually impaired Voter provides their fingerprints for biometric verification.

e) Dual Authentication and Verification: Our system authenticates and verifies each visually impaired voter by checking both the password and fingerprint

f) Vote Casting: If the fingerprint is verified (Yes), the visually impaired voter can now proceed to cast their votes; if not (No), they cannot proceed and the process ends.

g) RSA Encryption: This encrypts the visually impaired vote data with a public key hereby making data available to only authorized government electoral individual officials.

h) Salting: We add a salt string to visually impaired voters' password to enhance security. So for example if the visually impaired voter's password is @Anc1324 random strings of character 9f2e8d6a4c1b72a2 of salt is added and it becomes @Anc13249f2e8d6a4c1b72a2, this is used as input into hashing.

i) Hashing: Hashing is used to ensure that voters data are not changed or altered by unauthorized users and are not in plain text. It satisfies the integrity of voter's data. Here voters data input is being processed and a string of hash values is generated to uniquely represent voters input data. Government authorized officials can compare hash data to ensure that there is no breach in data integrity.

j) Storage: Our database holds and store all information of visually impaired voters. Information can be retrieved by government authorized officials as needed.

k) End: After the E-voting process is successful and complete the process ends.

D. Use case Diagram of the system

1) User: Our use case diagram for our system illustrates the interactions between visually impaired voters and system administrators with the E-Voting system.

a) Register: Visually impaired voters sign up to our system by providing necessary information.

b) Login: Visually impaired voters access our system using their credentials.

c) Dual Authentication: Our system verifies each voter's identity through a password check and biometric check. This is dual authentication.

d) Review Candidates: Each visually impaired voter can look over the list of candidates before selecting their choice.

e) Cast Votes: Once decided, each visually impaired voter submits their vote for their chosen candidate.

2) System Administrator:

a) Generate Results: After the E-Voting process ends, the administrator and authorized government official processes visually impaired voters' data to tally votes and produce the election results.

b) Manage Voters Data: The administrator and authorized government official oversees the voters' information, ensuring it is accurate and secure throughout the E-Voting process.

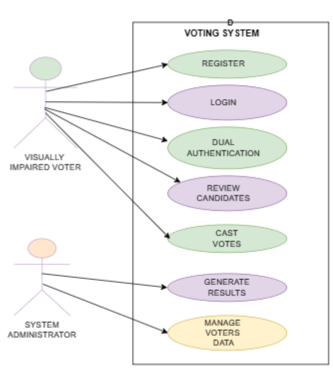


Fig. 4. System Use case diagram

E. Methods and Materials

For our project we sent out survey questionnaires to the ophthalmology department at Pj rapha care clinic limited, 50 individuals information were gotten and used for our analysis.We analyzed the data we collected to gain deep insight,understand and know the age group of individuals who are visually impaired, what kind of visual impairment they have, how often they participate in the elections using the E-voting system and manual system electoral voting that are currently existing. From our findings from analyzing our survey we were able to gather the following information as follows.Individuals who are visually impaired and are under the age of 30 have a low participation rate of (70Also, Individuals who are visually impaired and are 30-40 years have a low participation rate of (50Individuals who are visually impaired and are 41-50 years have a low participation rate of (60Finally, individuals who are visually impaired and are above the age of 50, which is 50+ have a low participation rate of (80We derived that individuals above the age of 51 have more visual eye defect condition. We also analyzed that the overall significant majority of 65Below is a graph derived from analyzing our data.

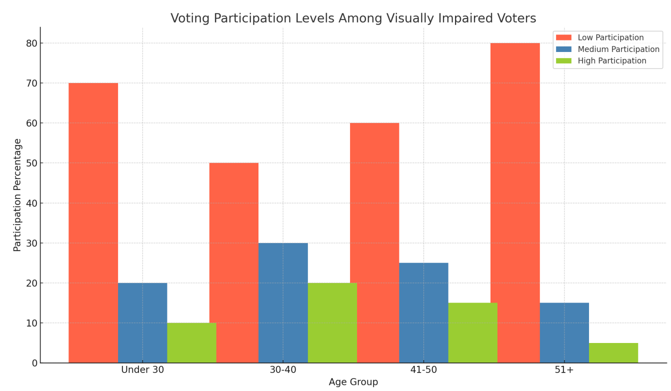


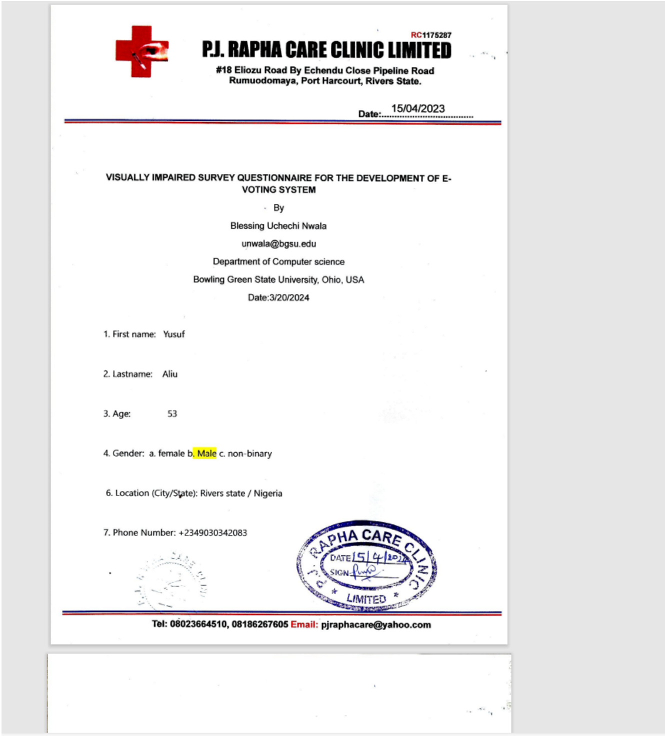
Fig. 5. Data analysis graph

F. Software Development Process

For our research work, we make use of python programming language, html and CSS. We utilized the waterfall software development life cycle, using the following steps overtime we are able to achieve our aim and tackle the security, privacy and data integrity issues faced by visually impaired voters using the current E-voting systems.

a) Requirement gathering: We first began by gathering data of visually impaired patients by sharing a questionnaire. Our data was gathered from the ophthalmology department at PJ Rapha care clinic limited. We were able to identify the core needs and challenges faced by visually impaired patients with the current E-Voting systems that are currently being used. We tackled these challenges by designing an E-voting system that optimizes security, privacy,and data integrity of voter's data.

b) System Design: From our requirement gathering analysis we designed a robust system architecture that shows our modules, mechanism and techniques utilized in our system

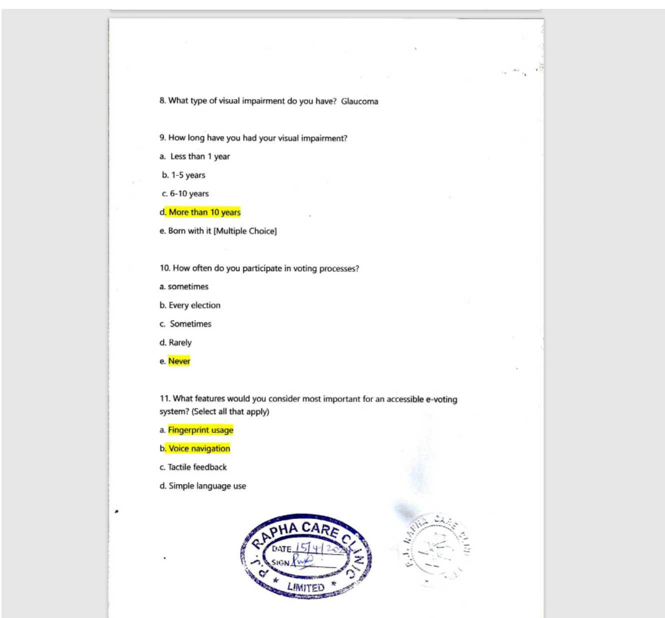

RC1175287
P.J. RAPHA CARE CLINIC LIMITED
#18 Eliozu Road By Echendu Close Pipeline Road
Rumuodomaya, Port Harcourt, Rivers State.
Date: 15/04/2023

VISUALLY IMPAIRED SURVEY QUESTIONNAIRE FOR THE DEVELOPMENT OF E-VOTING SYSTEM
By
Blessing Uchechi Nwala
unwala@bgsu.edu
Department of Computer science
Bowling Green State University, Ohio, USA
Date:3/20/2024

1. First name: Yusuf
2. Lastname: Aliu
3. Age: 53
4. Gender: a. female b. Male c. non-binary
6. Location (City/State): Rivers state / Nigeria
7. Phone Number: +2349030342083

Tel: 08023664510, 08186267605 Email: pjraphacare@yahoo.com

Fig. 6. Sample questionnaire


8. What type of visual impairment do you have? Glaucoma

9. How long have you had your visual impairment?
a. Less than 1 year
b. 1-5 years
c. 6-10 years
d. More than 10 years
e. Born with it [Multiple Choice]

10. How often do you participate in voting processes?
a. sometimes
b. Every election
c. Sometimes
d. Rarely
e. Never

11. What features would you consider most important for an accessible e-voting system? (Select all that apply)
a. Fingerprint usage
b. Voice navigation
c. Tactile feedback
d. Simple language use

Fig. 7. Sample questionnaire

development to distinctly tackle the challenges we found out. We integrated dual authentication, RSA encryption and decryption, salting and hashing.

c) Implementation: For the implementation of our work, we make use of visual studio, html, python and CSS for our software development, we also utilize the use of our braille specialized keyboard and fingerprint scanner for password creation and authentication and employ the use of RSA encryption and decryption mechanism, salting and hashing technique.

d) Integration and testing: We test all the units developed and integrated into our system to see if they meet visually impaired voters' needs to tackle challenges faced during E-Voting electoral process.

e) Deployment: Our System is made available to our user target who are the visually impaired voters for use and released to the government and market after real time deployment.

f) Maintenance: From our user feedback we would make necessary modifications to continuously improve system performance and efficiency to serve our users better making them actively participate in the E-Voting electoral process and perform their civic duties.

IV. Results

Below are our system front-end design results.

1) Welcome page: The welcome page is the first page of our system design, it welcomes the visually impaired voter to use our system.

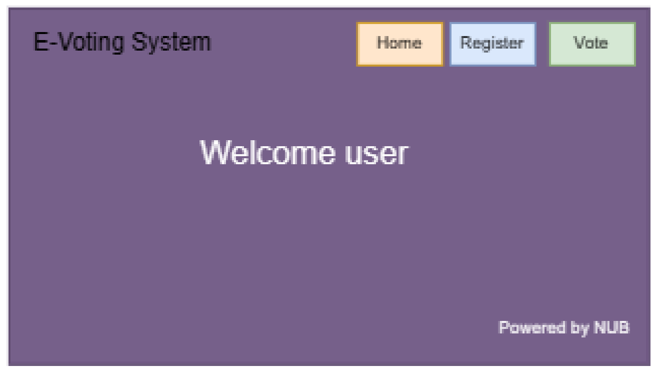


Fig. 8. Welcome Page

2) Registration page: This allows a user to input their credentials and create a password using our system.

3) Login page: This page allows a user to login to our system using their unique username and password. Our system authenticates user at this phase if authentication is successful user can select a candidate and vote.

4) Candidate Selection Page: This phase allows a user to select and vote for their preferred candidate.Each Candidate and country is represented by their party flag and their initials of their first and last name. From our candidate selection page we see two candidates baring HB represented by different distinct colors, this identifies that they are different individuals, from different parties.

5) Thank You Page: This page displays the thank you message to the user for voting their preferred candidate.

A. Discussion

Our project demonstrates significant enhancements in e-voting security and accessibility for visually impaired individuals. By integrating dual authentication mechanisms such as fingerprint scanning, password entry via a Braille keyboard and employing RSA encryption and salted hashing, the

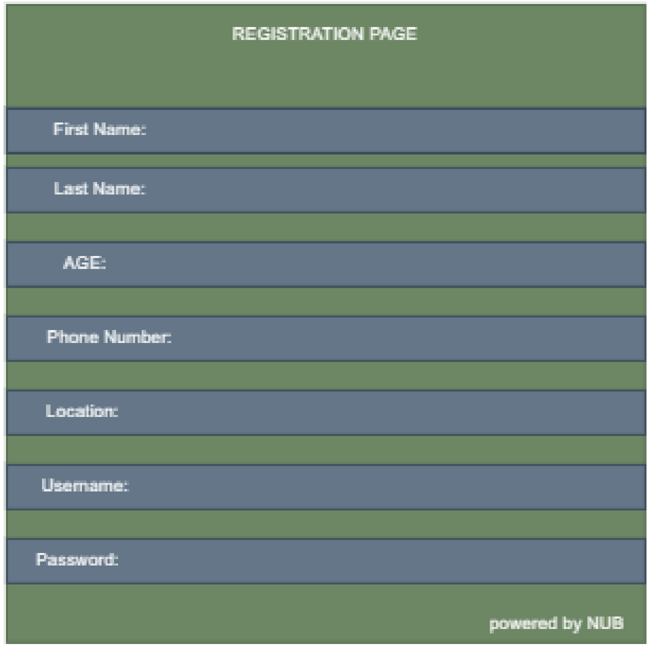


Fig. 9. Registration Page

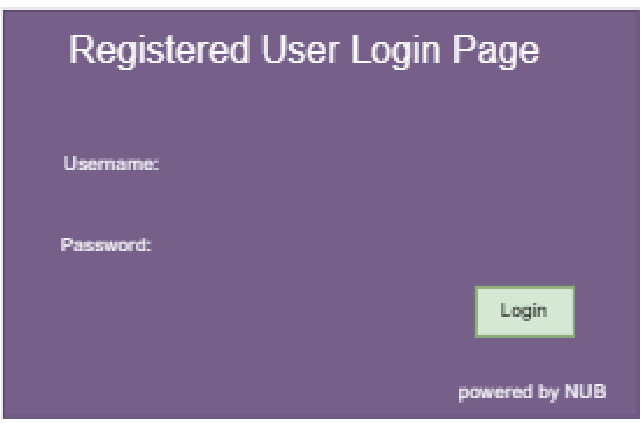


Fig. 10. Login Page

system significantly reduces potential security breaches. This development not only fills existing gaps in voting technology accessibility but also fortifies the privacy and security of the voting process, encouraging wider participation during elections among visually impaired voters.

V. Limitation

Our project faces several limitations such as:

a) Time for Deployment: Due to time constraints and a lack of necessary hardware, our project's design, implementation, and deployment phases were significantly compressed. This limited timeline and resource shortage hindered our ability to fully develop and refine the system as initially planned.

b) Price: Our system is expensive due to the high price of hardware such as the braille keyboard and other hardware devices used in system production.

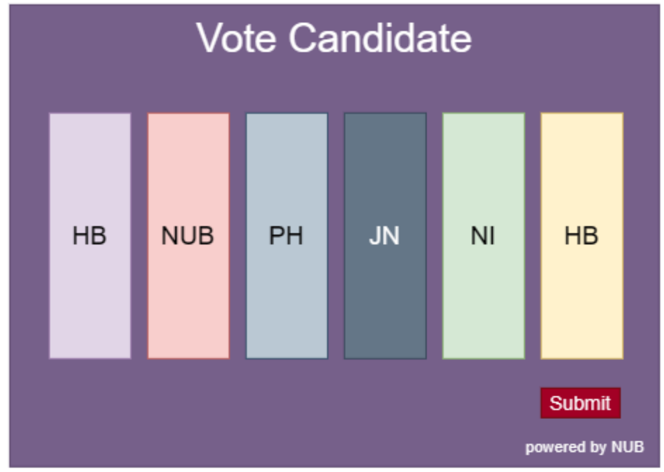


Fig. 11. Candidate Selection Page

Fig. 12. Thank You Page

c) System Complexity: The advanced security features, while beneficial, increase the complexity of the system, potentially impacting user experience and adoption.

VI. Future work

Our primary goal in future is to transition from a theoretical model to a practical, deployable system. Real-World Implementation: We aim to develop a fully operational system to be used in actual electoral processes by visually impaired patients in future.

a) Continued Enhancements: We aim to incorporate user feedback to refine usability and security, possibly integrating newer technologies like blockchain for even better security and transparency in future.

VII. conclusion

Our system supports visually impaired voters' active participation in elections by upholding their rights and enabling them to do so independently and with dignity. By incorporating dual authentication that is a fingerprint scanner for biometric validation and a Braille keyboard for password generation. We reinforce security protocols, such as hashing and salting, to safeguard the confidentiality and integrity of voter data. The foundation of the CIA triad in cybersecurity, confidentiality, integrity, and availability, are upheld while using RSA encryption to secure data storage. Our system's strategy not only protects visually impaired persons' private information but also gives them the confidence to carry out their civic responsibilities.

REFERENCES

[1] "The Americans with Disabilities Act and Other Federal Laws Protecting the Rights of Voters with Disabilities," ADA.gov, Feb. 27, 2024. https://www.ada.gov/resources/protecting-voter-rights (accessed Mar. 02, 2024).

[2] D. Choki, T. Penjor, T. Phuntsho, D. K. Rai, and K. Muramatsu, "Design of Electronic Voting System for Visually Impaired Persons Using Arduino Mega 2560," Bhutan Journal of Research and Development, Apr. 2022, doi: https://doi.org/10.17102/bjrd.rub.10.2.015.

[3] H.N. Odikwa, A.P. Ekong, and O.M. Thom-Manuel, "Design and Implementation of Electronic Voting System for Visually Impaired and Blind Persons in Sub-Saharan Africa," Department of Computer Science, Abia State University, Uturu, Nigeria; Department of Computer Science, Akwa Ibom State University, Ikot Akpaden, Nigeria; Information and Communication Center, Ignatius Ajuri University, Port-Harcourt, Nigeria, 2020, pp. 19-10.

[4] R. G. Alzamel and R. A. Obeidallah, "Accessible Voting Systems for Visually Impairments," International Journal of u- and e- Service, Science and Technology, vol. 9, no. 11, pp. 363–370, Nov. 2016, doi: https://doi.org/10.14257/ijunesst.2016.9.11.32.

[5] Kanchana M, G. P. V, K. Ramar, and S. Hariharan, "Secure E-Voting System using Deep Learning Techniques," Dec. 2022, doi: https://doi.org/10.1109/cisct55310.2022.10046486.

[6] H. H. Ali and S. H. Shaker, "Secured E-voting system based on iris identification," AIP Conference Proceedings, Jan. 2023, doi: https://doi.org/10.1063/5.0119826

[7] O. Okediran, "A Performance Evaluation Of A Multifaceted Electronic Voting Framework," Acta Electrotechnica et Informatica, vol. 19, no. 2, pp. 3–8, Jun. 2019, doi: https://doi.org/10.15546/aeei-2019-0008.