Bachelor of Science Honours in Information Systems

M. T. De Silva

DESIGNING AN INFORMATION TECHNOLOGY BASED VOTING SOLUTION FOR PERSONS WITH VISUAL DISABILITIES

MADHUKA THISURI DE SILVA

14020122

University of Colombo School of Computing

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Declaration

I, M.T. De Silva (2014/IS/012), hereby certify that this dissertation entitled 'Designing an Information Technology Based Voting Solution for Persons with Visual Disabilities' is entirely my own work and it has never been submitted nor is currently been submitted for any other degree.

....

Date Signature

I, Dr. (Mrs.) T.A. Weerasinghe, certify that I supervised this dissertation entitled 'Designing an Information Technology Based Voting Solution for Persons with Visual Disabilities' conducted by M.T. De Silva in partial fulfilment of the requirements for the degree of Bachelor of Science Honours in Information Systems.

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Date Signature

I, Prof. G.K.A. Dias, certify that I supervised this dissertation entitled 'Designing an Information Technology Based Voting Solution for Persons with Visual Disabilities' conducted by M.T. De Silva in partial fulfilment of the requirements for the degree of Bachelor of Science Honours in Information Systems.

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Date Signature

Abstract

Sri Lanka currently uses a paper-based voting system for conducting elections. Voters with visual disabilities using this paper-based voting system have to depend on the assistance of another to vote. This violates the blind voter’s right to privacy. Considering this issue, the present study aimed to design an information technology-based voting solution.

Research was conducted based on use-inspired design science approach along with design science research process. Also, User Centered Design (UCD) methods were used. A study was conducted on identifying the design features of existing voting systems that are accessible for voters with visual disabilities. Interviews were conducted with voting professionals, election authorities, and blind voters whilst making observations to identify their behaviours.

The proposed system consists of two ballot interfaces: Button Tactile (BT) Ballot with button controls and Touch Tactile (TT) Ballot based on a touch interface. The BT Ballot consists of only four buttons whilst a blind voter can vote simply using only one button. TT Ballot consists of transparent tactile sleeve with holes aligned with voting options displayed on the touch screen. The sleeve acts as a guidance for the blind voter. The design features of the interfaces were informed by the concept of multi-modality and universal design guidelines. A prototype of the system was provided to a group of users to obtain feedback before final implementation of the system. Design features were modified after gathering feedback. System was implemented, and evaluation was carried out based on ISO usability metrics and System Usability Scale.

From this study, knowledge was gathered about the requirements of blind voters. Also, a critical evaluation was made on the design features implemented in existing voting systems that are aimed to provide accessibility for voters with visual disabilities. Results could be interpreted that voters with visual disabilities prefer to use this multi-modal voting solution. Users preferred the Button Tactile Ballot more than Touch Tactile Ballot while some had no preference. However, in terms of efficiency, the Touch Tactile Ballot was slightly quicker than the Button Tactile Ballot. Effectiveness wise too, the Touch Tactile Ballot was slightly better as measured by the number of completed ballots without errors.

Research study indicates that Multi-modal voting solutions can address voting needs of voters with visual disabilities ensuring an accessible and usable vote.

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List of Abbreviations

AFB	American Foundation for Blind
ATM	Automatic Teller Machine
AVBAP	Assisted Voting By Another Person
BT	Button Tactile
CMEV	Centre for Monitoring Election Violence
DRE	Direct Recording Electronic
EVM	Electronic Voting Machine
e Ballot	Electronic Ballot
ISO	International Organization for Standardization
IT	Information Technology
IDEA	International Institute for Democracy and Electoral Assistance
NLP	No Light Perception
PO	Polling Officials
SPA	Special Provisions Act
SUS	System Usability Scale
TT	Touch Tactile
UCD	User-Centered Design
UD	Universal Design
UN	United Nations
VVD	Vote with Visual Disability
VVPAT	Voter Verified Paper Audit Trail
WHO	World Health Organization

1 Chapter One: Introduction

This chapter introduces the research problem with the motivation to conduct the research, whilst mentioning goals and objectives that were planned to be achieved.

1.1 Motivation

As a citizen of any country, one would have an interest in engaging with the governance and political decision making in different levels. As once mentioned by Thomas Paine, one of the founding fathers of the United States of America, voting rights to elect representatives, leads to the protection of other rights [1]. While the political rights of the majority of mankind is adequately identified and addressed, individuals with disabilities are facing various challenges in realizing their political and voting rights [2].

Based on the fact sheet provided by the World Health Organization (WHO) in October 2017, it is estimated that 253 million people live with vision impairment [3]. In Sri Lanka, amongst the persons with disabilities, a significant portion of the population is visually impaired whilst having the right to vote, which approximates to be 1 million (5.1% of total population), according to the statistics published by the Department of Census and Statistics in 2012 [4].

Diverse approaches have been taken with this regard in the international context, to find and implement solutions to facilitate the persons with disabilities, including visual impairments or blindness, in their respective territories and jurisdictions. For instance, United States passed the Help America Vote Act 2000 (HAVA Act) [5], while Section 49N in The Conduct of Elections Rules, 1961 of India [6], provides provisions to enable voters with different disabilities to vote.

In Sri Lanka, an awareness campaign under the title “Disability isn’t a reason to keep them away from voting”, was organized by various disability rights advocates and Disabled Person’s organizations (DPOs), and facilitated by CMEV (Centre for Monitoring Election Violence) [7], which eventually lead to the enactment of the Elections (Special Provisions) Act, No. 28 of 2011 [8].

As per provisions of the above-mentioned Elections (Special Provisions) Act, No. 28 of 2011, it is allowed for a proven person with a disability (an eligible individual adhering to the stated requirements by the act) to accompany someone who is capable of viewing a ballot paper, and mark the choice upon the preference of the voter [9].

With the evolution of technology, a number of solutions and prototypes were proposed by various authorities and vendors, around the globe [10]. Everyone deserves to vote privately and independently. However, it is evident that the prevailing polling process in Sri Lanka does not cater into the requirement of visually impaired voters, where in most of the scenarios such voters may have to rely on assistance of another to vote. Therefore, the questions of secrecy and certainty arise, whether the choice was kept to themselves by the assisting personal, and the respective vote was casted on the intended choice, since the space for manipulation is high on such process [11].

1.2 Goal

This research presents an approach to address the difficulties faced by voters with visual disabilities in Sri Lanka, during the act of voting, by designing and proposing an effective solution, using Information Technology.

1.3 Research Problem and Objectives

The research question aimed to solve by this research is, "*How to provide an independent voting experience for Sri Lankans with visual disabilities in the voting process using an IT based solution*?". This should enable an accessible vote, which supports to maintain the secrecy of the vote. In order to answer the above research problem, a set of objectives were prepared.

1.3.1 Objective 1

In the current context of Sri Lanka, an accompanying individual is allowed to cast the vote on behalf of the visually impaired voter. This raises the issue of not being able to have a secret vote by the visually impaired voter. In finding a solution to this problem, an analysis has to be carried out on the existing voting systems . systems. Thus, it is necessary to,

Identify interface design features of existing voting systems that support persons with visual disabilities to vote.

1.3.2 Objective 2

It is vital that voting interfaces of any suggested voting technology should satisfy the main purpose of casting a vote, where it shall ensure or verify that the intended preference of the voter was made. This concerns the effectiveness of the interface. Also, it is necessary to ensure other usability aspects such as, efficiency and satisfaction and learnability. Thus, it is required to understand appropriate design principles and,

Identify interface design features that are required to provide an accessible and usable vote for persons with visual disabilities.

1.4 Scope and Delimitation

Based on Sri Lankan context, a solution will be designed and developed to cater the eligible voters with visual impairment after going through an in-depth study of previous and remaining voting technologies and systems.

1.4.1 Definitions and Classifications of Visual Disabilities

There are more variations pertaining to disabilities that an eligible voter may be experiencing but this research is concentrated around the individuals who are with visual impairment (Low Vision) or blindness. According to the International Classification of Diseases -10 (Update and Revision 2006), vision function is classified in 4 broad categories: Normal vision, Moderate vision impairment, Severe vision impairment, and Blindness.

Moderate vision impairment and severe vision impairment taken together with blindness represent all vision impairments [3]. Blindness or total blindness is the complete lack of light perception and form perception, and is recorded as NLP (Zero Light Perception) and low vision is a condition caused by eye disease, in which visual acuity is 20/70 or poorer in the better-seeing eye and cannot be corrected or improved with regular eyeglasses [12].

There is a lack of proper definitions for visual disabilities in the Sri Lankan context, which leads to the implication of the above-mentioned universally accepted definitions clarified by the World Health Organization. In spite of the above-mentioned focussed disability, individuals with other sight or vision complications shall make use of this solution.

1.4.2 Intellectual Capabilities

Within the local social paradigm, there are individuals proficient in using information and communication technologies or in other words technically competent and as well as individuals who are less biased in favour of using such technologies. Both of these diversifications were needed to be addressed. Since it was reported that adult literacy rate of aged 15 and over was 91.2% in 2012 (latest) in Sri Lanka [13], assumptions were made that eligible voters are up to a comfortable level of understanding the native languages they are accustomed with.

1.4.3 Voting Procedure

The prime purpose of voting is to allow voters to exercise their right in expressing their choices with respect to a country's development particularly focussed on aspects such as "specific issues, pieces of legislation, citizen initiatives, constitutional amendments, recall and/or to choose their government and political representatives" [14]. In order to facilitate this process technology has evolved to assist voting where almost all voting systems considering the international context and local context following steps shall be considered:

1. Voter identification and authentication
2. Voting and recording of votes cast
3. Vote counting
4. Publication of election results

Even before the voter authentication, there are other considerations such as voter registration processes, which are mandatory to be followed in order to be an eligible voter. Here the research conduct is focussed only on addressing the voting stage with marking the preference and submitting the vote.

1.4.4 Administration and Legal Considerations

There is a lack of legal provision related materials concerning electronic voting since currently a non-electronic voting procedure is followed. There by design considerations are freely thought without having any impact of legal aspects.

1.4.5 Context of Applicability

The research conduct is addressing the situation in Sri Lankan context; however, the outcomes can be applicable to similar context where it may have a voting procedure that does not cater the accessibility of voters with visual disabilities and also other factors such as intellectual capabilities.

1.5 Research Approach

Use-inspired design science approach by Reeves, Herrington and Oliver [15] was followed with a methodology based on design science research process by Offermann and Platz [16]. User Centered Design (UCD) methods were used along the research methodology because the designing a voting solution aimed at voters with visual disabilities has a significant impact from user input and evaluation.

1.6 Significance of the Study

According to studies conducted in Sri Lanka it was understood that there are gaps in research focussed on addressing to provide equal opportunities for people with disabilities. Majority of the disabilities encountered were due to visual impairments [17].

The Convention on the Rights of Persons with Disabilities (CRPD) by United Nations (UN), “first human rights instrument that provides for reasonable accommodation to be accorded to persons with disabilities in the realization of their rights” [18], states about the political facilitation for persons with disabilities under the Article 29, “Participation in political and public life” [19] which describes that it is required to ensure that persons with disabilities are able to freely vote and be elected, with respect to:

- Voting procedures being appropriate, accessible and easy to understand
- Protecting the right of persons with disabilities to vote by secret ballot in elections and public referendums without intimidation

Lack of accessibility in the environment we live contribute to act as barriers for improving the quality of life for the people with disabilities. It is a moral obligation of the society to drive towards creating an environment that caters of all including persons with disabilities. Thus, this research conduct contributes to be a part of that journey.

The ultimate goal of this study is to design a functioning prototype which addresses the research problems identified earlier, for the eligible voters with visual disabilities which is empathy driven and human computer interactions disciplines are taken into consideration where a prototype is designed and developed.

1.7 Chapter Summary

Voting is basic human right and when considering Sri Lankan context, there is a clear evident shortcoming of the existing voting mechanism where it does not address the voting accessibility for the persons with visual disabilities in terms of the vote being an independent and a secret one. Persons with visual Disabilities deserve the rights and privileges as same as others. Thus, the objectives of the research revolve around enhancing the voting accessibility for the person with visual impairments and blindness such that it preserves their basic human rights and ensure that their voting journey is congruent with others. A solution is designed by the research conducted aiming to deliver a functioning prototype which caters the above-mentioned objectives and goals taking an Information Systems Development Approach.

1.8 Outline of the thesis

Second chapter explains the background with the related work which also explains how it differs from our research methodology. In the third chapter, we have explained the research methodology with the relevant design methods that we are planning to perform to accomplish our objectives whilst also providing justifications to our methodology selections. Fourth chapter explains how the research problem is analysed using interviews, user studies and literature review. The solution design with the concept and design features are stated in fifth chapter. Chapter six and seven explains how the prototype was built and implemented. Evaluation of the study is explained in chapter eight. The thesis is concluded with the Discussion and Conclusion chapters.

2 Chapter Two: Background

Different voting systems are being utilized in the international context. Selection or the development of these systems depends on the perspective with respect to the confidence on the system. Study of voting systems also shows that it is an area that lack knowledge and requires more research and development [20].

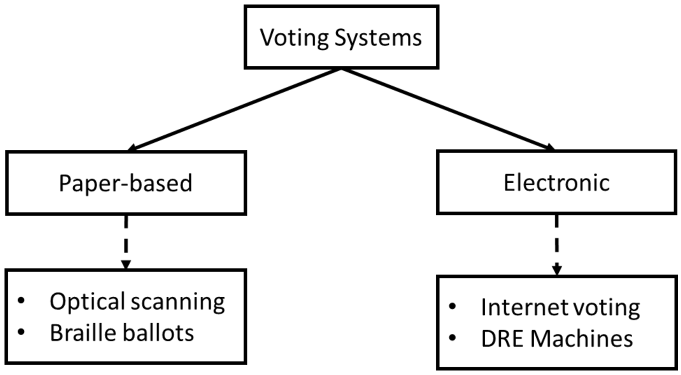


Figure 2.1 : Types of Voting Systems Supporting Blind Voters

Types of voting systems that support voters with visual disabilities can be identified as in Figure 2.1.

2.1 Paper Based Voting Systems

Paper-based voting systems provide advantages such as paper ballots being easily understood by voters and such ballots are inherently voter verified because they are marked directly by the voter. These systems are still being used by different countries but it does not support individuals with visual impairments from voting independently [21] unless optical scanning or tactile methods are incorporated.

2.1.1 Optical Scanning Systems

AutoMARK VAT is an example for optical scanning system (Figure 2.2) [22]. To use this type of optical scanning systems blind voter needs assistance in scanning and retrieving the ballot. And also, it reads from a ballot that was initially designed to be read and marked using a pen.

Figure 2.2 : AutoMARK VAT Optical Scanner

However, in the case of paper-based voting system if optical scanning is supported, it can be accommodated for the visually impaired voters for a certain extent [23]. Even if that is the case, optical scanning systems essentially require voters to reach and hold a device, stylus or a pencil to mark the choice which is ultimately difficult for both, persons with visual impairments or any mobility impairments. It has a braille labelled keyboard, a touch screen, multiple language translations, and an audio facility. Interface provides zooming features and contrast changing options. Text-to-speech is used to read out the ballot but this ballot is scanned into the system which leads to multiple problems [11] as follows.

- Blind voter needs assistance in scanning and retrieving the ballot
- This system reads from a ballot that was initially designed to be read and marked using a pen.
- Braille keypad is located on the right-hand side which can be an issue for voters who left handed. Additionally, the Braille keypad is placed in an angled position, which is ergonomically cannot be considered to be natural.

2.1.2 Braille ballots

Further to support paper-based voting, Braille ballots can be considered as an option but the braille literacy is questionable in different contexts. For an instance in Sri Lankan context, according to the Ministry of Social Welfare (2003), 71% of vision impaired persons have had some sort of schooling [24] and even if that is the case, most are unable to use the braille knowledge later, only 41% of individuals who know Braille are able to use it [25]. With such being noted it is quite infeasible to make them use Braille ballots.

Figure 2.3 : Vote-Pad Tactile Sleeve

Paper based voting systems are also being facilitated with tactile ballots where a cardboard (or any other material) sleeve is provided that allows for tactile location of marking fields [26], with or without braille supported by embossment. One such tactile based example can be given as the Vote-Pad, a non-electronic system equipment approved [27] and used in situations where paper ballots are used for voting (Figure 2.3) [11]. In United Kingdom, all polling stations are legally required to provide a tactile voting device to any visually impaired voter [28]. And also, in other countries such as Ghana [26], Ireland [29], Canada, Yemen, Myanmar, Sierra Leone, Guatemala, Tanzania, Costa Rica and many African countries [30] are facilitating voting with tactile ballots. The process is simple and it does not need advanced technical equipment but it has some issues as follows [11].

- Ensuring ballot is slipped right
- Verifying whether pre-punched holes are correctly lined up with the targets on the ballot
- Privacy is questionable since stray marks on the plastic sleeve can indicate how ballots have been marked
- How can an error be corrected?

Another may suggest why not make use of vote-by-mail systems for the visually impaired but there are serious security, privacy and voter-coercion concerns associated with these systems [10].

2.2 Electronic Voting Systems

As per the explanations provided by the International Institute for Democracy and Electoral Assistance (IDEA) Policy Paper, Electronic Voting (e-Voting) is a broad range of voting systems that apply electronic elements in one or more steps of the electoral cycle: the recording, the casting and/or the counting of votes [31], [32].

In identifying types of Electronic Voting (e-Voting), mainly two classifications can be described based on the environmental controls applied where e-Voting is allowed in a controlled/supervised environment or e-Voting implemented in uncontrolled environments such as outside a polling station [31], for an example, Internet Voting (i-Voting).

2.2.1 Internet voting

In the Internet voting typology, the voters cast their choice from any computer connected to the Internet—including from their home [33]. With respect to national level elections, only few nations have occupied or implemented such technology for voting based on various reasons, such as a mean to allow access to the election process for voters who may otherwise find it difficult to go to their polling location on Election Day [34]. However, it has its own risks and challenges focused on security, privacy and secrecy issues with respect to technological aspect and then also on other aspects such as observation of the process [34].

If further analysed on i-Voting case studies, out of the very few nations who have applied it, Estonia, Canada and France can be studied in depth for better understanding of the benefits and the risks associated in i-Voting [34].

In the case of Estonia, in 2005 they became the first nation to hold a legally binding general election over the internet, where voting was conducted via the Estonian ID cards or Mobile-ID that enable secure remote authentication and legally binding digital signatures [35]. For the visually impaired, Estonian Nation’s i-Voting provide unassisted private voting by means of a client application where even multi-language setups are also possible [36].

Estonia did not give up the challenge but it was reported that their voting mechanism had to face several denial-of-service attacks although the country’s infrastructure for digital democracy is highly developed where they were forced to maintain its traditional voting infrastructure alongside the i-voting option [34]. Based on a research conducted it was concluded with the recommendation to discontinue use of the i-voting system due to the massive risks incorporated and tracked out of it while also noting the fact that certainly, additional protections could be added in order to mitigate specific attacks but attempting to stop every credible mode of attack would add an unmanageable degree of complexity [37].

With respect to Canadian i-Voting system, they have given attention for visually impaired voters by improving web accessibility via several techniques such as screen reading or magnification software programs, or electronic Braille keyboards. Special hidden links have also been added to almost every page to allow for easy navigation with a screen reading program (reading what is being typed or what appears). Similar suggestions (as for the Estonian voting system) were made after research [38], for Canadian voting system with respect to security, where it explains that Internet voting only be adopted after the numerous technical threats outlined above can be suitably mitigated, and strong mechanisms put in place to prevent undetected changes, thus making the system more reliable, verifiable and convincing for voting by the public.

In the case of France, in 2014 Journalists from a news site was able to prove that it was easy to breach the allegedly strict security of the election and vote several times using different names when they utilized i-Voting [39]. With above mentioned security threats, additionally and more importantly a secrecy violation of votes has been observed during a study conducted by the U.S. Vote Foundation in July 2015 [40], where none of the existing Internet voting systems provides adequate security for public elections or guarantees voter privacy [41]. In e-Voting category where it is allowed in a controlled or a supervised environment such as a polling station, the generally known voting technologies are Optical scan based voting and Direct Recording Electronic (DRE) machines [31].

2.2.2 Direct Recording Electronic Machines

The other type of electronic voting system or the newest is the Direct Record Electronic (DRE) machine which is sometimes referred as "e-voting" generally should not be confused with other e-voting such internet voting because DREs are stand-alone machines that record votes in their internal memory [21]. Once the voter inserts plastic card (smart card), system gets ballot interface activated where the voter can choose either by touch, dial or buttons and include an audio component for visually impaired voters. Some DREs print the ballot and some might not. There are much more varieties observed in DREs produced day by day.

For an instance now, there are DREs focussed on multimodality enhancing accessibility for people with disabilities further such as providing voice input for selecting [42].

Some of the common issues identified in DREs can be listed as inadequacy of most of the systems' audio access features and long-time taken of using this feature, lack of simultaneous and synchronized audio and visual outputs, Confusing menu-selection systems, lack of adjustable settings (audio, magnification, contrast and display colour settings), lack of independent capability to switch between different access modes without the help of poll worker, the requirement of entering identity card or ballot paper where it again needs support from another and the lack of a verification method to ensure the vote is made as intended [10][43], etc.

But it should be noted that the mentioned issues are being addressed by newer versions of DREs researched [43], [44].

Not just equality but security and transparency are also considerable factors that should be considered in a voting system [21]. Those factors cannot be made perfect or make the pertaining issues to be null but the attempt should be to mitigate vulnerabilities and risks as much as possible.

As a summary on potential of electronic voting in general can be explained as the abilities such as tabulation of more accurate results than in paper-based voting where it is prone to human error, never running out of paper ballots at a polling centre, provide multiple languages to users who may not have English as a first language and more importantly being able to address people with disabilities, such as blindness [45].

Following matrix, Table 2.1 is derived from the Policy Paper published by International Institute for Democracy and Electoral Assistance (IDEA) where it shows typical strengths and weaknesses that different e-voting solutions tend to have compared to paper-based equivalents. Cases where these details are very important are classified as ‘mixed’ [32].

Table 1 : Comparison of e-voting solutions with paper-based voting by IDEA

Electoral issues compared to paper voting	**Internet voting**	**DRE**	**Optical Scan**
Presentation of ballot papers	Mixed	Mixed	Weakness
Greater accessibility	Mixed	Mixed	Weakness
Secrecy of the vote	Weakness	Mixed	Mixed
Risk of manipulation by outsiders	Weakness	Mixed	Mixed

2.3 Sri Lankan context

The prevalent voting facility provided for the people with disabilities by the Sri Lankan Jurisdiction based on the Elections (Special Provisions) Act, No. 28 of 2011 [8], explains that it is allowed for a person with proven disability (an eligible individual adhering to the stated requirements by the act) to accompany someone who is capable of viewing a ballot paper and mark the choice upon the preference of the voter [9].

As per the policy brief on political rights and representation of persons with disabilities which was conducted by Centre for Monitoring Election Violence (CMEV) of Sri Lanka (2017), it is explained that while several other countries have introduced facilities like e-voting, Braille voting and even postal voting for the persons with disabilities, the Sri Lankans who can be benefitted by such arrangements, still remain to be addressed [2].With the above mentioned and explained difficulties faced by visually impaired voters, it is quite clear that there is a pressing need for further research into the ability of technology to facilitate independent voting by people with certain types of disabilities [21].

In addressing those mentioned difficulties and with the advancement of technology, one can see that the technology based innovative voting systems can be developed and are being already witnessed by several nations. It is apparent of an evolvement of an era of building electronic based voting systems where it gives more attention to the inclusiveness with usability implications [46].

It is true that technology is certainly cannot or is not the answer to every access problem and also for an instance it cannot avoid the need to visit the polling station (where internet voting is not allowed by law and jurisdictions) but the technology can be essential to independent voting at the moment of casting the vote. And also, another benefit that should be appreciated is that implementation of present-generation electronic voting equipment tends to considerably reduce the number of uncounted votes [21].

From a disability access perspective, electronic based voting systems accommodate one of their critical needs in voting, allowing a secret and independent ballot for people with disabilities rather than relying on their closed ones or on assistance from a poll worker to vote behalf of them.

2.4 Chapter Summary

In many contexts it is observed that voting by the visually impaired using a paper-based system, situation is complicated where even if tactile or braille options are considered it leads to need of assistance and literacy issues. In the Sri Lankan context, it is further cumbersome due to lack of confidentiality or secrecy of the vote being made as another individual is voting behalf of the visually impaired person. In some contexts where paper-based ballots are used, they provide or ensure that each polling station has at least one EVM (Electronic Voting Machine) to enable the persons with disabilities to vote.

Electronic voting can be used to design a solution but consideration should be given on choosing the appropriate electronic voting method. In the case of internet voting, again the confidentiality or secrecy of the vote is questionable since manipulation can exist which is applicable for anyone, irrespective of being visually impaired or not. Also, vulnerability is high with respect to serious security concerns which demotivates to implement internet-based voting method.

Optical scan-based voting may show some appropriateness with benefits mentioned earlier such as secrecy can be preserved unto some extent, but the assistance required to handle the equipment (inserting ballot paper and using optical scan device to vote) can lead to doubt on secrecy.

Finally using DRE machines can be seen as a viable option or a voting system that seems to have more potential when the risks and benefits are compared among other electronic voting systems and with the primary concern given with respect to ensuring secrecy of the vote.

3 Chapter Three: Methodology

After conducting background study that related to similar research, design gaps were identified in different voting systems. To design the voting solution catering the research problem and bridging the gaps, Design Science approach was followed. This chapter focusses on explaining the research methodology with the relevant stages in detail.

3.1 Overview

Design science paradigm is fundamentally a problem-solving paradigm [47] which has its roots in engineering and sciences of the artificial. “It seeks to create innovations that define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, and use of information systems can be effectively and efficiently accomplished [47]”. Thus, a methodology based on design science was considered as the research approach (Figure 3.1) [15] [16].

Figure 3.1 : Design Science Methodology P. Offerman et al.

Along using this approach, UCD methods (drawing personas, storyboarding and writing user flows) were used because they are vital to focus on the end users and to create empathy towards the users as shown in Figure 3.2.

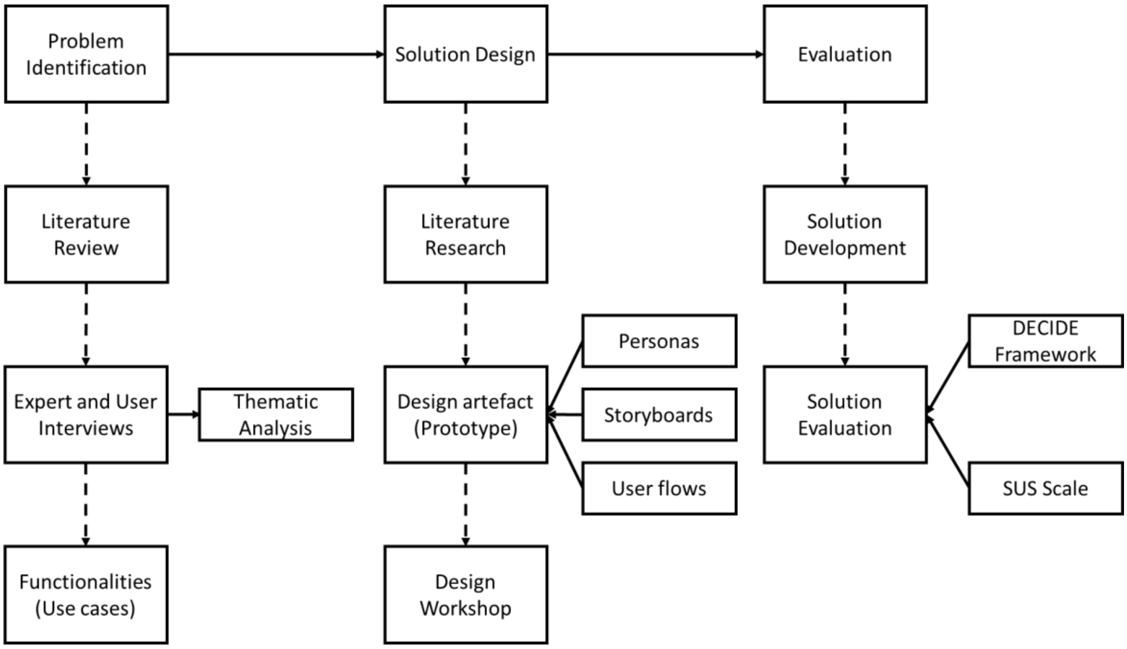


Figure 3.2 : Research Methodology

The steps and the methods followed in the research methodology are illustrated in the Figure 3.2. The subsequent sections explain the methods shown here.

3.2 Sample

Samples of participants with visual disabilities were required for conducting interviews and prototype testing as shown in Figure 3.2. The total population consisted of students of University of Colombo and students of Sri Lanka Council for the Blind. These participants showed demographic variations. Age range of the total population was between 20 years and 74 years. All participants were fluent and capable of understanding Sinhala language. Some participants had the ability to understand Tamil and English slightly but were not fluent. The electoral districts of the participants were Colombo, Kalutara, Puttalam, Chilaw, Moneragala, Ampara, Kurunegala, Gampaha, Galle and Kandy. Participants had total blindness and partial blindness. The samples were drawn randomly from the total population.

3.3 Problem Identification

In this stage, it is expected initially to justify the significance of the research questions pursued. Since the research is not involved in proving a theory with empirical data, it was advised to develop a system to demonstrate the validity of the solution, based on the suggested new methods, techniques, or design. This approach is equivalent to a proof-by-demonstration [48].

This initial phase of the methodology can be summarized as an in-depth study of the background of the research problem in various perspectives. Here main research question was divided into further answering 3 questions (Figure 3.3).

1. What are the design features of existing voting systems?
2. What are the procedures followed in the electoral voting process?
3. What are the design considerations informed by the behaviours and experience of blind voters?

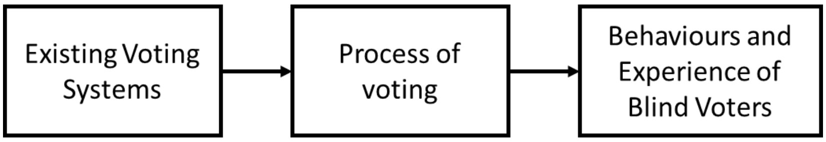


Figure 3.3 : Questions for Problem Identification Phase

In order to answer above questions, three steps were carried out (Figure 3.4); conducting literature review and conducting interviews. In understanding the behaviours and experience of the blind voters, studies were performed by conducting interviews andobservations.

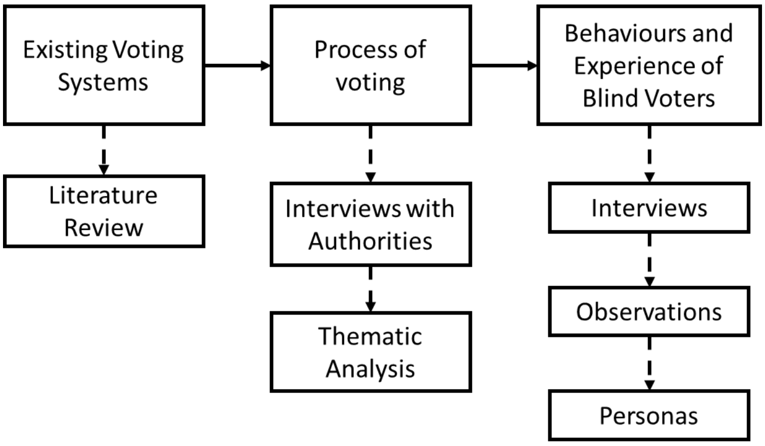


Figure 3.4 : Methods for Problem Identification Phase

3.3.1 Study on Existing Voting Systems

A systematic literature review was conducted based on the guidelines for performing systematic literature reviews in software engineering [49], with the intention of understanding what paths have previous similar research has followed and what are their findings. The purpose of this activity was to find facts already being discovered or designs developed earlier. Thus, repetition of concepts or ideas is minimal whilst it was a guidance to whether any modifications bring in improvement to existing voting designs or create new voting designs. This stage also helped to find differences among existing voting designs which leads to critical analysis via comparisons. Thus, supporting to understand the different aspects of the research problem.

The goal of this review was to understand how privacy and usability are defined in the ‘Voting Technologies’ context, and what frameworks and guidelines are being recognized. There were more than 100 papers in our sample. The papers were collected using text and phrases such as “voting”, “electronic voting”, “privacy”, “usability”, “blindness”, “voter”, “voting interface”, “voting theoretical framework”, “e-voting”, “secrecy”, “secret ballot”, “confidentiality”, “visually impaired”, “accessibility”, “Universal Design”, “User Centred Design”, “voting tools”, “voting system”, and “assistive voting technologies”. The two research questions we attempted to answer are described below:

Q1: What are the definitions, frameworks and key aspects of privacy in voting systems?

Q2: What are the design guidelines and key design considerations of improving usability in voting interfaces focussed for voters with visual disabilities?

3.3.2 Conducting Interviews with Stakeholders and Experts

This focus group consists of stakeholders such as who contribute to the decision making of whether to accept such voting system, individuals who are working in close connection with voting related, individuals who are knowledgeable about persons with vision disabilities.

The information from the interview transcripts were analysed by the research method, Thematic Analysis that helped to identify different patterns in gathered data. These understandings were proceeded to the following steps of the research methodology when designing the actual solution. Main goal of the interviews was to understand functionalities or factors that contribute to the designing of a proper voting solution.

Individuals that has an influence on the research context were identified of two categories: experts in the elections and persons belonging to authorities that manage blind communities. Then a set of semi structured questions were created with the intention of having the interviews similar to a discussion rather than answering strictly structured questions. The interviews were scheduled and conducted by taking their consent. Notes were taken down and an in-depth analysis was carried out using Thematic Analysis.

3.3.3 Conducting Interviews with Persons with Visual Disabilities

A focus group of blind voters were interviewed with the intention of identifying different types of personas that the development of the voting solution should focus upon. Drawing personas is a User Centered-Design method and a research method [50]. According to Interaction Design Foundation [51], an easy template is provided for creating personas, which is being referred here in order to form the objectives and thus then write the questions based on those objectives. Following objectives are set by modifying the objectives of the above-mentioned persona according to the research context,

1. Including some context in the background
2. A tag line, indicating what the persona does or considers relevant in his or her life
3. Relevant skills the persona has in the area (IT and Voting) of the solution that is developed. Thus, identifying the minimum requirements for voting. (Ability to read numbers and images by non-blind and language skills of the visually impaired)
4. Some context to indicate how they would interact with the solution (in terms of different technologies)
5. Any goals, attitudes, and concerns they would have when using the voting solution
6. Quotes or a brief scenario, which indicate the persona's attitude toward the voting system.

Since answering questionnaires by blind persons can be causing difficulties to them, the interviewing approach was decided to be the more convenient. The interviews were used to gather information related to level of blindness, usage of technology-based tools, literacy levels and opinions on electronic voting.

A questionnaire was designed in order to identify personas. The questionnaire was constructed in a structured format to ensure that all blind users are presented with exactly the same questions. Expert evaluation was obtained for the questionnaire. Modifications were done from feedback from supervisors and advisors. Questionnaire is in Appendix B.

Sample population of the research was consisted of 10 persons with visual disabilities (Total blind and low vision) who are eligible to vote. The sample was selected using convenience sampling since reaching blind persons from all locations was not feasible. Also, it was convenient for the person who faced the interviews to reach a place of closer proximity.

Sample consisted of participants from four districts of Sri Lanka: Colombo, Gampaha, Kalutara, and Puttalam. Also, they belonged on the age range of 18 years to 67 years.

A team of four was prepared by giving a training on how to conduct the interviews. Before conducting actual interviews, all the interviewers tried asking questions with each other to gain an understanding and as a practice. The team was given printed questionnaire forms to note down answers and other important points. Before conducting the interviews, a consent was obtained from the participants ensuring the confidentiality of the information provided.

Then the information noted on the papers were taken into MS Excel sheets for further analysis. Information related to different questions were then illustrated using appropriate charts, explained in detail on certain important facts and transformed to personas. Also, observations made during interviews on activities like how they engage in using their mobile phones contributed to the formation of personas.

3.3.4 Define Functionalities Using Use Cases

This stage involves defining the functionalities of the resulting system to achieve the stated objectives. Thus, drawing and writing use case was followed. This will also act as guide to design the flow of the voting process in the next stage of the methodology.

Generally, a use case captures a contract between the stakeholders of a system about its behaviour [65]. It shows how an actor interacts with the system. Use cases helps to illustrate different sequences of behaviour, or scenarios, that are dependent on requests made and conditions surrounding the requests. Initially use case diagram was constructed based UML standards using Creately, an online diagramming tool.

In the UML (Unified Modelling Language) standard, it does not discuss about writing of a use case but rather it explains a graphical representation of the functionalities expected from a system. Use cases are fundamentally a text form, but can be explained otherwise in different forms such as flow charts, sequence charts, or programming languages [52].

Till recent times, a comprehensive detailed use case template introduced by Cockburn in 1998 and later modified in 2002 were adapted as a practice for software development. However latest trends and new practices showed how lengthy use cases have led to mindlessly filling out without focusing on the important parts of the use case, and nobody will know the difference [53]. Based on explanations provided by Rosenberg and Stephens (2007) [53], a simple use case template was used (Table 3.1) to describe the use cases drawn based on UML concepts.

Table 2 : Use Case Template by Rosenberg and Stephens

Use case name	
Actors	
Preconditions	
Basic course	
Outcome	
Alternate course	

3.4 Solution Design

This phase involves the understanding of the studied domains of voting and accessibility for blind persons, the application of relevant scientific and technical knowledge, the creation of various alternatives, and the synthesis and evaluation of proposed alternative solutions [48].

3.4.1 Storyboarding

After defining the functionalities, the system was designed with a flow catering the functionalities. Identifying the flow of steps and different scenarios required a repeated process of thinking, noting down and modifying. This was achieved with a tool used in IS development and UCD, called *Storyboarding*. Storyboarding was used to show how a person with visual disability might progress through voting task using the system being developed by drawing a series of sketches.

Storyboarding is a concept that was initially used by animators and filmmakers which enabled them to pre-visualize a motion picture or interactive media sequence [54].In the same manner storyboard concept has been utilized frequently to predict and develop a visual story relating to the problem, design, or solution [55]. In other words, it helps to imagine or visualize how users would be interacting with the design during various situations and emotions.

Storyboarding made sense because initially user research was conducted by identifying different users or personas.

Literature also mentions storyboarding as an example of low-fidelity prototyping that is often used in conjunction with scenarios [56]. Storyboards were sketched using a tool, Articulate Storyline software. Storyboarding process was inspired by the method called "Aristotle's seven elements of good storytelling" as shown in Figure 3.5, which is also a template provided by Interaction Design Foundation [55].

Figure 3.5 : Aristotle's seven elements of good storytelling

1. Plot: struggles people are facing and how are they trying to improve
2. Character: users involved in the story
3. Theme: obstacle that needs to be crossed, or the end goal of the project
4. Dialogue: statements made by users and their expressions with emotions
5. Melody: providing a good description or a narrative of what is happening in the story
6. Décor: surrounding situation or any external factors that has an impact on the story
7. Spectacle: Plot twists or alternative directions that could happen

3.4.2 Design Concept and Features

A solution was designed explaining and illustrating the concept and features. The features were aligned with design guidelines and were justified with proper reasoning. The features were modified after prototyping based on the end user feedback received.

3.4.3 Drawing User Flows

After drawing storyboards and the design, user flows were drawn based on the storyboards reflecting alternative and sub scenarios which needs more detail to describe the design flow. According to Interaction Design Foundation [57], "a user flow diagram is a simple chart outlining the steps that a user has to take with the product designed in order to meet a goal". User flows are focussed only on what happens between the user and the system. Thus, it shows the action taken by a user and the response by the system to that action. It is said that user flows are showing the "how" or the execution of ideas.

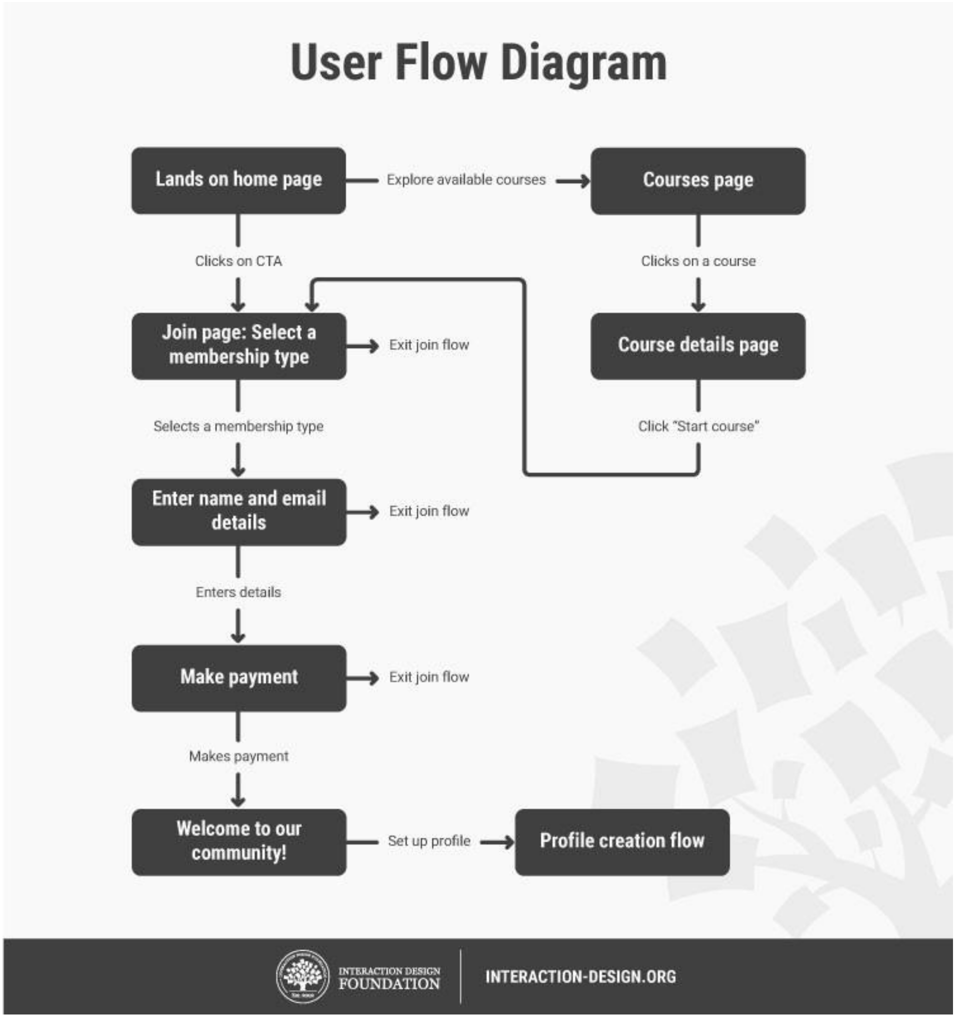


Figure 3.6 : User flow template with an example

User flows were drawn based on the template (Figure 3.6) by Interaction Design Foundation [57]. Initially user flows were then subjected to many modifications after feedback from prototyping.

3.4.4 Design Workshop

Design workshop is identified in further sub-divided sections: prototyping the design, pre-survey with participants of the workshop and results of the workshop. Results explain the performance of the participants with the voting interfaces from the observations and feedback gained from post survey.

Prior to system implementation it was necessary to validate the design features. A simple prototype was presented to the blind users, which was capable of providing an experience similar to the design features identified. Initially, following objectives were listed in order to evaluate the design features.

Objectives for creating a prototype and obtaining feedback were identified in three categories: Tactile buttons, touch screen with tactile sleeve and audio instructions as follows.

1. Tactile buttons
    a. Identifying their capability to locate the buttons based on the shape and described location
2. Touch interface with tactile sleeve
    a. Identifying their capability to locate the holes
    b. Identifying their capability to use single tap for selections
    c. Identifying their capability to use double tap for confirmations
3. Audio instructions
    a. Identifying the sufficient time interval required to select an option
    b. Identifying their capability to understand audio instructions

These objectives are stated with the intention of analysing the modifications required before implementing the final solution. In order to satisfy the objectives, a set of activities were planned and conducted (Table 3.2).

Table 3 : Activities aligning the objectives

Objective	**Activity**
1 a	Audio Instructions: "A round button exists in the middle of the bottom section of the device. Press it now." Participant: Locates the particular button and press it. Feedback prompt: "Your attempt is successful. This button is used to vote." Alternatives: If the participant does not press the correct button, a prompt states them to retry.

	Measure: Number of attempts *Note: This activity was repeated for all tactile buttons.*
2 a	Audio Instructions: "Five holes are there in this device. Touch the first hole now." Participant: Locates the particular hole and touch. Feedback prompt: "First hole. Your attempt is successful." Alternatives: If the participant does not touch the correct hole, a prompt states them to retry. Measure: Number of attempts *Note: This activity was repeated for all holes in the tactile sleeve.*
2 b	Audio Instructions: "To know what an option is for, use single tap to listen it. To select an option, use double tap. Now tell me the political party represented by the first tactile hole." Participant: Locates the particular hole and use single tap. Then he/she tells the examiner what they heard. Feedback prompt: "First hole United Kingdom Symbol Lion Symbol." Alternatives: If the participant does not tap the correct hole or uses double tap, a prompt states them to retry. Measure: Number of attempts
2 c	Audio Instructions: "Now vote for political party A." Participant: Locates the particular hole and use double tap. Feedback prompt: "You voted for Political Party X successfully." Alternatives: If the participant does not tap the correct hole or uses single tap, a prompt states them to retry. Measure: Number of attempts
3 a	Instructions by examiner: "Press the vote button when you hear United

	Kingdom." Audio Instructions: "First hole United States of America Symbol Eagle. Beep Beep Beep (3 seconds) Second hole United Arab Emirates Symbol Falcon …" Participant: Locates the particular hole and touch. Feedback prompt: "Your attempt is successful." Alternatives: If the participant does not touch the correct hole, a prompt states them to retry. Measure: Number of attempts Note: This activity was repeated for 4 second time interval and feedback was obtained.
3 b	Participants are requested to provide feedback about the different voices after each set of activities.

Based on the design concept and the objectives of the prototyping activity, a prototype was built (See section 6 Prototyping) using:

- MS PowerPoint slides to show the necessary content and interact with
- DELL laptop with a touch interface
- Tactile sleeve made out of rigifoam. Holes were cut and rubber buttons were placed.
- Wireless headphone to play audio instructions

The voting list was constructed using country names. The symbols were adapted based on the real animal-based symbols that are used to represent the relevant country. A sample set of audio instructions were recorded by three voices and was subjected to expert evaluation. Then the necessary modifications were made in the instructions and how the speakers convey the instructions.

Table 4 : Demographic Information Gathering

Age	… Years
Gender	Male/Female
District	
Blindness category	Total blind/ Partial blind
Blind from which age	
Smart Phone Experience	

Demographic information was gathered as in Table 3.3. Then the activities were conducted by allowing the participants to attempt an activity maximum of 3 times due to time constraints. After 3 attempts the participant was given instructions to carry out the next activity. Feedback was obtained after some activities and after all the activities were completed. The feedback was noted and observations were also made at the same time. However, after obtaining consensus of the participants, video recording was carried out for further study of observations. Screen recording was also carried out that supported in tracking touch or taps performed by participants to interact with the device.

3.5 Evaluation

3.5.1 DECIDE Framework

Here DECIDE [58] framework was used as a guidance to conduct the evaluation. It is a well explained and a comprehensive framework which lists six important aspects to consider when evaluating designs.

1) Determine goals of evaluation

Main goal of the research and the goal for the evaluation is to design an accessible and usable IT based voting solution for persons with visual disabilities. Evaluation tests will capture voting experiences by blind persons. The results will be in the forms of quantitative and qualitative.

2) Explore specific questions to be answered

In order to achieve the goal of this evaluation, a set of question will have to be answered as follows. These questions were adapted from previous research conducted on Universal Design Ballot [44]. Evaluation of the design will be based on ISO 9241-11 Usability measures [59] which considers following as underlying factors to consider.

- Effectiveness (ability of users to complete tasks using the system, and the quality of the output of those tasks)
- Efficiency (level of resource consumed in performing tasks)
- Satisfaction (users' subjective reactions to using the system)

3) Choose the evaluation paradigm and techniques

There are 4 evaluation paradigms explained in this framework and how to choose a suitable one. An evaluation paradigm determines the kinds of techniques that are used [56]. Among the paradigms "Usability Testing" paradigm was chosen because this paradigm requires a prototype to be tested with users and evaluators has a strong control over the evaluation. Quantitative methods are used to measure performance but interviews and questionnaires are used to get users' opinions. Findings provide a benchmark for future versions [56], which is easier when the prototype has to be modified and get subjected to testing again.

Therefore, based on the above justifications, we have to accommodate for Usability testing paradigm. According to the paradigm chosen, following evaluation techniques have to be carried out [56].

- Observing users: Video and Interaction logging, which can be analysed to identify errors, investigate routes through software, calculate performance time.
- Asking users: Conducting user satisfaction questionnaires and interviews.

4) Identify the practical issues

- Users: Voting solution is ultimately used by eligible voters, thus certain demographic conditions have to be satisfied, being above eighteen years of age. Users should be having a vision loss to some extent as defined (blind variations).
- Facilities and equipment: This will be a major concern since an election environment have to be created to provide a similar experience. Screen recording and video recording of user actions have to be planned. For an instance, how many cameras and where do you put them [56].

- Schedule and budget constraints: Time should be planned ahead for each user for using the system.
- Expertise: Evaluators should be trained to conduct the interviews, that are conducted afterwards using the system. Evaluators should be ready to support the users and have the ability to note down special observations made.

5) Decide how to deal with the ethical issues

Since users are being observed and their feedback will be taken, it is a must to ensure that confidentiality is maintained in the information they provide. Their consent was obtained in a form of a voice recording since the participants are blind.

6) Evaluate, interpret, and present the data

- Validity and Reliability of the evaluation technique measures have to be considered.
- Validity is maintained by applying the same evaluation metrics of a previous research and used by many other usability focussed software development scenarios.
- Reliability is not highly guaranteed because convenience sampling was used in all interviews, prototyping and evaluation sessions. Validity was aimed to be maximised by reducing biases by having a well dispersed sample and evaluations being based on a quantitative scale.

3.5.2 Measuring Usability

"Usability is not a quality that exists in any real or absolute sense, it can only be defined with reference to particular contexts". It can be explained rather being a general quality of the appropriateness to a purpose of any particular artefact [56].

Metrics (Table 3.4) was used for data collection and analysis (based on ISO standard for Usability and previous research work) for the evaluation of the system.

Table 5 : Usability Measures

ISO 9241-11 Usability measure	**Questions**	**Measures**
Effectiveness	Does the voting solution enable the main task of voting as intended?	Voting errors
Efficiency	How quickly can they vote using the proposed voting solution?	Time taken to perform tasks. (Time spent on system before marking choice, voting time, Total time taken)
Satisfaction	To what extent voters are satisfied with the design?	System Usability Scale (SUS) [60]

System Usability Scale (SUS)

This was introduced in 1996 by John Brooke [60] and also published in Journal of Usability Studies [61]. The System Usability Scale (SUS) is a simple, freely available, ten-item Likert scale giving a global view of subjective assessments of usability [60]. The SUS scale is being advised to be answered right after the system is used by the participants. If respondents feels that they cannot respond to a particular item, they should mark the centre point of the scale [60].

Questions taken separately makes no sense and true essence is captured when the composite measure is considered, which is generated by the simple SUS calculation. Each item's score contribution will range from 0 to 4. For items 1,3,5,7, and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU. SUS scores have a range of 0 to 100 [60]. Score gained based on SUS question can be interpreted according to research by Aaron Bangor, Philip Kortum and James Miller (Figure 3.7) [62].

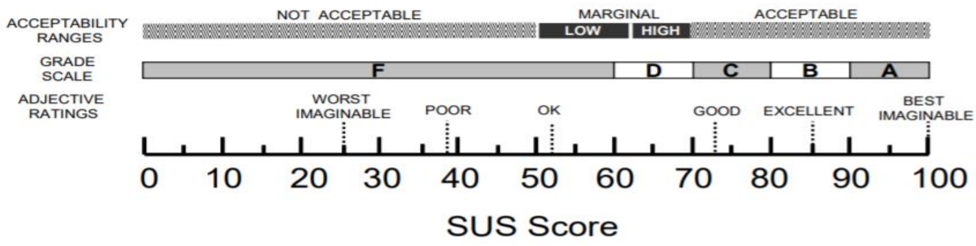


Figure 4. A comparison of the adjective ratings, acceptability scores, and school grading scales, in relation to the average SUS score

Figure 3.7 : Comparison of SUS with other Ratings

As noted above, using a scoring system ranging from 0 to 100 often leads to researchers interpreting SUS scores as percentages, which they are not. The normative data collected [61] provided the basis for positioning SUS scores as percentiles, providing a more meaningful basis for interpreting SUS scores [60]. An added advantage of SUS is that, at no extra cost, we can extract additional information on learnability of the system from the SUS analysis [63].

3.5.3 Evaluation Procedure

Participant consent was obtained for audio recording. Demographic information was collected from the participants by reading out a questionnaire and answers were noted down. Participants faced the training and performed the voting process in the relevant ballot interfaces and they were randomly assigned for the two ballot interfaces. After using each interface, participants were asked to rate their voting experience by agreeing or disagreeing to the 10 statements provided system usability scale (SUS). After both trials were completed, participants were asked to choose their preferred ballot and feedback was noted. Interactions with the interfaces were video recorded and feedback were audio recorded. Time spent on conducting all trials with training varied (25 to 45 minutes). As shown in Figure 3.8, evaluation was carried out in three steps: conducting pre-trial interviews, participants performing the tasks and conducting post-trial interviews.

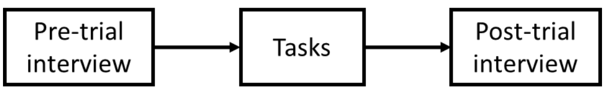


Figure 3.8 : Evaluation Procedure

1) Pre-trial interview

Demography information was collected: Age, educative level, types of vision disability, previous computer/ATM/touch screen usage.

2) Tasks

Each participant was randomly assigned to use one of the interfaces first (A) and the other second (B). As other usability studies of voting experiences [5, 10], participants were given the name of a candidate they should vote for based on the sample ballots. Participants actions were video recorded and their interactions were screen recorded. Tasks assigned to participants:

- Task 1: Interface Type A with instructions
- Task 2: Interface Type A without instructions
- Task 3: Interface Type B with instructions
- Task 4: Interface Type B without instructions

3) Post-trial interview

Interviews were conducted after participants completed the tasks. Participants were subjected to the following:

- SUS questions with a five-point Likert scale with 5 corresponding to ‘‘strongly agree’’.
- Choosing the preferred interface
- Any comments (on either interface, instructions, etc)

Evaluation form is in Appendix F.

3.6 Chapter Summary

Use-inspired design science approach is used for the research conduct. Random sampling is used all the interviews and activities where blind voters were involved. Problem identification phase is carried out by conducting literature review and interviews. In solution design phase, UCD methods such as storyboarding, creating personas, and user flow drawing are used in the methodology. DECIDE evaluation framework is used for evaluating the voting solution.

4 Chapter Four: Problem Identification

4.1 Study on existing voting systems

From this study it was clear that designing voting technologies by electronic means is a better and almost the only way to provide accessibility to a secret ballot for the visually impaired voters. Electronic means of voting allows them to caste the vote independently without the need to get assistance. Also, avoiding any external coercion when compared to paper-based voting mechanisms. However, there are challenges, vulnerabilities and considerations that should be addressed in order to gain the true right to democracy. Table 4.1 shows the analysed existing voting systems that has features to support voters with visual disabilities. The unique design features and design issues of those systems are listed down. This list does not show a one to one mapping of design features and design issues but rather two independent fields. The listed design features briefly explain the voting mechanism of the system, what features are used in order to make the system accessible for voters with visual disabilities and if any concern is provided to include features to ensure privacy from an interface level perspective. These features are discussed and compared further in depth under in sections: 4.2.1 and 4.2.2.

Table 6 : Summarizing design features and issues of existing voting systems

Voting system	**Design features**	**Design issues**	**References**
AutoMARK VAT	• Optical scan voting • Braille buttons • Audio instructions • Contrast, audio tempo, and audio volume configuration • Screen privacy option	• Assistance for ballot insertion and retrieval • Assumption of Braille awareness • Reading from a scanned ballot paper • Only one contrast option • Screen privacy option shows no sync with display	[10] [64] [11] [65]
Vote-Pad	• Used with paper ballots • Audio instructions • Plastic sleeve with pre-punched holes • Rubber dots with holes • LED wand to verify vote	• Ballot insertion to the sleeve • Ink marks on sleeve • No method to change the vote • Poor ballot instructions	[66] [11] [10]

AVC Edge	• Touch-based voting • Separate handheld control box • Audio instructions with human voice recordings • Braille buttons • Screen privacy option	• Assumption of Braille awareness • Card activator require assistance • Cannot change contrast • Control box is not inbuilt • Screen privacy option shows no sync with display • Accidental touch on unintended spaces	[67] [68] [10] [69]
E-slate	• Rotation dial and buttons • Audio volume configuration • Braille buttons	• Scrolling for lengthy lists • Less familiar rotation dial interaction • Cannot change contrast	[69] [67] [70] [11]
Prime III / One4all	• Multimodal voting • Buttons, Touch based and voice based	• Poll worker initiates system • Voice-based vote accuracy issues in noisy background	[71] [42] [43] [72]
Universal Ballot Design Interfaces (EZ ballot and Quick ballot)	• Multimodal voting • Buttons and Touch based • Choice of two ballot types • ‘EZ ballot’: Linear navigation with two tactile Yes and No buttons • ‘Quick ballot’: Random (hierarchical) navigation with slide rule • Contrast, audio tempo, and audio volume configuration	Quick ballot: • Less familiarity of slide rule interaction • Accidental touch on unintended spaces • Touching inactive areas due to lack of guidance on the touch interface EZ ballot: • Unavailability of button controls to navigate to a previous option	[73] [44] [74]

As shown in Table 4.1, existing voting systems were compared based on the following comparison factors:

- Interface features intended to provide accessibility for voters with visual impairment
- Navigation interactions provided within the system
- Design issues explained based on expert evaluations and user evaluations found in research literature
- Design methods and principles used by the stated voting systems

4.1.1 Study relevant to Question 01

Question 01: '*What are the accessibility and privacy related design features included in voting systems to support voters with visual disabilities and what are the issues identified in those design features*?'

Among the systems that accommodate paper-based voting, optical scanning method is frequently used (e.g. AutoMark VAT). Such systems read from the scanned ballot paper and provide audio instructions for blind voters. However, issues arise in the insertion and retrieval of the ballot paper, which requires support from polling workers [9]. Vote-Pad (Table 4.1) is another paper-based voting system which supports voting by the persons with visual disabilities that scans the paper and read the ballot options. Vote-Pad has a unique design feature that differentiates it from other optical scan-based voting systems, by having a plastic sleeve with pre-punched holes. Voters can mark the vote by listening to audio instructions and also by following along using the rubber dots situated next to holes.

After the ballot is marked, voter can confirm the vote using a wand that vibrates when it detects a mark [55]. However, issues exist in this design feature where the stray marks left on the sleeve can be used to predict the vote. And also, there is no method to ensure that the pre-punched holes are correctly aligned with the preferences on the ballot and proper ballot insertion to the sleeve is also a difficult task [9]. Similar to general paper-based voting, Vote-Pad does not allow for changing the vote marked.

In general, voting systems have made use of buttons and audio instructions to make voting accessible for voters with visual disabilities. Among those existing voting systems, most are designed based on the assumption that persons with visual disabilities are braille literate (e.g. AutoMark VAT, AVC Edge, E-slate) as listed in Table 4.1. Thus, those systems provide buttons with braille embossments. Some systems have used buttons without using Braille but using other techniques to support blind voters. One such design is Quick ballot design provided by Universal Ballot Design Interfaces [65], which has used only two buttons for voting labelled as 'Yes' and 'No' on located on right and left side of the voting tablet device respectively. However, this ballot design has not accommodated buttons for navigation to previous options. Systems like

AVC Edge [57] also provide buttons to support voting by the blind but the buttons are placed in a separate handheld control box which is used as an external add-on. This is a common technique used in already built systems to make accessible for blind voters but reviewed to be not user friendly [59] and integration of external components cannot be ensured to be compatible always.

In contrast to systems that provide buttons, e-slate voting system has a rotation dial for navigation in voting lists. This dial can be rotated clockwise to navigate through options forward and anticlockwise to go backward [60]. Inefficiencies arise when there are long voting lists and due to less familiarity of the rotation movement [59].

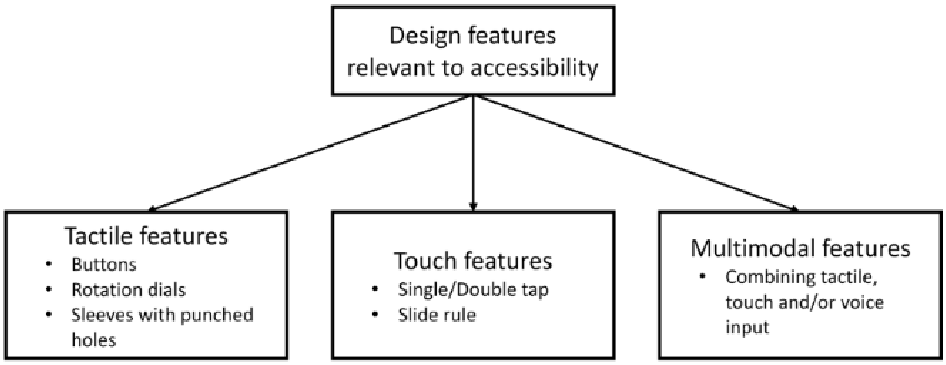


Figure 4.1 : Design features relevant to accessibility

In order to make voting accessible, multimodal concept (Figure 4.2) is adhered by some systems (e.g. Prime III and Universal ballot design interfaces) where the voters are given the freedom to vote in the method they prefer. Prime III is one such system that enables voting by three modes: Touch-based, pressing buttons and voice-based. For a total blind voter, accessible modes are the buttons and voice-based voting. However, it has only 90% accuracy at an SNR (Signal to Noise Ratio) of 1.44 [64]. Thus, accuracy is questionable if noise in the background is not maintained at least at a level of SNR 1.44. Additionally, in Prime III, poll worker has to initiate the voting system and let the voter begin the voting process. Thus, it is being dependent on the assistance of poll worker while having space for voter coercion [10].

Another system that adheres to multimodal concept is Universal ballot design interfaces that provides two ballots, 'Quick ballot' and 'EZ ballot'. In EZ ballot design, voting is made accessible to blind voters by adding slide rule [66] interaction design feature in the touch interface. Evaluations report that this slide rule less familiar to blind voters and is less of a natural interaction [65]. However, EZ ballot also has design issues such as accidental touch on unintended spaces and spending excessive time touching inactive areas due to lack of guidance on the touch interface [65].

In terms of outputs other than displays, audio is considered as the interface that is accessible for the blind voters. Even if that is the most frequently used or convenient, there still remain issues not addressed such as audio feedback takes longer than reading unless the user can and is able to understand audio playback at high speed [23]. Voter who are blind or visually impaired have to rely on short term memory to a larger extent compared to sighted voters.

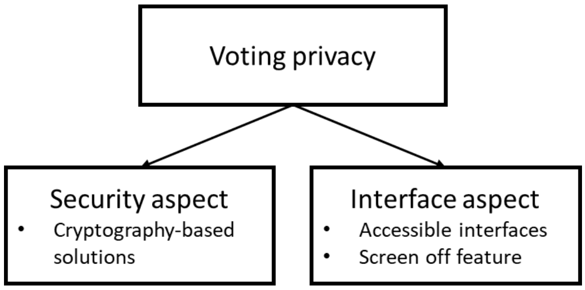


Figure 4.2 : Voting privacy related aspects

Privacy of voting systems is also facilitated in an interface aspect (Figure 4.3). Some voting systems (e.g. AutoMARK VAT, AVC Edge, refer Table 1) uses a mechanism where the display is turned off when the blind voter starts to vote using audio instructions. This feature has received negative evaluation from voters with partial visual disabilities because of the lack of synchronisation between what is shown on display and audio instructions [59].

Another study states that privacy of the vote marked by person with visual disabilities is ensured by 2 aspects: Voting interface should be accessible and no record should be made that a certain vote was made by a blind or a visually impaired voter using a reading impaired interface during the voting process [50].

A very significant note was made where it is mentioned in the literature that ballot validation should be accommodated for visually impaired voters, or anyone, to hear through headphones, and that no record should be made that a certain vote was made by a blind or a visually impaired voter using a reading impaired interface during the voting process and any ballot-ID should be generated in a manner that does not identify the voting booth or machine utilized for voting [26].

Among the electronic voting technologies, DRE (Direct Recording Machines) can offer better options to accessibility for those with a disability, but it can be argued that most DREs in use today produce unexpected high error rates but proper testing and following other practices DRE or electronic voting systems can be made effective than legacy or traditional voting mechanisms (paper based) [38].

Among the existing voting systems that address visually impaired voters, usability issues included the need to have intuitive interface layout, compatibility of screen readers, and proper instructions for either partial and total visually impaired participants [37]. In some cases, it was understood that elderly voters find it difficult managing new voting equipment, suggests the need to identify different demographic criteria and requirements. It is necessary to improve not only the system's usability, but also the voting instruction manual [37].

It was apparent that for sighted users, usability was the key requirement and less attention on device compatibility or technical support but for persons with disabilities it was essential whether the voting equipment allowed them to vote by themselves, without the need of support from officials [37] where it is even stated that "Voters who ask for help risk compromising their anonymity" [39].

4.1.2 Study relevant to Question 02

Question 02: '*What are the methods followed when designing voting systems that support voters with visual disabilities*?'

Among the prevalent usability evaluation models, UTAUT (Unified Theory of Acceptance and Use of Technology) was related to performance and effort expectancy, social influence, facilitating conditions, and behavioural intention [37]. As per the International Organization for Standardization (ISO 9241-11, 1998), usability is evaluated based on the effectiveness, efficiency and user satisfaction [40]. Another prominently used usability measurement approach is the SUS (System Usability Scale) which is also known as a "quick and dirty" method to allow low cost assessments of usability in industrial systems evaluation [41] [42].

UCD and UD principles are followed by researchers in designing new voting systems and interfaces [43] [44] [45]. "The User-Centered Design (UCD) process, and its derivative forms, is an approach that includes interaction with users throughout the product's design and development cycle to gather data and test design assumptions" [45]. The basic ideology behind this process is to ensure that usability is incorporated into a product's design from the beginning of the design process and evaluated throughout the development process [45]. In this process there are various methods utilized such as creating user profiles (or personas), drawing up use case models, drawing story boards and mock-ups, prototyping, conducting heuristic reviews and continuous user testing. But it is argued that the UCD process itself is neither necessary nor sufficient to ensure usability, having UCD applied does not provide total assurance that end output is a usable system or product. One major reason for this kind of counter argument is due to the necessity of contribution by designers and developers who have relevant skills and experience in UCD process.

Managing ballot secrecy and security are very important considerations where such responsibilities are with security experts and election administrators whilst it is discussed that different sciences such as behavioural science [38], human factor research [46] shall be learnt and adapted in order to ensure that what is recorded on ballots accurately matches voters' intent and the ability for voters to trust that voting systems are user friendly.

In designing any system voting or other, practice is to follow guidelines and such well accepted and equipped guidelines among voting systems can be identified as VVSG [38] [47]. But it is also understood that any small change in the way people vote has an impact on usability such as selecting layouts to wordings in instructions. And also, these standards and guidelines are to be applied across large domains where "they do not address functional issues, since they cannot account for the intended users, activities, and goals of a product" [45]. Thereby even if using guidelines is a proper way to initiate designing a voting system which can avoid a set of usability problems, it has the space build sufficient usable voting systems, leading to the practice of conducting more usability testing, both during the design process and after the design is finalized, similar to prototyping techniques [38] [45].

In designing and developing voting applications, it is advised in many studies that voters should not expect to be aware of new tools in different operating systems or adding assistive tools (such as screen readers and magnification tools) after developing the voting system but rather focus on designing voting applications that has accessibility features in built from initial design stages itself [47] [48] [45]. It is stated that consideration shall be given to addressing a wide range of functional abilities and disabilities that are present in the voting population [47] [45]. This then leads to the identification of the necessary components and relevant critical tasks involved in the voting process such as "activating the ballot; getting instructions/help; obtaining information on the ballot; selecting choices; verifying ballot choices; submitting ballot" [47]. It is discussed in the literature that with a greater emphasis on the language usage for voting systems with respect to providing specific ballot or other interface instructions [47].

Among the voting technologies using mobile voting as a method of remote voting is anticipated. A study has introduced Slide Rule, a set of multi-touch interaction techniques that improve the accessibility of touch screen-based mobile devices, and that can be used on a multi-touch screen without any additional hardware buttons focussed on blind users [43]. Here the rule uses multi-touch gestures to interact with applications focussed on four main actions as to browse lists, to select items, to flip between pages of items and to browse the hierarchy [43].

Aside mobile touch interfaced based voting mechanisms, voting technologies such as DRE are made accessible by using multimodal interfaces based on recent developments in technology providing equity in access, and also privacy and security in electronic voting [44]. Here utilization of touch-screen displays, automatic speech recognition (ASR) options for inputs.

In terms of outputs other than displays, audio is considered as the interface that is accessible for the blind voters. Even if that is the most frequently used or convenient, there still remain issues not addressed such as audio feedback takes longer than reading unless the user can and is able to understand audio playback at high speed [45]. Voter who are blind or visually impaired has to rely on short term memory to a larger extent compared to sighted voters.

When designing voting interfaces, in order to enhance the accessibility for voters with blindness, interface layout is a key consideration where there is research conducted in creating different ways to have the voting interface layout, linear layouts, random direct selection layouts [40].

In order to address partially blind voters, a design consideration shall be to have large buttons that afford pressing which thus eliminates confusion about ballot options [44]. Another assistive tool that is externally used are the tactile components with or without braille embossments [49].

It is noted that some studies show that voting interfaces should exhibit simplicity since a considerable number of persons will not be familiar with new technologies and features and also concentration on data insertions such as the input of identification data should be of minimal effort and easy to handle. It is advised that designing voting interfaces users' familiarity or experience in using other technological similar applications or systems shall be considered [48].

4.2 Interview Data Analysis

Interviews were conducted with 9 persons with visual disabilities. It was conducted with the support of Sri Lanka Council for the Blind. The participants of this event answered a questionnaire asked by the interviewers.

4.2.1 Visual Disability

In the sample, only 3 were totally blind and remaining participants were partially blind with some slight variations in sight as in Figure 4.4.

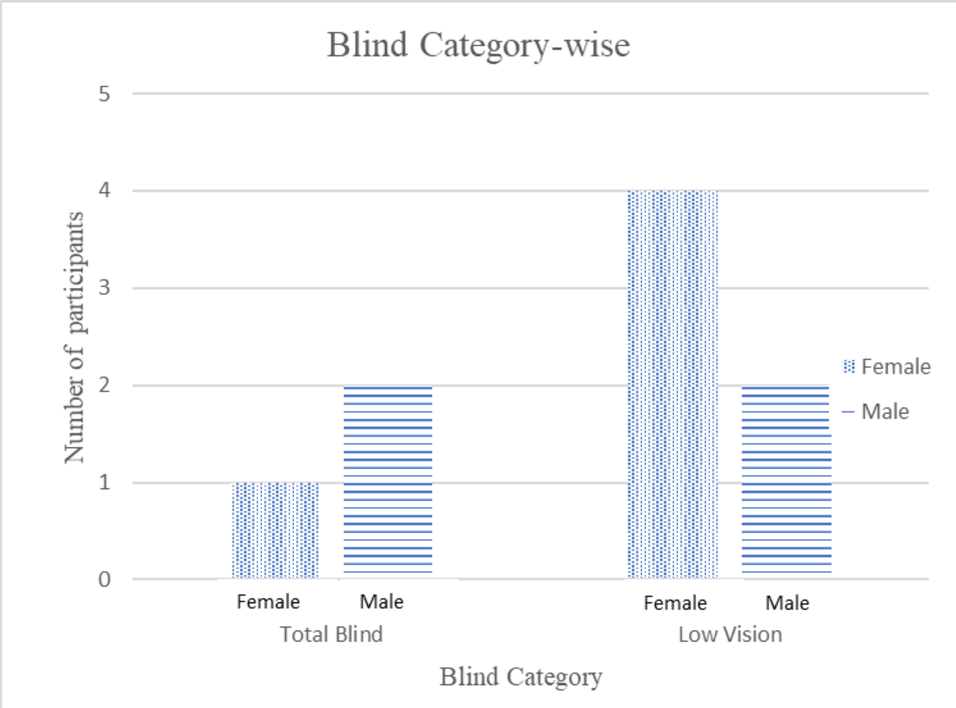


Figure 4.3 : Blind Category-wise Variation

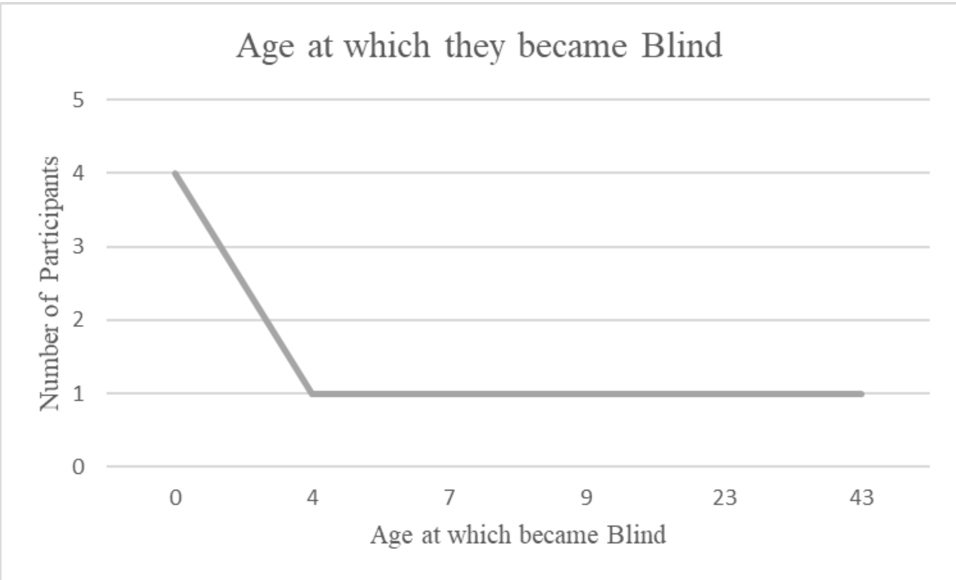


Figure 4.4 : Age becoming Blind Variations

As shown in Figure 4.5, 4 participants have become blind from birth and others at various age levels due to different causes.

4.2.2 Literacy Levels

Literacy levels of the participants were identified in terms of language competency in Braille and Information Technology usage. All the participants were Sinhala native speakers whilst majority of them did not know or slightly knew Tamil (Figure 4.6). English literacy was apparently greater compared to Tamil and only one participant responded as he/she does not know English.

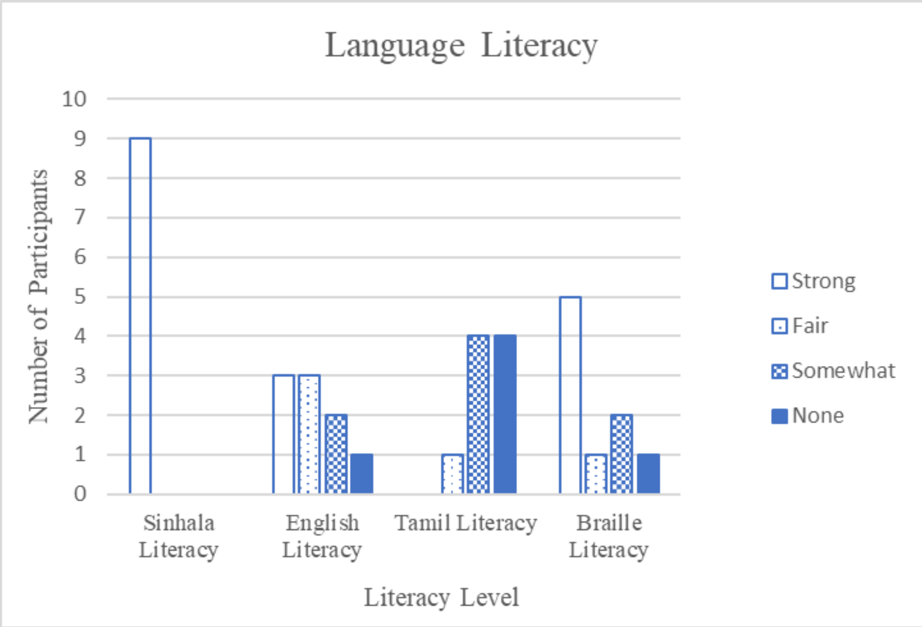


Figure 4.5 : Language Literacy of Participants

As it was necessary to ensure that the questionnaire address all possible literacy factors that has an impact on the design, Braille literacy was also questioned. Many responded as they are aware of braille as in Figure 4.6. Reason could be because the institution teaches braille there itself and it was a student that joined recently mentioned that he/she does not know braille.

IT literacy or the ability to use new technologies was understood by asking about their experience with usage of Automatic Teller Machines (ATM) and Mobile Phones. According to findings of the literature review and the interviews with election professionals persons who are capable of operating an ATM have the capability to use an electronic voting solution implying that similar interfaces are incorporated [21]. According to the interviews conducted, 2 persons had the experience of using an ATM.

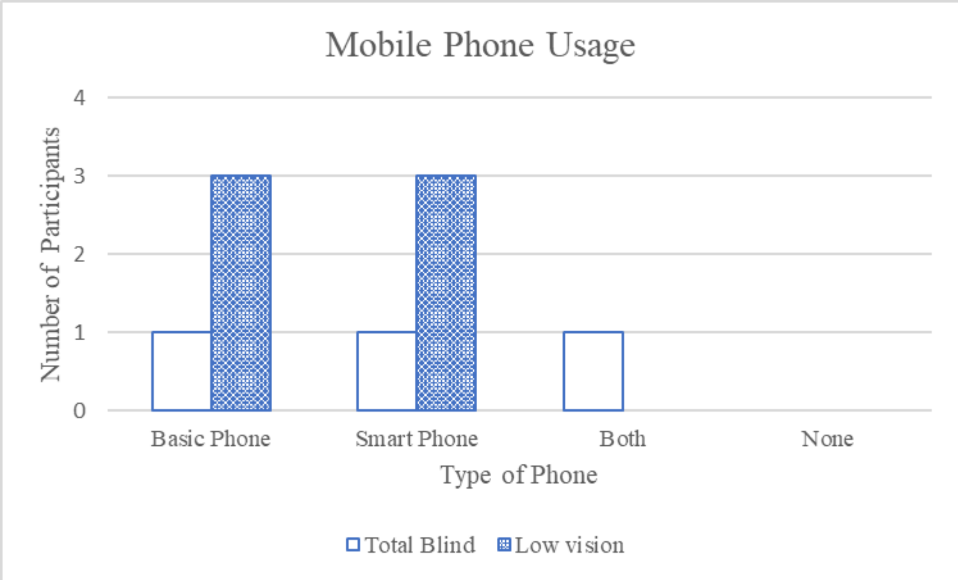


Figure 4.6 : Mobile Phone Usage of Participants

All the participants had experience of using a mobile phone irrespective of the type of the mobile phone. Among the participants, 3 persons have used a basic feature phone with a majority of 7 persons having the experience of smart-phone technology (Figure 4.7). One of the participants was identified to be familiar with both types of mobile phone technologies.

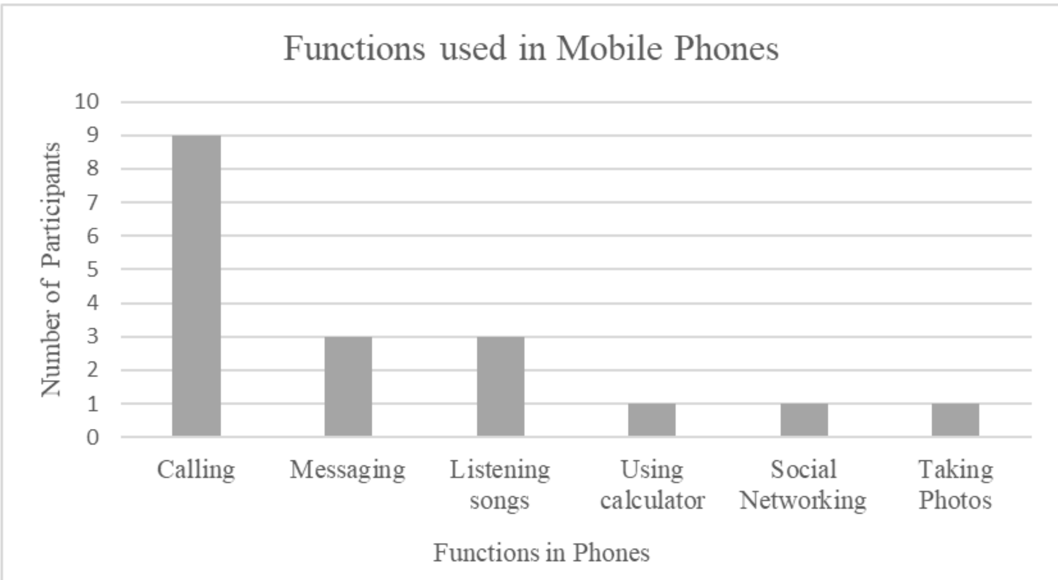


Figure 4.7 : Functions Used in Mobile Phones by Participants

All of the participants had the experience of using mobile phone to take a call whilst 3 of them have also used it to message and to listen to songs. Few had used mobile phones for social networking, taking photos and to perform calculations (Figure 4.8).

When the participants were asked how they accessed the phones they provided different opinions based on their individual experiences. According to that;

- Majority can use the audio features to navigate and perform functions
- Some are familiar with the Google Talkback feature in Android phones
- Some of the participants who had basic phones reported that they memorize the key placements

4.2.3 Preference for Electronic Voting

Except one all the participants stated that they would like to use an electronic voting device. The participant who did not prefer to use electronic voting device revealed that he wore a spectacle with a magnifying lens which is sufficient enough to vote in the current voting procedure.

4.3 Personas

A persona is not a real person but rather a fictitious one where it does not necessary to understand the entire person, but it is way to focus on a special area (attitudes and behaviours) that is relevant to the domain of the system that is being developed. There are 4 general perspectives of personas: Alan Cooper's goal-directed perspective [75]; Jonathan Grudin, John Pruitt and Tamara Adlin's role-based perspective [76]; the engaging perspective; and the fiction-based perspective [77]. For the research, goal-oriented perspective was used because persona descriptions were based on data gathered and it is a psychological tool for looking at problems and a guide for the design process [77].

There is not strict structure for creating personas but as mentioned earlier in methodology section, explaining the objectives of conducting interviews, a template provided by Interaction Design Foundation [51] was used (Table 4,2). Here four personas were identified from the interviews conducted as follows (Figures 4.9 - 4.12).

Table 7 : Persona Structure

<table>
<tr><td>Picture
Name
Tag line</td><td>Goals
Pain points</td><td>Education Level
Language Literacy</td></tr>
<tr><td rowspan="2">Blind status
Age
Working status
Gender
Location</td><td>IT Literacy</td><td>Accessibility Tools</td></tr>
<tr><td>Mobile Phone Experience</td><td>How will they react with electronic voting device?</td></tr>
</table>

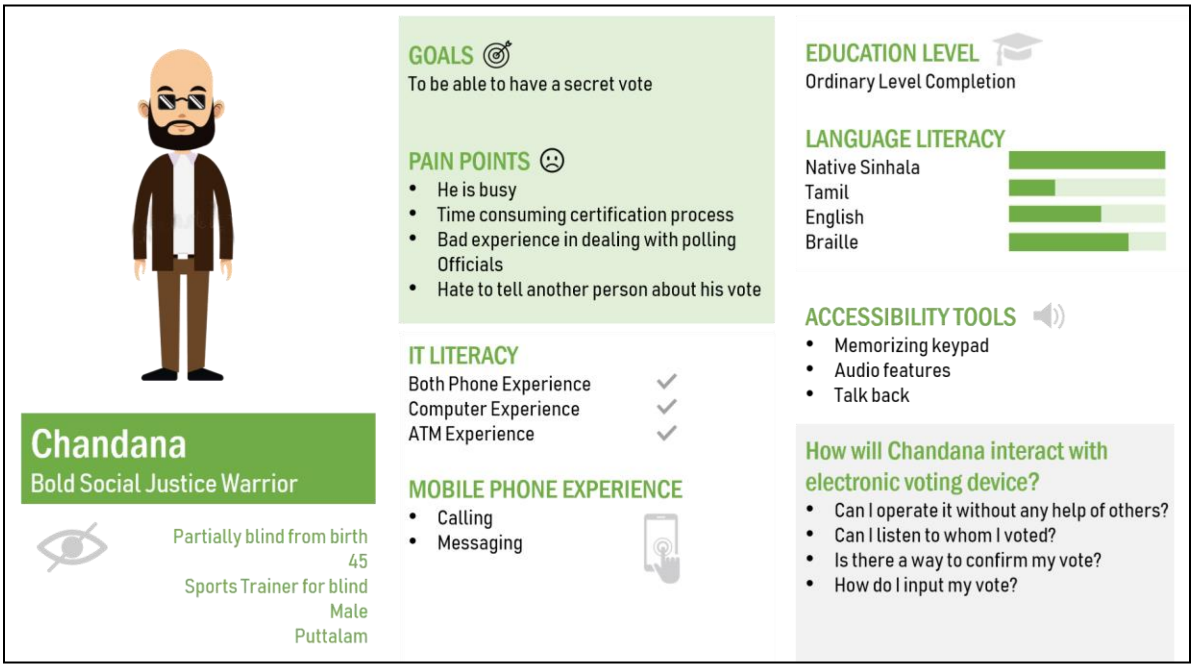


Figure 4.8 : Persona 1

Chandana's persona indicates ability to use keypads by memorizing the locations and the functionality. In addition, his experience in using smart phones gives us the opportunity to make use of touch interfaces.

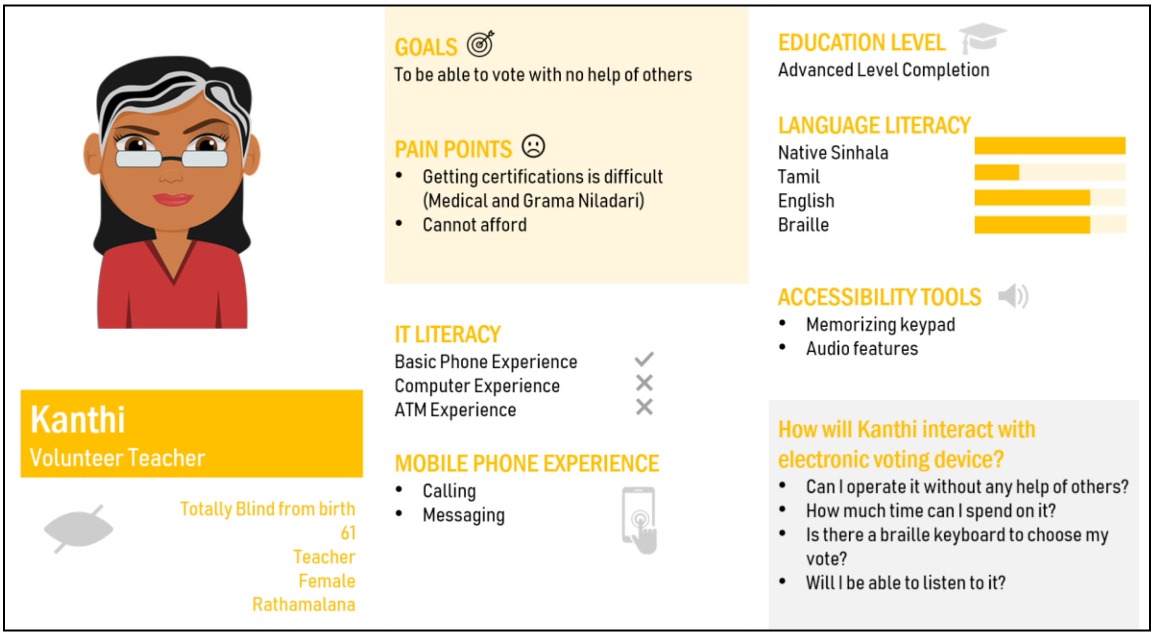


Figure 4.9 : Persona 2

Kanthi's persona shows us that there are persons with visual disabilities who are not yet experienced in using smart interfaces. However, she is capable of using keypads with her experience in using basic phones with tactile keypads.

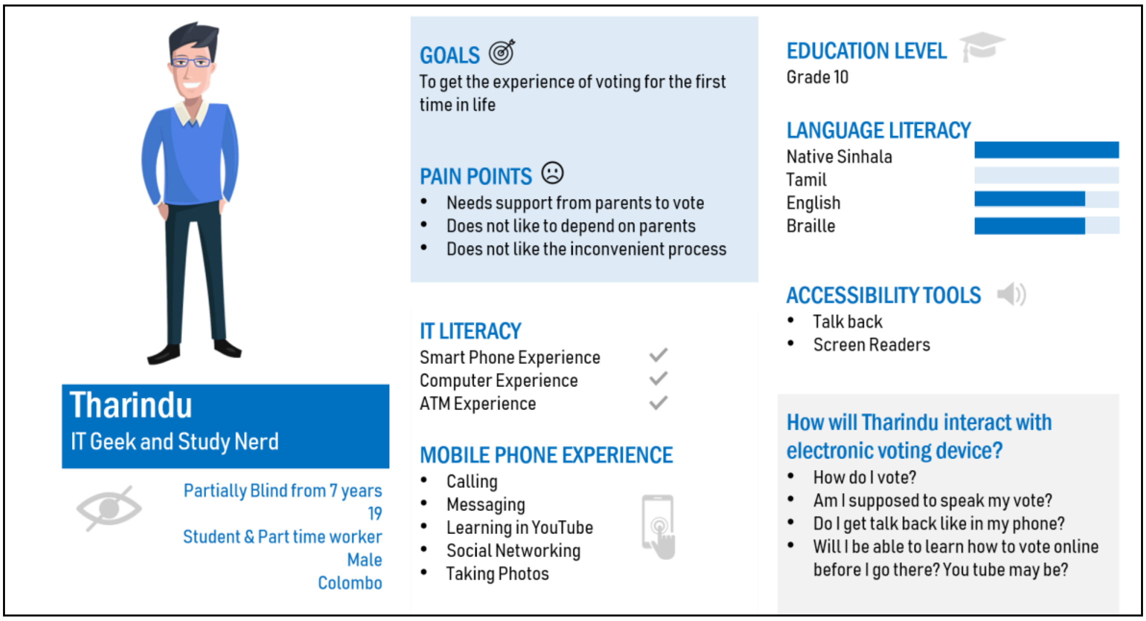


Figure 4.10 : Persona 3

Tharindu is tech savvy persona with advanced skills and understanding in using accessibility tools available for persons with visual disabilities such as screen readers and Google talk back feature for mobile phones. However, he has no experience in using phones with keypads. Namali is similar to Kanthi but she is not Braille literate. Namali has not used touch phones but she is very talented in painting showing her ability to make use of touch sensitivity.

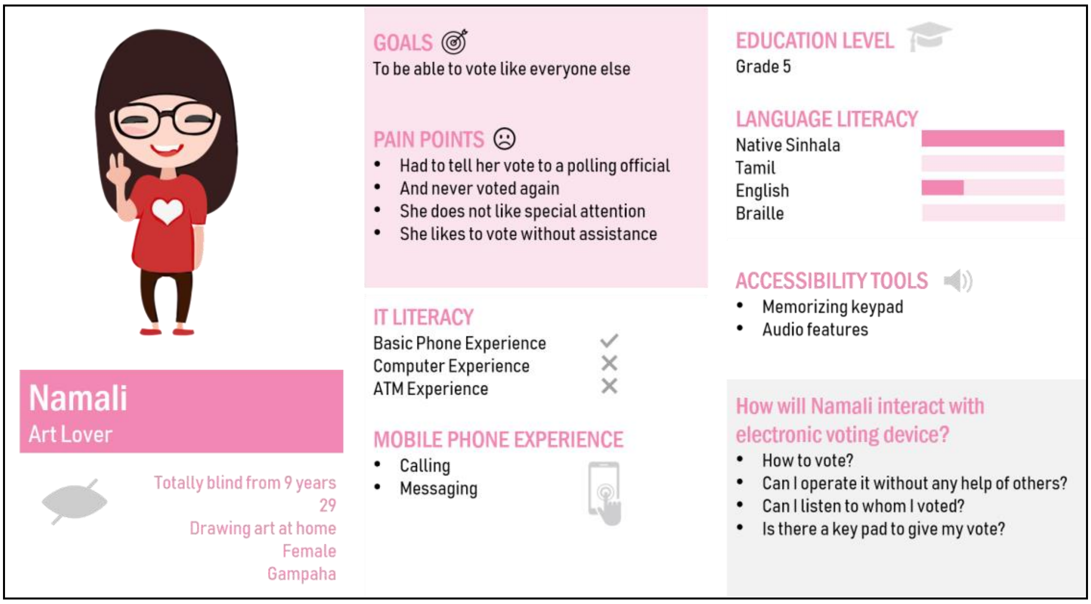


Figure 4.11 : Persona 4

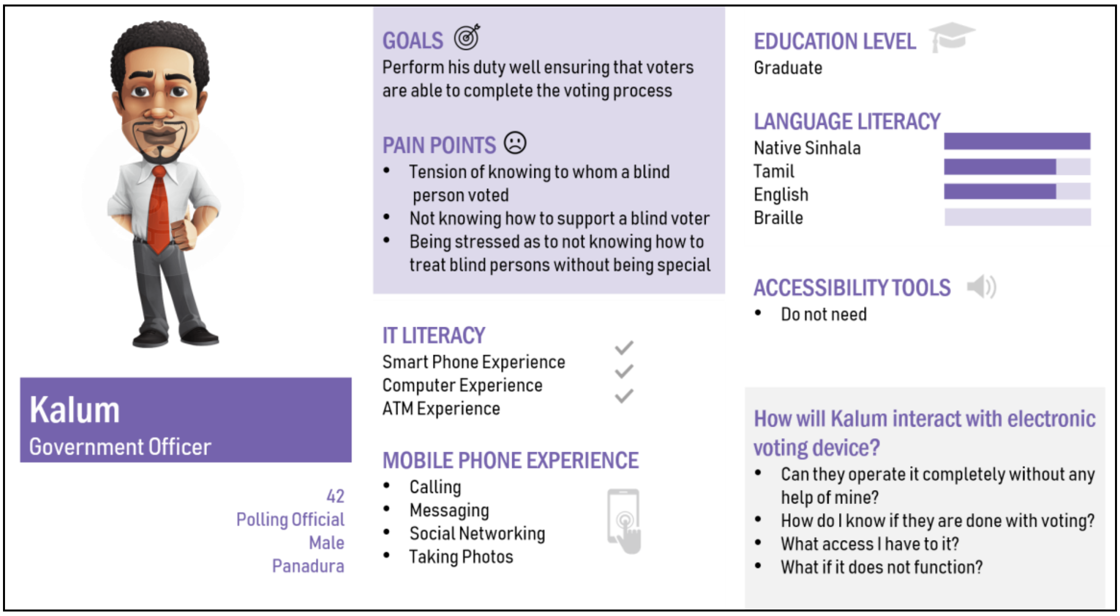


Figure 4.12 : Persona 5

It is mentioned that Personas are used to identify the goals from the main character's point of view and also to identify the characters who can be influencing the decisions [76] [78]. Thus, more personas were identified as Kalum and Veena with the intention of giving a thought to these characters as well during the design process (Figures 4.13 and 4.14). Kalum or Election Polling Official was identified here because polling officials will be engaged in the voting process and they may have to operate the voting device at some instances.

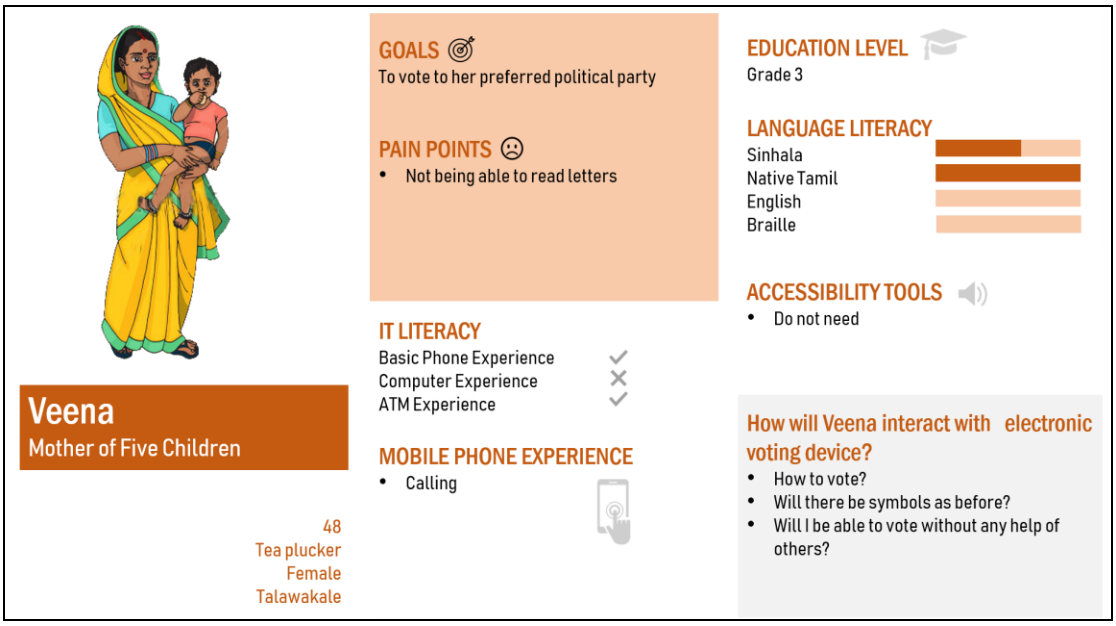


Figure 4.13 : Persona 6

Veena or the person who is living in upcountry working as tea plucker was brought into concern due to the important point noted during discussions with election interested parties that persons living in such context tend to have low literacy. However, the scope of research is limited to persons with visual disabilities but since universal design guidelines were being based certain concern was given on other factors as well.

4.4 Thematic Analysis

4.4.1 Overview

Thematic Analysis was conducted based on the widely used framework or the six-phase guide by Braun and Clarke (2006) [79]. Interviews were transcribed and then coded. Coding was about identifying a common phrase or word that could represent the meaning of a chunk/block in the transcript. Coding process was performed using the comment feature found in MS Word application software. Next the codes identified in previous step were mapped into themes and sub themes using a tool, mind maps (Creately). The themes were refined several times and finally it was analysed to identify the essence of each theme and how themes correlate each other.

4.4.2 Step 1: Become familiar with the data

During the initial phase of the research, interviews were conducted. Thus, those were required to be transcribed in order to conduct a thematic analysis. Goal of this analysis is to understand what factors are required to be focussed on when designing the IT based solution in order to answer the research problem. Since transcribing needs to have an output of a transcript that is meaningful, audio recordings were listened to several times. Although the process was time consuming, it supported to be familiar with the data that needs a critical analysis later.

4.4.3 Step 2: Generate initial codes

Here, open coding was used because there was no initial list of codes. Thus, it was necessary to modify codes during the coding process. Coding was about identifying a common phrase or word that could represent the meaning of a chunk/block in the transcript. It was understood that some codes repeated whilst some did not.

Since the aim was to address a specific research question, a theoretical thematic analysis was required to be conducted rather than an inductive one. Thus, all the text in the transcript was not coded but instead text relevant or meaningful for the research question were coded. Coding process was performed using the comment feature found in MS Word application software. List of codes can be found in Appendix A.

4.4.4 Step 3: Searching Themes

In this phase, as per the framework guides, the codes identified in previous step were mapped into themes and sub themes using a tool, mind maps (Creately) as follows. Here, intention was only to map the codes into some theme without giving much concern on whether these codes are all essential for final analysis or whether even these are overlapping. Most of the codes were identified to be falling under one theme but some were showing links to more than one theme. There were codes which indicated no theme relevance but such were not disregarded at this stage.

'Braille is less liked and used by blind persons' was found repeated in both themes, Braille literacy and Braille ballots. Codes such as 'mobile phones have text books reading in English but not in Sinhala', 'blind readers using audio books of Daisy organization', 'practice on symbols and using symbols to vote' were showing no theme relevance at this stage. Initial map has 20 main themes and 127 codes. Themes can be found in Appendix B.

4.4.5 Step 4: Reviewing Themes

According to the framework, this step has 2 levels of reviewing and refining themes as follows.

1. To ensure that themes are related to the collateral data set. Coded data extracts relevant to each theme are being re checked to ensure that themes give the same meaning as the related data.
2. To ensure validity of individual themes in relation to the whole data set. Here, the themes were re-checked by going through all interviews.

During this phase changes were made (Table 4.3);

- It was evident that some themes are not really themes. For an instance, Indian voting does not have to be a theme but the codes under it should be facts related to the sub theme called 'Hiring EVM' which falls under 'Available Voting Options'.
- Some themes were needed to be broken down into separate themes or sub themes considering internal homogeneity and external heterogeneity to have distinct themes.

Table 8 : Reviewing Themes

Theme	**Sub Themes**
Current Voting Process	• Issues of Current Voting • Actions taken to improve voting by blind
Available Voting Options	• Hiring EVM • Braille Ballots • Tactile Voting • Internet Voting • Touch Interfaces
Using EVM	• Challenges for using EVM • Support for using EVM
Screen Readers	• Screen Reader Types
Voting system should address	• Addressing Blind Variations • Vote Verification • Audio Option • Secrecy & Privacy
Relationship between Literacy and Electronic Voting	• IT Literacy • Braille Literacy • Language Literacy
Facts related to Blindness	• Blind Definitions • Blind Variations • Statistics related to Blind Persons

- It was understood that following themes identified in earlier stage should become sub themes that falls under a new main theme called 'Available Voting Options',
    - Hiring EVM
    - Braille Ballots
    - Tactile Voting
    - Internet Voting
    - Touch Interfaces
- It was understood that following themes identified in earlier stage should become sub themes that falls under a new main theme called 'Facts related to Blindness',
    - Blind Definitions
    - Blind Variations
    - It was understood that codes that were under the theme 'SPA' (Special Provisions Act) were all about issues of SPA except for the code 'SPA act passed for voters with disabilities', which was disregarded at this stage because it is a well-known 'fact' and less of value in the analysing.

The themes generated at this stage can be found in Appendix B.

4.4.6 Step 5: Defining and Naming Themes

This stage was about identifying essence of each theme and how themes correlates each other, as the framework describes. It is about determining what aspect of the data each theme captures. During this phase it was focussed more on the relevance of themes with the research question, "How to support the visually impaired individuals in the voting process with an IT based solution?". Thus, following final thematic map was identified after a thorough analysis for each theme and their relations with each other. Thematic table can be found in Appendix B.

4.4.7 Step 6: Summary of Analysis

It was understood that with respect to the previous map and research question, there are mainly 2 themes (Figure 4.15) that speaks the overall data,

1. Factors to consider when designing a voting solution for the blind.

2. Available design options.

It was clear that many variations can exist in blindness but there are 3 distinct variations that needs to be addressed when designing. Thus, their abilities should be matched with the design options provided in the final solution.

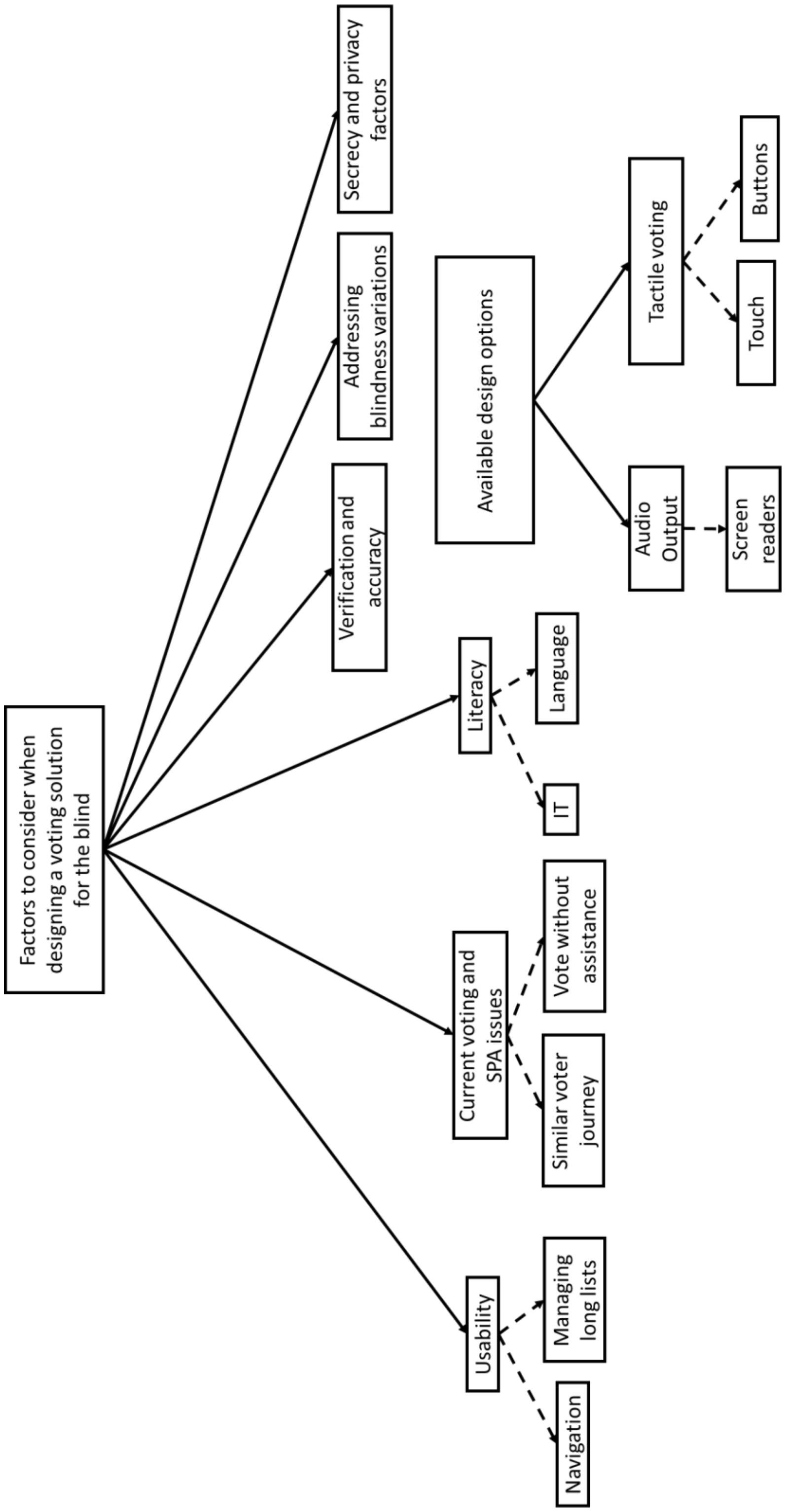


Figure 4.14 : Final Thematic Map

Braille literacy is low and is it being less learnt by new generations as well. Here focus will be taken away from Braille due its less usage and awareness. Thus, IT literacy and Language literacy are the key literacy factors that needs attention when designing the solution. Few suggested that knowing to handle mobile phones by blind users nowadays is good indication of their favourable IT literacy but also it does not prove that all are IT literate. Thus, adapting familiar mobile phone features can be done but the natural interactions should be maintained to make sure majority of blind voters can cope with the new IT based solution. Even if the local context the overall statistics shows how literate Sri Lankans are, there are geographical variations among the literacy levels. It is discussed that all voters are not having English literacy, and language preference options should be given concern.

Providing audio facility was the suggested way to guide the blind voters through the voting process if braille reading option is ignored. Considering audio feature gives the raise to more concerns such as the accent of the speaker, speed adjustments, and more. It is also understood that effect of having less braille literacy or any reading literacy (non-blind person) can be overcome by audio option. With respect to input features, contradicting opinions were made regarding touch interfaces where one mentioned about its inconvenience to scan over the screen which is time consuming. Few others had opposing ideas since touch phones are now being used by blind persons with the use of inbuilt or installed audio features.

It was discussed that solution designed should be very simple and easy to understand because the vote should be marked quickly and it can be done only once at a time. Thus, it should be an intuitive design which can be easily informed/taught to blind voters before the voting day or voting moment. Here navigation and managing long lists will be key considerations that needs more attention to improve usability because currently in the local context a high number of political parties are existing. Also, analysis showed that there should be a mechanism to allow the blind voters to verify that the vote was made as intended. For a non-blind voter VVPAT (Voter Verified Paper Audit Trail), printed paper can be used but for the blind some other method has to be configured.

4.5 Defining functionalities using Use Cases and Use Case Narratives

Use case diagram was drawn (Figure 4.16) defining the functionalities of the voting system.

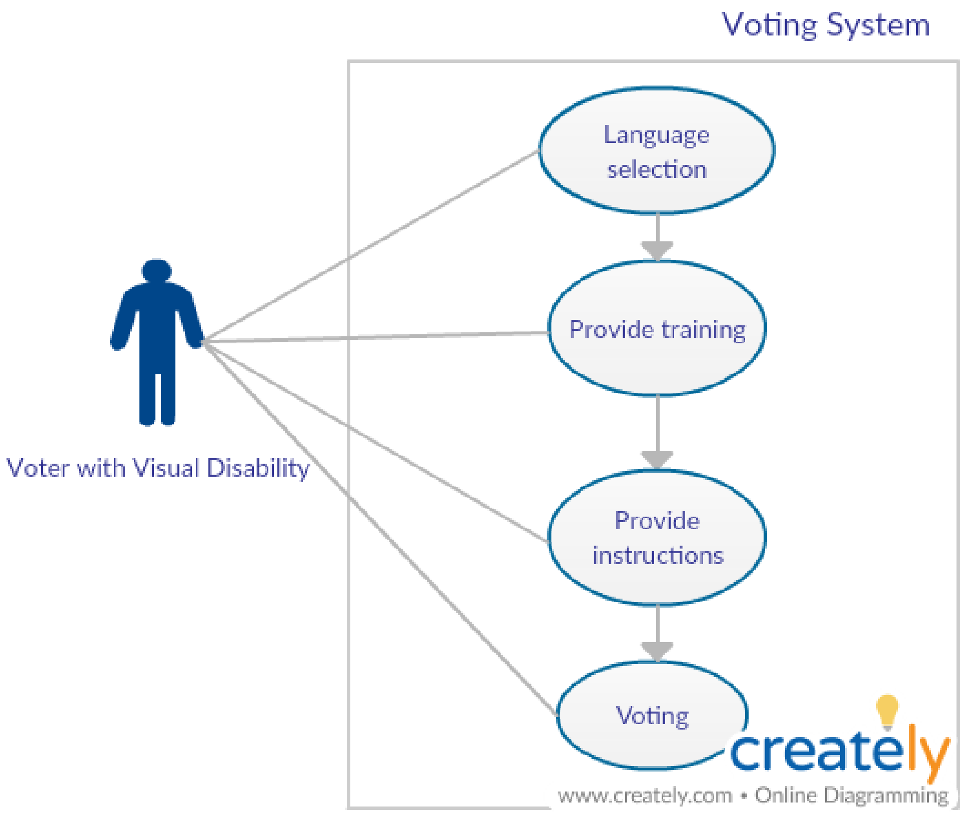


Figure 4.15 : Use Case Diagram

Use case narratives for the above use case diagram (Figure 4.16) are found in Appendix C. Voting use case is sub divided into 4 because there are different types of elections in local context.

- Presidential elections: Voters are allowed to mark vote by ranking up to three candidates.
- Local elections: Voters are allowed to mark vote only once and the vote is marked for the preferred political party only.
- Parliamentary/ Provincial elections: Voters should mark vote for the political party and then can mark up to 3 crosses for the preferred candidates of the earlier marked political party.
- Referendum Election: Voters can mark vote only for one preference.

5 Chapter Five: Solution Design

5.1 Storyboarding

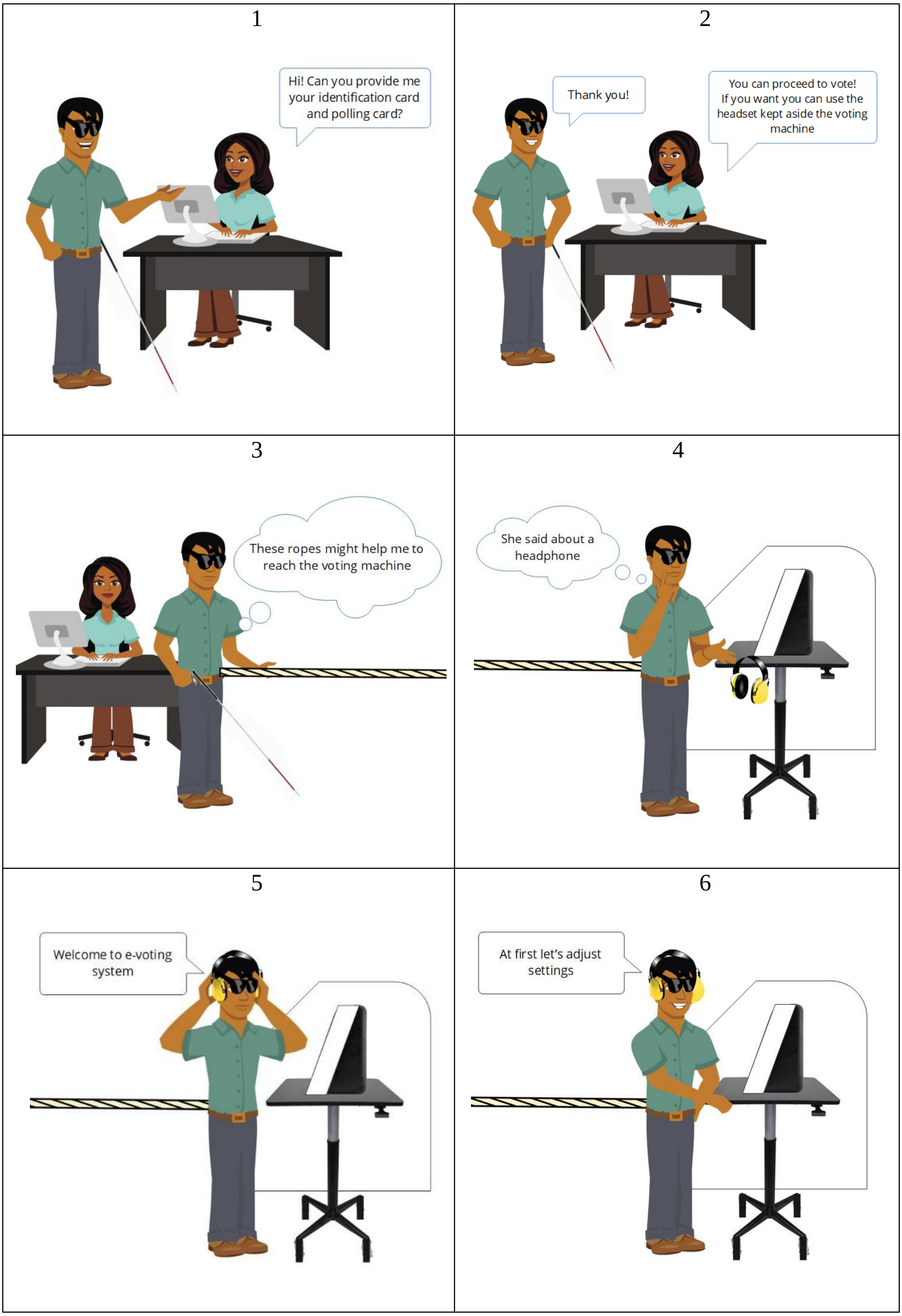
Storyboards were drawn visualizing the voter journey. This section illustrates two storyboards.

5.1.1 Storyboard 1: Voting Process

This storyboard illustrates how the voter would proceed without any obstacles. Table 5.1 shows how the storyboard was constructed based on the template (See section 3.4).

Table 9 : Storyboard 1 Description

Theme	Voting Without Any Obstacles
Plot	This storyboard shows how a blind voter completes the voting process without facing any complications and the most desired way.
Characters	Polling Official (PO), Blind Voter (User)
Décor	Polling station
Spectacles	Storyboard 2


1
Hi! Can you provide me your identification card and polling card?
2
Thank you!
You can proceed to vote! If you want you can use the headset kept aside the voting machine
3
These ropes might help me to reach the voting machine
4
She said about a headphone
5
Welcome to e-voting system
6
At first let's adjust settings

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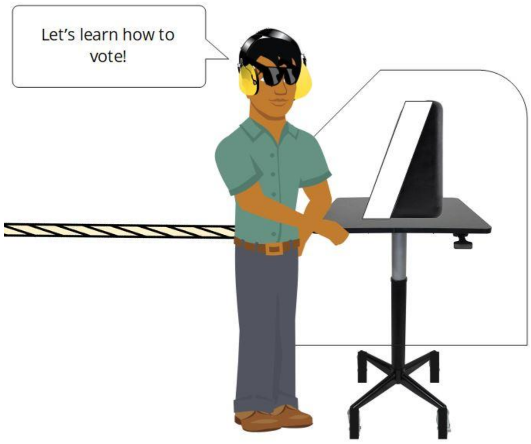
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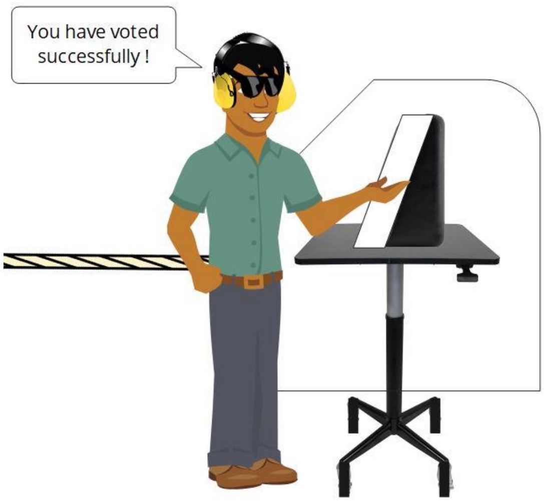
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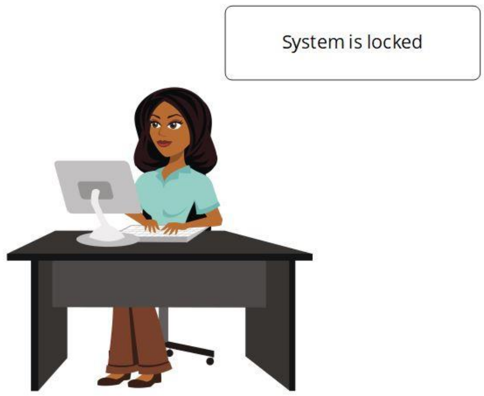
</td></tr>
</table>

Table 10 : Storyboard 1

Table 5.2 Illustrates the Storyboard which shows the voter journey without any obstacles.

5.1.2 Storyboard 2: Obstacles in Voting

This storyboard illustrates obstacles faced by a voter with visual disabilities. Table 5.3 shows how the storyboard was constructed.

Theme	Obstacles in voting
Plot	This storyboard shows what type of obstacles are faced by a blind voter during voting which are painful for them
Characters	Blind Voter (User)
Décor	Polling station
Spectacles	-

Table 11 : Storyboard 2 Description

Table 5.4 illustrates the storyboard 2 which shows the obstacles faced by a blind voter while using an electronic voting machine.

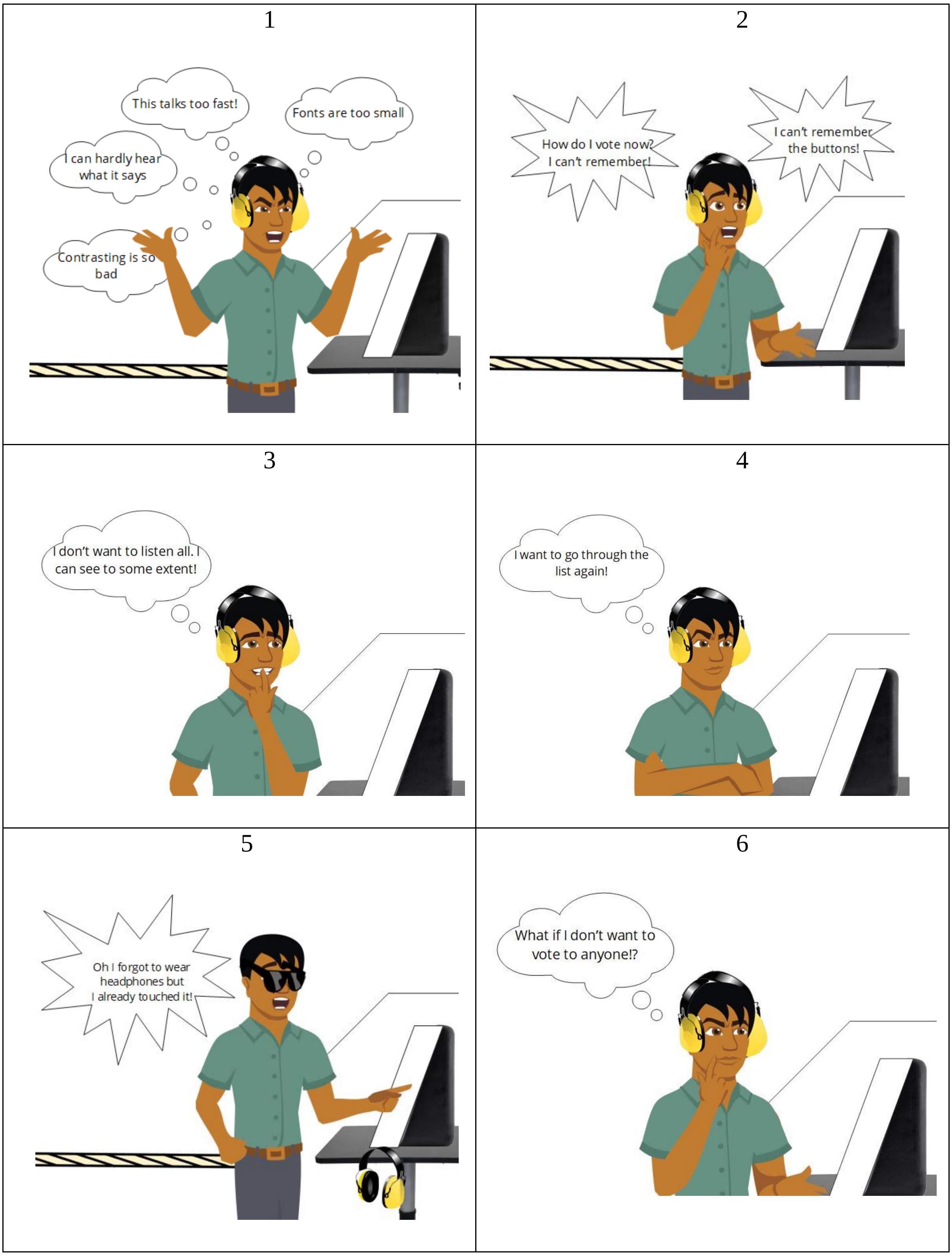

Table 12 : Storyboard 2

5.2 Initial Design Concept and Design Features

After storyboarding, voter journey (See section 5.3.1) was designed with two types of interfaces. The two interfaces were designed based on a set of features.

5.2.1 Interactions

In the journey of the voter with visual impairment, it is required to identify the features that are required for navigation and how the voter interacts with the voting system (Table 5.5).

Table 13 : Navigation and Selection Features

Interaction Type	**Actions**
Navigation	• Navigating through languages • Navigating through settings • Navigating through political parties /candidates
Selection	• Selecting preferred language • Adjusting settings • Selecting the preferred political party/candidate • Confirming vote

As in Table 5.5, there are two major interactions of the ballot interfaces: navigation and selection. Navigation interactions are required to navigate among different pages, different political parties/candidates and different options available in settings menu. Selection interactions are required to select an option provided in the interfaces and also to confirm the vote.

5.2.2 Multi-modality

A voting interface with both touch and buttons was designed based on the results obtained from the interviews and literature review. As shown in Figure 5.1, voter with visual impairment can vote using either the touch interface or using the button interface. This is based on the underlying design concept of multi-modality. "*A multimodal HCI system is simply one that responds to inputs in more than one modality or communication channel*" [80]. Multimodal guidelines by Reeves et al was followed when designing interfaces to adhere for multi-modality [81],

- Designed for the broadest range of users and contexts of use, since the availability of multiple modalities supports flexibility.
- Multimodal systems should be designed to adapt easily to different contexts, user profiles and application needs

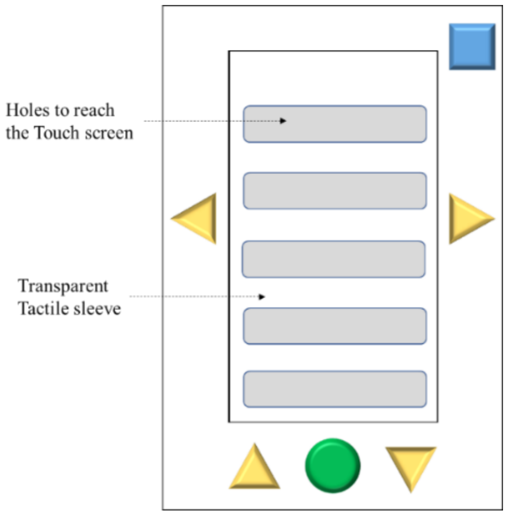

Figure 5.1 : Voting Interface with the Tactile Sleeve

Voting systems designed based on touch interfaces have reported in many errors due to accidental touch [82]. And also, interviews (See section 4.3) also showed the difficulty of scanning the whole touch screen in terms of using touch phones. Thus, a tactile sleeve is designed to act as a guidance as shown in Figure 4. It shows that a tactile transparent sleeve with holes is placed on top of the touch interface.

For easy reference, interfaces are named as follows.

- Voting interface with buttons: Button Tactile Ballot (BT Ballot)
- Voting interface with touch: Touch Tactile Ballot (TT Ballot)

5.2.3 Using Button Tactile Ballot

In the Button Tactile (BT) Ballot (Figure 5.2), up, down and settings buttons are used for navigation and select (circular green) button is used for selections (Figure 5.3).

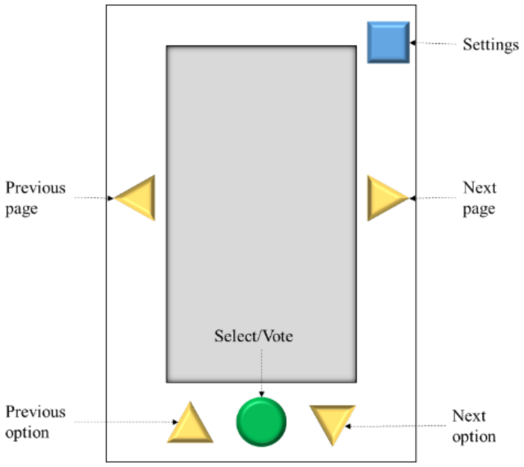

Figure 5.2 : Button Layout and Relevant Functions

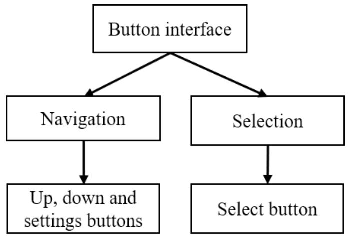

Figure 5.3 : Interactions of Button Interface

The political parties or the candidates are announced through audio recordings. After each political party/candidate, there is a pause allowing the voters to cast their vote. If the voter prefers the political party/candidate, then the voter should press the green circular button (Figure 5.2). Otherwise the voter can wait to the system announces the next political party/candidate or press the yellow triangular button on the right side (Figure 5.2). After a voter presses the green circular button, voter is instructed to confirm the vote using the same button.

Persons with visual disabilities prefers buttons since those are inducing the touch feeling. Here certain factors were given consideration with respect to tactile button layout feature.

- Unique shapes of buttons to perform different functions. Visually impaired persons are familiar with different shapes and they can identify the shapes easily when proper instructions are given.
- Circular button is used to vote or confirm a selection. Triangular shaped buttons are for navigation (up and down a list, next and previous among pages). Square shaped button is for adjusting system settings. Buttons are placed in different locations for the ease of identifying buttons with less confusions.
- Button are kept closer to edges because it was observed that blind persons tend to touch the corners and edges of items which they come across in day to day life, especially mobile phones.

5.2.4 Using Touch Tactile Ballot

In the Touch Tactile (TT) Ballot, single tap and double tap on the holes in the tactile sleeve are performed for both navigation and selection interactions (Figure 5.4). The political parties or the candidates are listed. When a hole is tapped once, the relevant political party/candidate is announced. If the voter requires to vote, then the relevant hole has to be double tapped. The voter is instructed to confirm the vote by tapping twice again through audio instructions (Figure 5.5). Here, the transparent sleeve with holes is used as a guidance to reduce the inconvenience of touching unintended areas and screen areas that has no response.

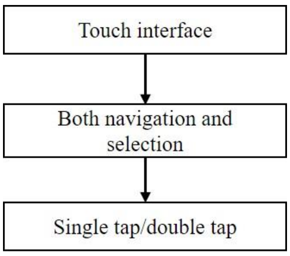

Figure 5.4 : Interactions of Touch Interface

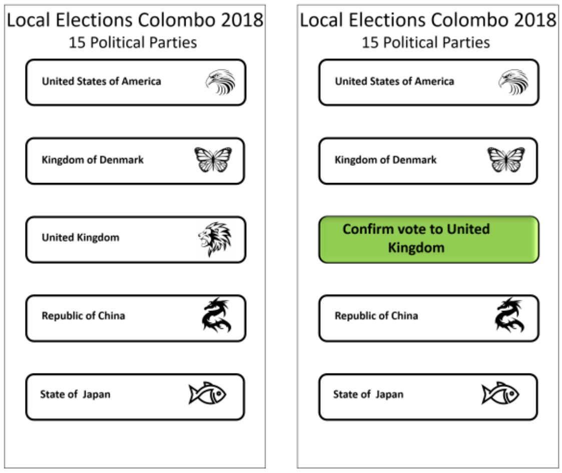

Figure 5.5 : Screens of Voting List and Vote Confirmation Prompt

Persons with visual disabilities have adapted the smart technologies incorporated with touch interfaces according to background and requirement analysis conducted earlier. Here certain factors were given consideration with respect to tactile sleeve feature.

- Tactile sleeve is transparent and it is placed upon the touch screen. Voter can access the touch interface through the holes.
- Edges of the holes in the tactile sleeve acts as a guidance to understand the boundary and thus, locate different holes one below the other.
- This supports to avoid the touching of inactive areas on the touch display, which is an issue identified in existing touch-based voting systems. Thus, the voter knows by intuition that holes are the only active areas.
- Touch interface supports mainly the personas of low vision persons and non-blind voters.

5.2.5 Inputs

Satisfying universal design concepts and following multimodality, voters are given the flexibility to vote via their preferred input method as follows:

- Voters can use the tactile buttons to caste the voter or perform other functions in the voting system.
- Voters can use the touch display by simply touching the holes to select and double tapping to confirm a selection made.

5.2.6 Outputs

Satisfying universal design concepts, voters are provided with perceptible information. To guide the voters throughout the voting process following methods are used:

- Voters can listen to the audio instructions that are being played automatically in a sequential manner, audio feedback when buttons are pressed and other prompts.
- Low vision voters can make use of the touch display.

5.2.7 Navigation

If audio instructions are followed sequentially without using touch interface, navigation in the voting system is linear. However, if the voter decides to make use of the tactile holes to vote or perform other functions, voter journey is not linear.

5.2.8 Visual design factors of user interfaces

Table 5.6 lists the factors considered in the visual design of the user interfaces displayed including justifications.

Table 14 : Visual Design Factors of User Interfaces

Factor	**Value**	**Guideline/ Framework/Research**
Font Styles	Sans-serif fonts, such as Arial or APHont or Courier	Research on Psychophysics of Reading America Foundation for Blind (AFB)
Font Size	18 point	AFB
Font line spacing	Spacing between lines of text is 1.5, rather than single space	AFB
Font Styling	Bold Avoid using italics or all capital letters.	AFB
Font colour	Black	AFB
Background colour	White	AFB
Colour contrasting options	White on black, Yellow on black, Black on yellow	[82]
Gap between select options	44px	Apple UI

5.2.9 System settings

Flexibility is a key factor to consider according to universal design where options should be provided for voters to make changes providing flexibility,

- Language selection
- Audio volume
- Colour contrast options
- Audio speed

Default settings are configured such that system is in medium audio volume, black text on white background contrast type, medium audio speed.

5.2.10 Further design considerations

Dimensions of the design is an important consideration where the finalized dimensions are described in the system implementation stage.

- Device dimensions
- Button dimensions
- Tactile hole dimensions
- Tactile dimensions
- System timeouts

5.3 Revised Design Concept and Design Features

Based on the analysis of the prototype results (*Section 6.5 Prototyping Analysis*), initial Ballots (See section 5.2) were revised along with the design features.

Figure 5.6 : Button Tactile Ballot and Touch Tactile Ballot (Front View)

Figure 5.7 : Button Tactile Ballot and Touch Tactile Ballot (Side View)

As shown in Figure 5.6 and 5.7, voter with visual impairment can vote using either the Button Tactile (BT) Ballot or using the Touch Tactile (TT) Ballot.

5.3.1 Voter Journey

Voter is instructed to wear the headphone by a polling official before the voter reaches the polling booth. After the voter reaches the polling booth and wears the headphone, he/she is instructed to tap on 'ENTER' to start (Figure 5.8).

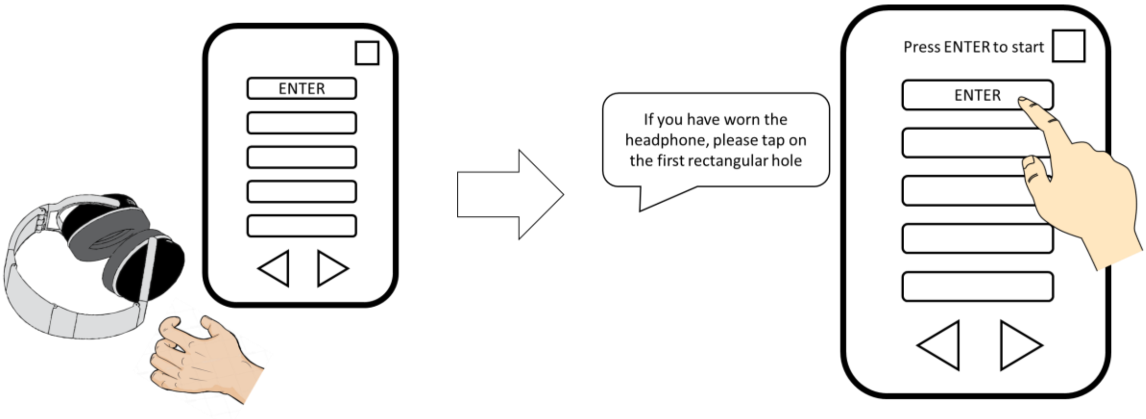

Figure 5.8 : Voter Journey Initiation

Then the voter is instructed to choose the preferred language (Figure 5.9). Voter is allowed to choose either of Sinhala, Tamil and English.

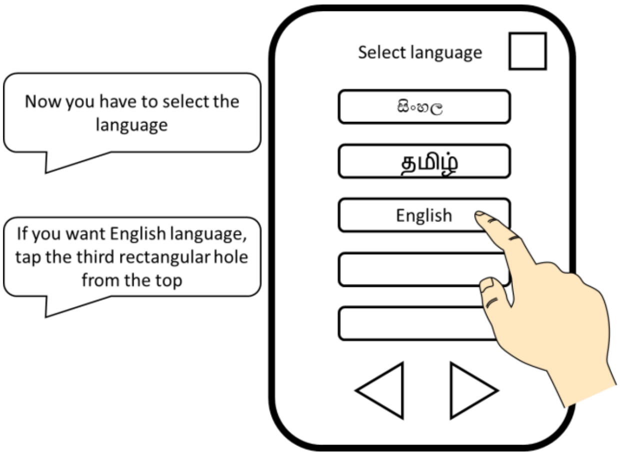

Figure 5.9 : Language Selection

After language selection voter is given a training (Figure 5.10 and Figure 5.11) on using the system controls specific to the interface selected for voting (either touch or buttons). Also, the voter can skip the training program. During the training, voter is acknowledged about the ‘settings’ by stating about the options available that can be modified: language preference, audio volume, audio speed, and colour contrast.

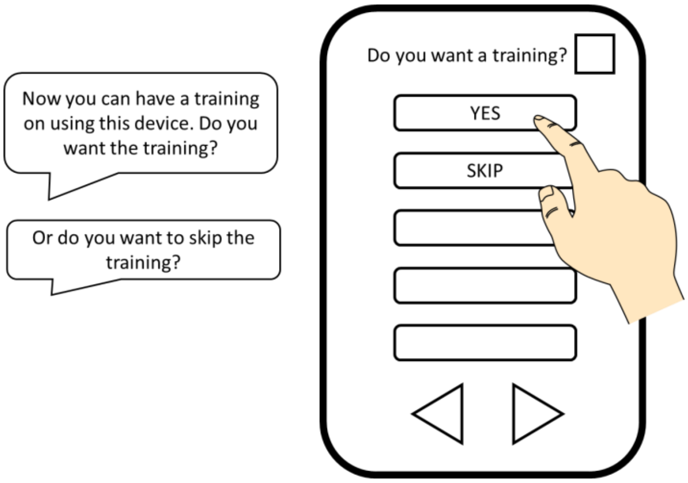

Figure 5.10 : Training Initiation

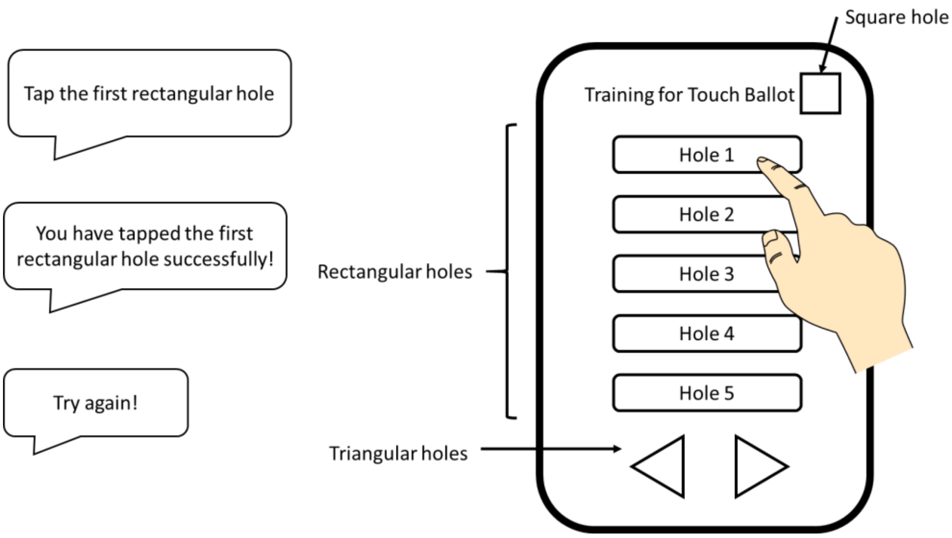

Figure 5.11 : Training Program

Next the system directs the voter to listen to the instructions on how to vote (Figure 5.12). Here also, the voter is allowed to skip the instructions. If the instructions are skipped voter is directed to voting page immediately.

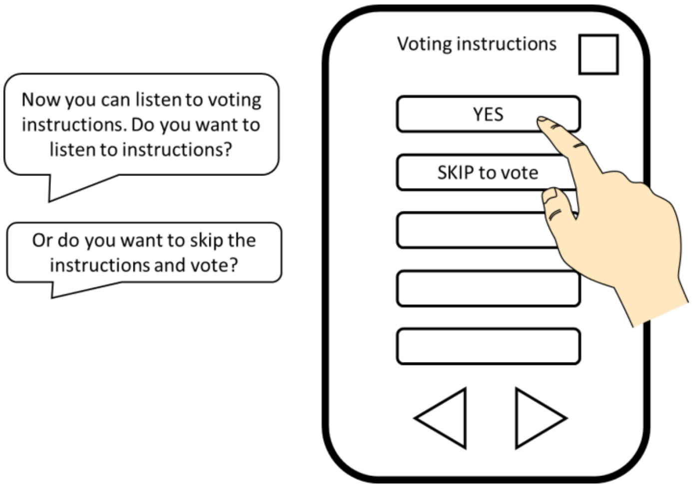

Figure 5.12 : Voting Instructions

If the voter chooses to listen to the voting instructions, he/she is asked whether they are ready to vote after playing voting instructions (Figure 5.13).

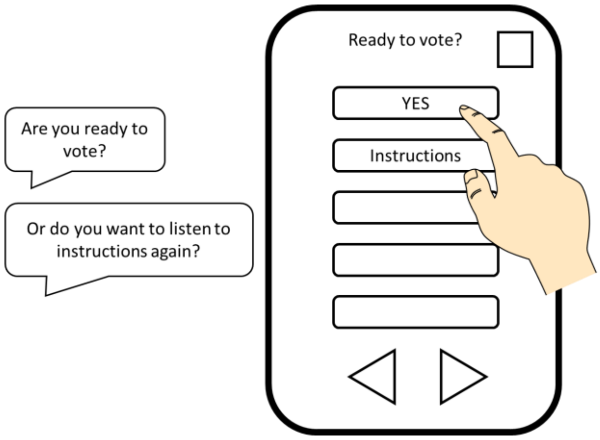

Figure 5.13 : Ready to Vote

When the voter is ready to vote, the voting list displayed (Figure 5.14). Here, the voter can select the preferred political party.

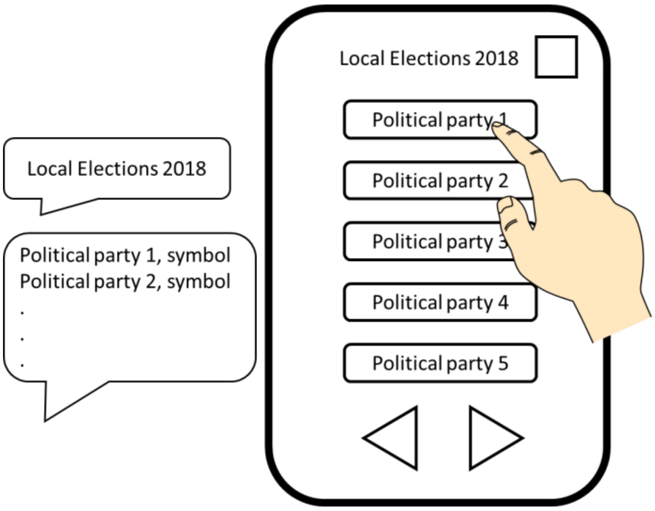

Figure 5.14 : Voting Page

Once the voter selects a political party, the system instructs the voter to confirm the vote by tapping again (Figure 5.15).

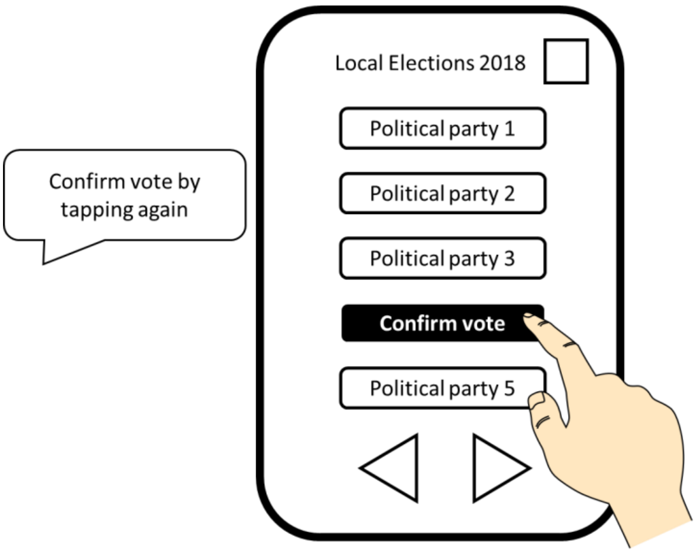

Figure 5.15 : Vote Confirmation

After confirming the vote, system acknowledges the voter about the successful completion of the voting and requests the voter to replace the headphone (Figure 5.16).

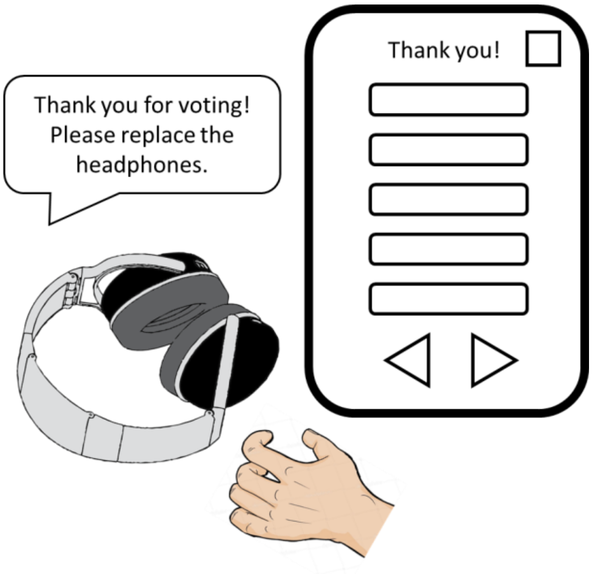

Figure 5.16 : Vote Completion

Voter journey was briefly explained here considering the touch interface. Sections 5.3.2 and 5.3.3 explains the in details procedure relevant to two interfaces separately.

5.3.2 Button Tactile Ballot

In the BT Ballot (Table 5.7, Figure 5.17), up, down and settings buttons are used for navigation and select (circular red) button is used for selections.

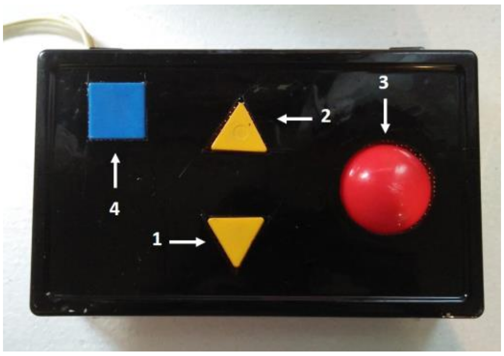

Figure 5.17 : Layout of Button Tactile Ballot

The political parties or the candidates are announced through audio recordings. After each political party/candidate, there is a pause (4 seconds) allowing the voters to cast their vote. If the voter prefers the particular political party/candidate, then the voter should press the circular red button (Figure 5.17). Otherwise the voter can wait until the system announces the next political party/candidate or press the yellow triangular button on the right side (Figure 5.17). After a voter presses the circular red button, voter is asked to confirm the vote by again pressing the same button. In this ballot, list is considered to be continuous rather than segregating to different pages. Thus, navigating along pages is not required. Table 5.7 lists the interactions performed during the voting process. Also, it shows the available ballot design features to support the interactions.

Table 15 : Interactions for Navigation and Selections Using BT Ballot and TT Ballot

Interaction	**BT Ballot**
Navigating to next option	Down button (1 in Figure 6)
Navigating to previous option	Down button (2 in Figure 6)
Navigating to settings option	Square button (3 in Figure 6)
Navigating to next page	Null
Navigating to previous page	Null
Selecting an option	Round button (4 in Figure 6)
Confirming an option	Round button (4 in Figure 6)

Colours and shapes for the Button Tactile Ballot were derived from the results of the prototype and previous research in a different context [83]. Justification for such adaptation from a different context is that, there is a lack of design guideline to follow when designing printed materials (not user interfaces) for blind context.

'Colour grab' android application was used to identify the colour codes of the paint available in local paint stores which required to choose contrasting colours. Colours chosen were #B93136: Red, #CFBD49: Yellow and #0030B9: Blue.

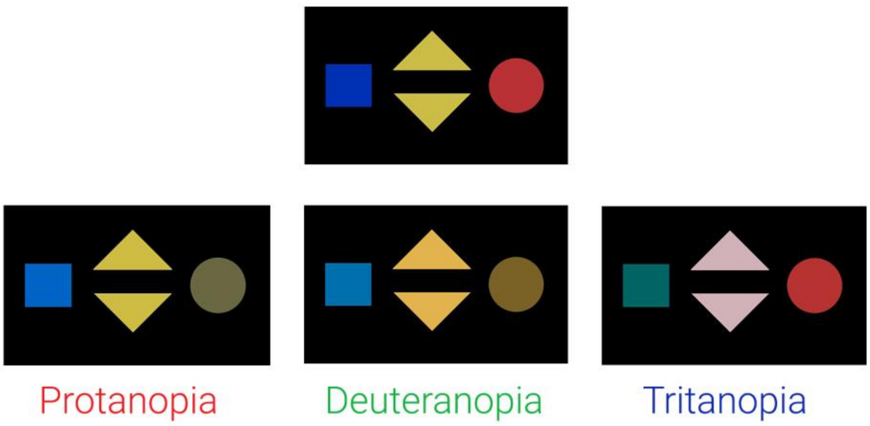

Figure 5.18 : Colour Contrast of Buttons

‘Colourblind Free’ android application was used to view button layout colours for different colour blind categories which is based on ImageJ/Vischeck simulation model. Figure 5.18 shows how the buttons appear for the main 3 types of colour blindness categories.

5.3.3 Touch Tactile Ballot

The TT Ballot is displayed in Figure 5.19. The political parties or the candidates are listed. When a hole is touched/tapped once, the relevant political party/candidate is announced. Then the voter is instructed to confirm the vote by tapping again through audio instructions. Here, the transparent sleeve with holes is used as a guidance to reduce the inconvenience of touching unintended areas and screen areas that has no response.

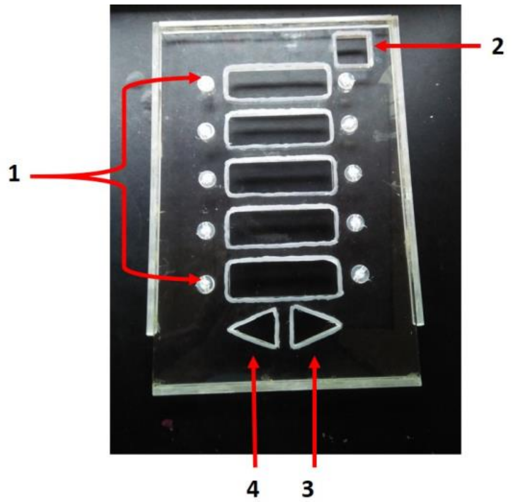

Figure 5.19 : Layout of the Touch Tactile Ballot

Table 5.8 lists the interactions performed during the voting process. Also, it shows the available ballot design features to support the interactions.

Table 16 : Interactions for Navigation and Selections Using BT Ballot and TT Ballot

Interaction	**TT Ballot Feature**
Navigating to next option	Touch/Tap relevant hole (1 in Figure 5.19)
Navigating to previous option	Touch/Tap relevant hole (1 in Figure 5.19)
Navigating to settings option	Touch/Tap square shaped hole (2 in Figure 5.19)
Navigating to next page	Touch/Tap triangular shaped hole (3 in Figure 5.19)
Navigating to previous page	Touch/Tap triangular shaped hole (4 in Figure 5.19)
Selecting an option	Touch/Tap relevant hole (1 in Figure 5.19)
Confirming an option	Touch/Tap relevant hole again (1 in Figure 5.19)

5.4 Design Features of the Ballots

Table 5.9 summarizes the design features of the ballot interfaces designed to support voters with visual impairment. It explains the justifications for these features and how the Universal Design guideline has been followed.

Table 17 : Design and Justifications

Design	**Justification aligning Universal Design (UD) Principles and Multi-modality (MM) guidelines by Reeves et al** [81]
Two ballot interfaces	UD Principle 2: Flexibility in Use MM: Designed for the broadest range of users and contexts of use, since the availability of multiple modalities supports flexibility [81]. Voters are given two methods of doing voting. They can choose their preferred method.
Having button controls	UD Principle 4: Perceptible Information

with unique features	Satisfying both two sub principles in UD, buttons have different shapes and colours. Thus, it is easily identifiable by persons with visual disabilities by feeling the shape of button. Having differently shaped buttons also helps to guide the voter with instructions.
Button Tactile Ballot: Voting by listening to the list of political parties/candidates and selecting within the given period of time interval	Principle 3: Simple and Intuitive use Principle 6: Low Physical Effort Here the complexity of voting is maintained by the simple press of a button while listening to audio clips. And also, it does not require high physical effort.
Touch Tactile Ballot: Simply touching/tapping the desired option	Principle 3: Simple and Intuitive Use Voters being familiar with single touch/tap interaction due to their experience in using smart phones.
Tactile sleeve with punched holes on top of the touch interface	Principle 6: Tolerance for Error MM: Error Prevention/Handling Tactile sleeve acting as a guidance for voters that would avoid touching unintended areas and less prone to errors that were reported in an existing voting system, which have touch interfaces [82].

5.5 User flows

User flows were drawn based on the template by Interaction Design Foundation [57], as explained in methodology chapter. User flows supports in visualizing the voter journey whilst addressing main flows and alternative flows described in use case narratives (*Section 4.6 Use Case).*

5.5.1 User Flow 1: Complete Voting Flow

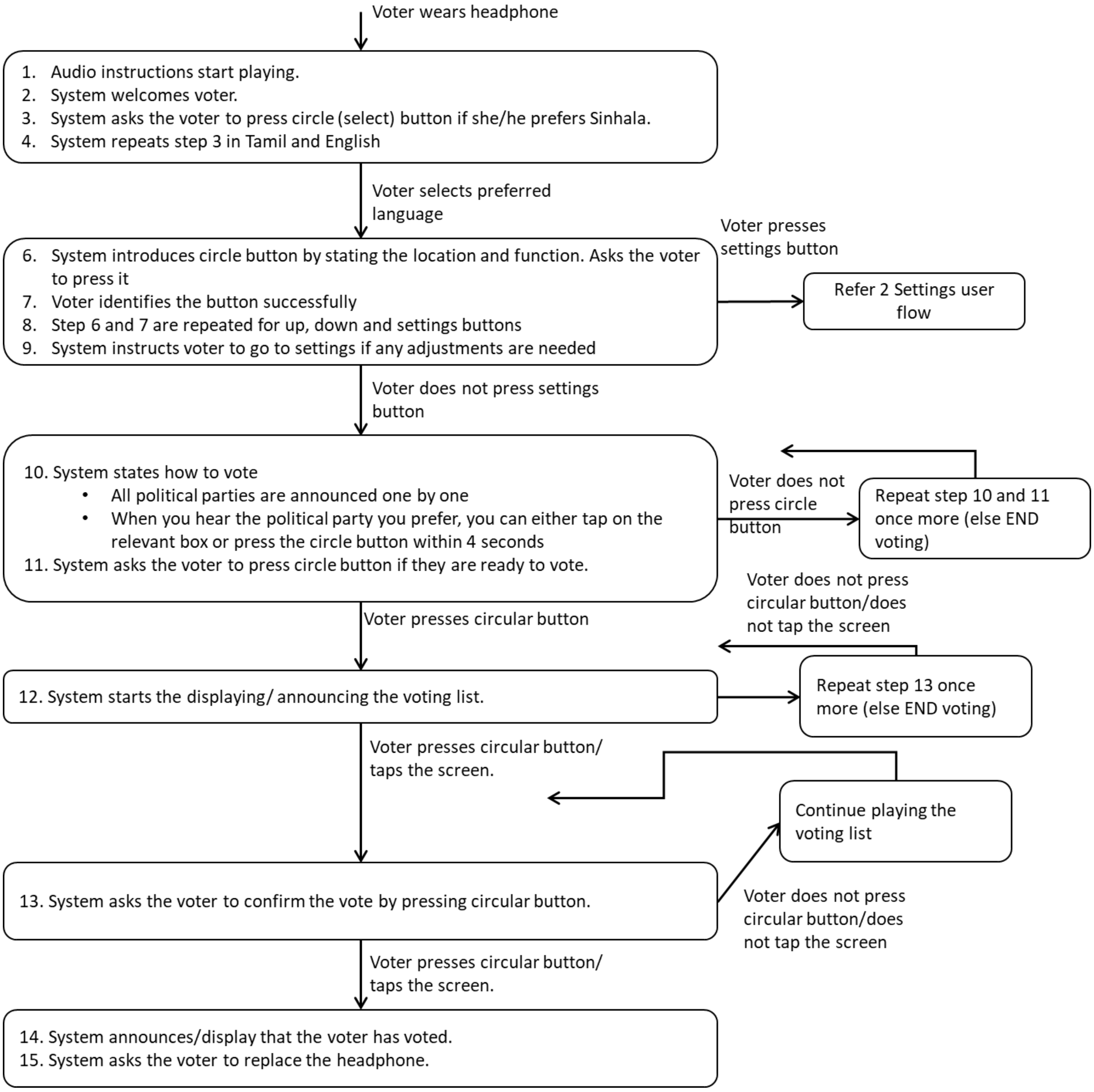

Figure 5.20 : User Flow 1: Complete Voting Flow

System starts the blind voter journey only when the voter wears the headphone (Figure 5.20). Thus, audio instructions are initiated to play. Voter is instructed to choose the preferred language. After language selection voter is given a training on the system controls (buttons or holes in touch interface) with an introduction about the settings button. Then the system notifies the voter that she/he has to vote now. Voter selects her/his preference and confirms the vote. System acknowledges the voter about the successful completion of the voting and requests the voter to replace the headphone.

5.5.2 User Flow 2: Settings Flow

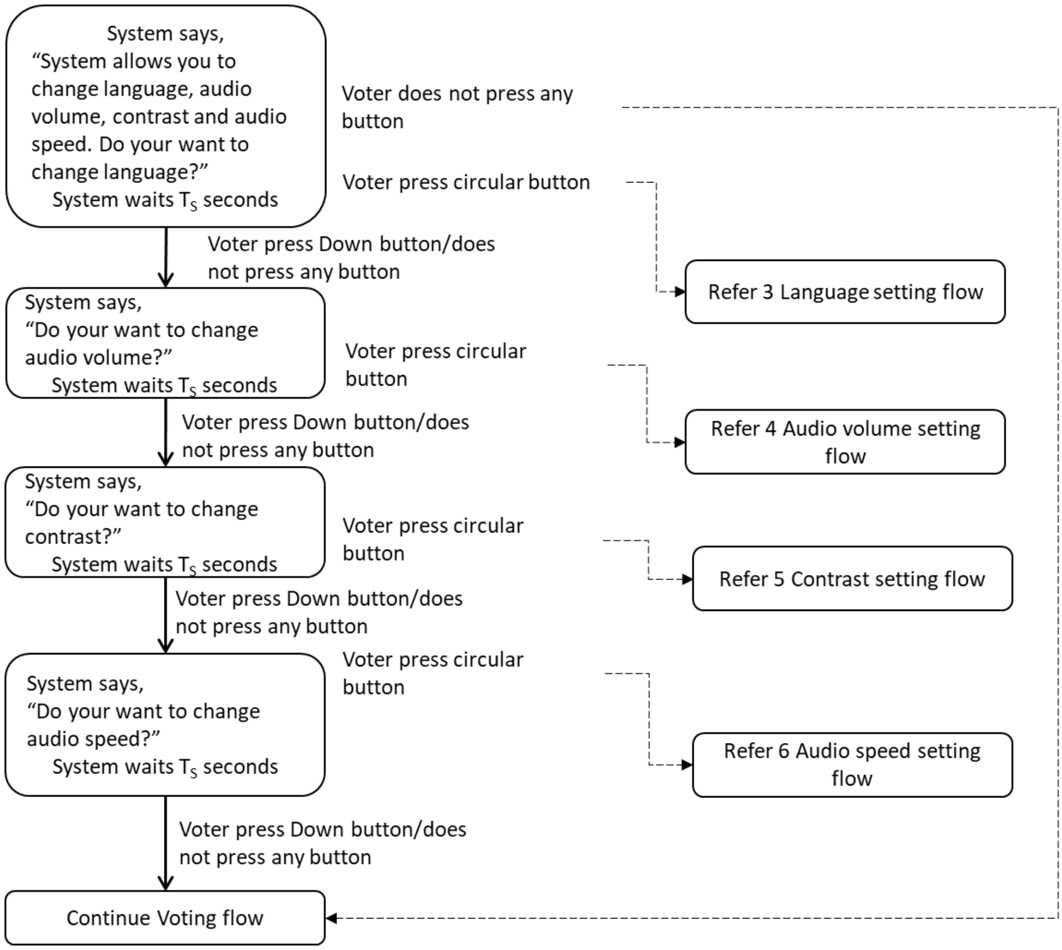

Figure 5.21 : User Flow 2: Settings Flow

As in Figure 5.21, if the voter presses the settings button, voter is given the opportunity to change settings under four criteria as explained in design concept: Language preference, audio volume, contrast options, and audio speed. For every option selected, voter is directed to separate user flows. The user flows for each setting are illustrated in Appendix D.

6 Chapter Six: Prototyping

As explained in methodology section a design workshop was conducted to obtain user feedback on the suggested voting interfaces by providing a prototype (Figure 6.1). Prototype was built using MS PowerPoint slides to show the necessary content, a laptop with a touch interface, tactile sleeve made out of rigifoam, rubber buttons and wireless headphone to play audio instructions. The voting list was constructed using country names. The symbols show the animals used by countries to represent their nation. A sample set of audio instructions were recorded by three voices and was subjected to expert evaluation. Then the necessary modifications were made in the instructions and how the speakers convey the instructions before using the voice clips in the prototype.

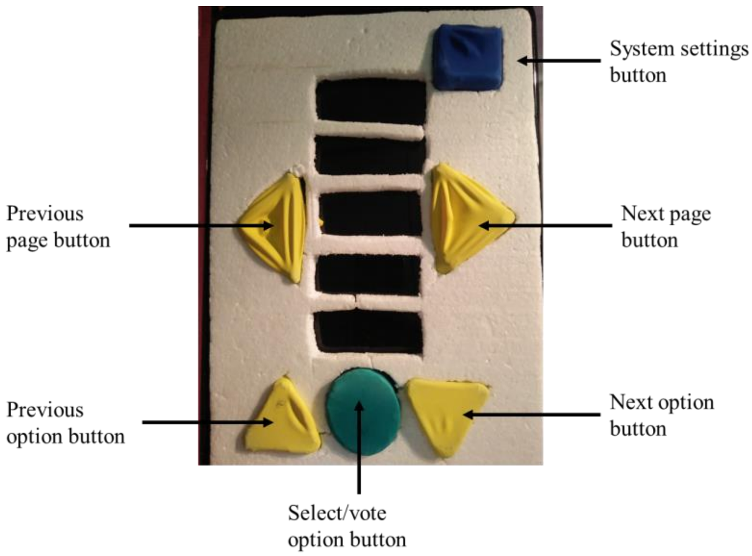

Figure 6.1 : Prototype

Figure 6.1 shows how the tactile sleeve appears to be when screen is off.

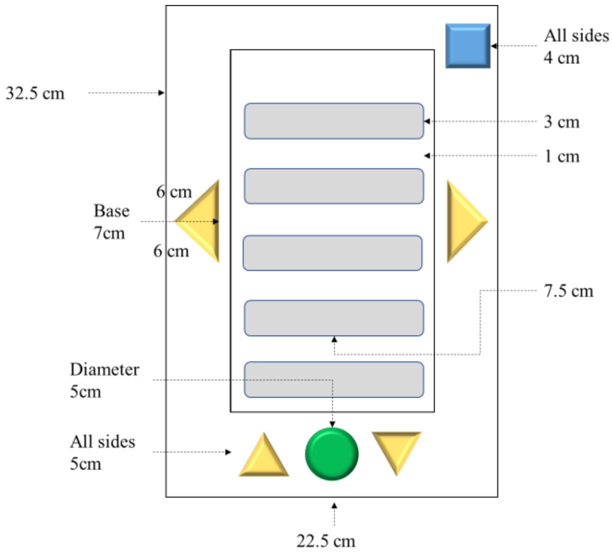

Figure 6.2 : Prototype with Dimensions

Figure 6.2 shows the dimensions of the prototype and Figure 6.3 shows how the prototype is visible when the voting list is provided **without** the tactile sleeve.

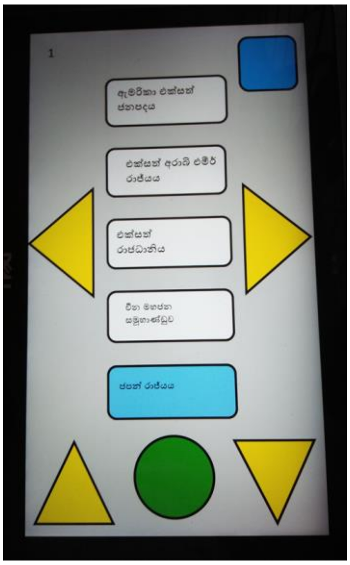

Figure 6.3 : Prototype without Tactile

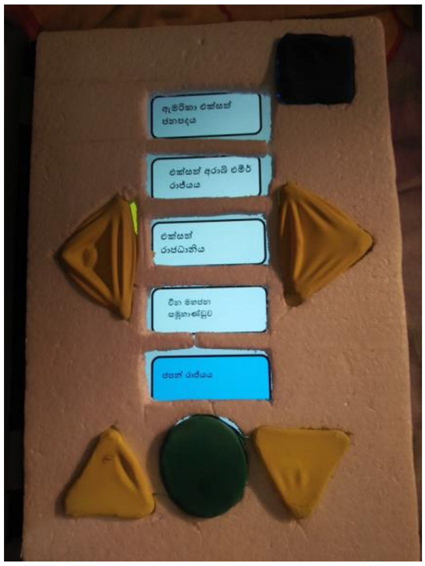

Figure 6.4 : Prototype with the Voting List

Figure 6.4 shows how the prototype is visible when the voting list is provided **with** the tactile sleeve.

6.1 Pre-survey with Participants of the Workshop

Participant ages of the sample were in the range of 20 years to 74 years (Table 6.1), where the average participant age was around 40 years. Among the participants, three (3) were partially blind and remaining majority of participants were total blind. All the participants had experience in using smart phones.

Table 18 : Demography and Blind Context of Participants of the Design Workshop

Age (years)	Gender	Blind at age (years)	Blind category	Smart phone experience	Tap vs Slide rule
20	Female	Birth	Total blind	Yes	Tap
25	Male	10	Total blind	Yes	Slide rule
25	Female	15	Total blind	Yes	Tap
28	Male	Birth	Partially blind	Yes	Tap
33	Male	17	Partially blind	Yes	Tap
47	Female	43	Partially blind	Yes	Tap
67	Female	4	Total blind	Yes	Tap
74	Male	10	Total blind	Yes	Tap

6.2 Participant performance of using button interface

Participants were instructed to identify and press the buttons based on the shape and the location of the buttons. Figure 6.5 shows how the participants could locate the buttons. All the participants were able to recognize the ‘select’ button, ‘next’ button, and ‘previous’ button at the first attempt. However, the ‘next page’ button and ‘previous page’ button were not identified by 88% of the participants in any of the attempts. Only 25% of the participants were able to identify the ‘settings’ button in the first attempt and the remaining participants were able to identify it at the second attempt. Most of the participants who identified the ‘settings’ button in second attempt, pressed the ‘next page’ button mistakenly in the first attempt. One of the participants stated that, ‘I did not think that this device has that much length. So, I did not take my hand that far'. Another participant with partial blindness mentioned that contrast of yellow colour of triangular buttons and green colour of circular button is not sufficient and it is confusing.

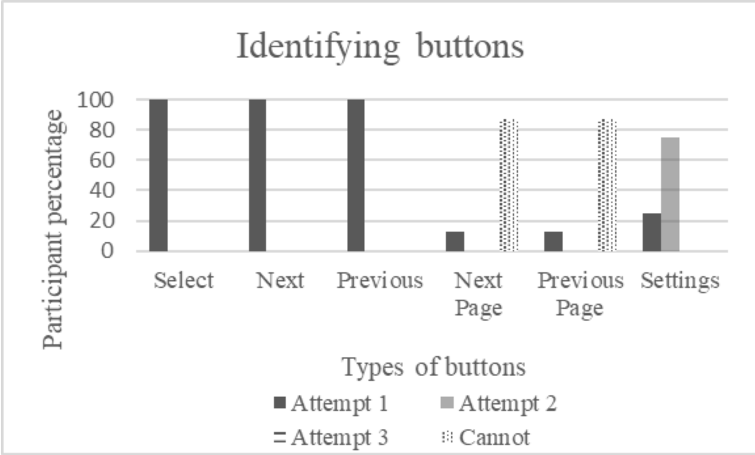

Figure 6.5 : How the Focus Group Identified Buttons

Then the functions of the buttons were explained to the participants and they were asked to press the correct button relevant to a particular function. The buttons were asked to press in the order: select, next, previous, next page, previous page, and settings. All the participants were able to identify the 'select' button and the 'settings' button at the first attempt but several attempts were made to identify other buttons (Figure 6.6).

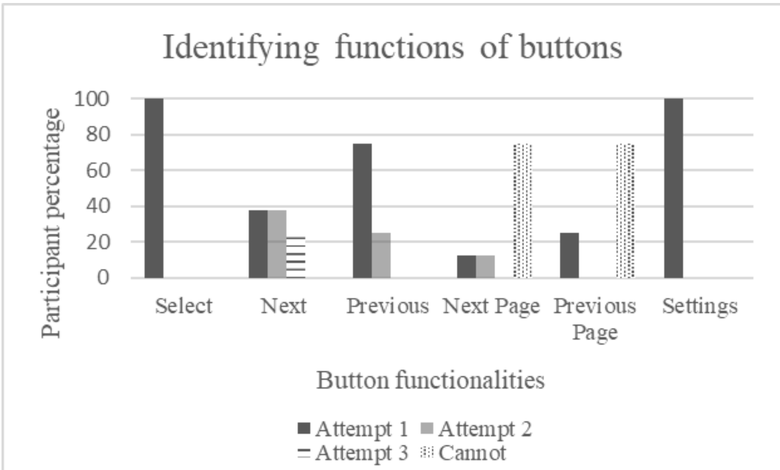

Figure 6.6 : Identifying Functions of the Button

63% of the participants could not figure out the 'next' button from the first attempt. It was observed that, they pressed the 'previous' button when they were asked to press the 'next' button. Although they made several attempts to identify the 'next' button, they easily identified the 'previous' button (triangular button on bottom left) because earlier they identified that the other button (triangular button on bottom right) is 'next' button.

Only 25% of the participants were able identify the ‘next page’ button and the ‘previous page’ button. Remaining 75% of the participants pressed the ‘next’ and ‘previous’ button instead of pressing ‘next page’ and ‘previous page’ buttons respectively. Some participants stated that having pages and navigating through pages is uneasy for them.

Some stated that space between buttons should be increased and few suggested that button shapes can be easily identified if the button sizes are reduced somewhat. Majority stated that shapes are unique and that they can figure out what they are. Few suggested that it would be better to have any mark on the triangular shaped buttons to differentiate between up and down functions.

6.3 Participant performance of using button interface

Participants were asked to identify and touch the five holes on the tactile sleeve in a sequential ascending order (1st hole, 2nd hole, 3rd hole, 4th hole, 5th hole). All the holes were identified by the participants but the attempts at which the holes were identified varied slightly (Figure 6.7). All the participants identified the 2nd, 3rd and 5th hole at the first attempt. 75% of the participants identified the 1st hole in the first attempt but 25% identified it in the second attempt. One of the participants who could not attempt correctly in the first attempt stated that, “I could not figure out where the holes started”.

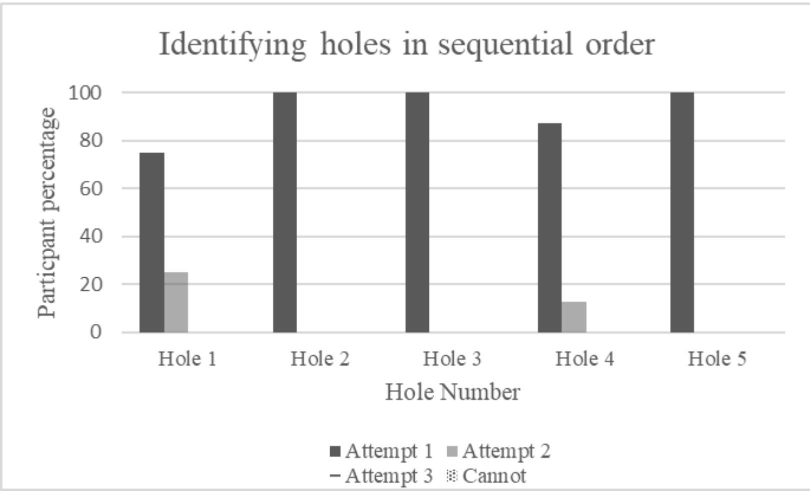

Figure 6.7 : How the Focus Group Identified Holes in Sequential Order

Then the participants were asked to identify and touch the holes in a random order (2nd hole, 4th hole, 3rd hole, 5th hole, 1st hole). Similar to the activity of identifying holes in sequential order, participants were able to identify all the holes in different attempts. All the participants were able to identify the 5th hole or the last hole. It was noted that 4th hole was identified correctly in several attempts (Figure 6.8) but identifying the 3rd hole showed a greater success. The participants explained that identifying the 3rd hole was easier since they knew where the 4th hole was located. Participants responded stating that starting hole of the device was not easily identifiable.

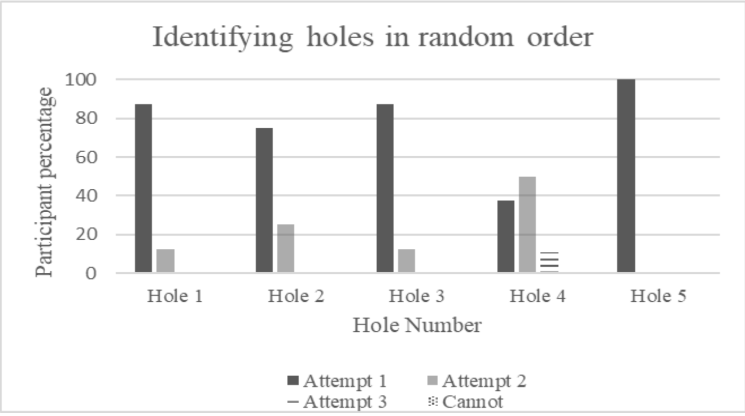

Figure 6.8 : How the Focus Group Identified Holes in Random Order

Participants were asked to rate about their preference about using a tactile sleeve (Figure 6.8). Majority of the participants (65.5%) rated the sleeve with holes as ‘good’. Participants preferred the sleeve explaining that, it helps them to touch the appropriate places without having to touch the whole screen. Participants with total blindness suggested that this design can be further improved if some guidance is present to track the holes instead of having to guess or remember the hole location.

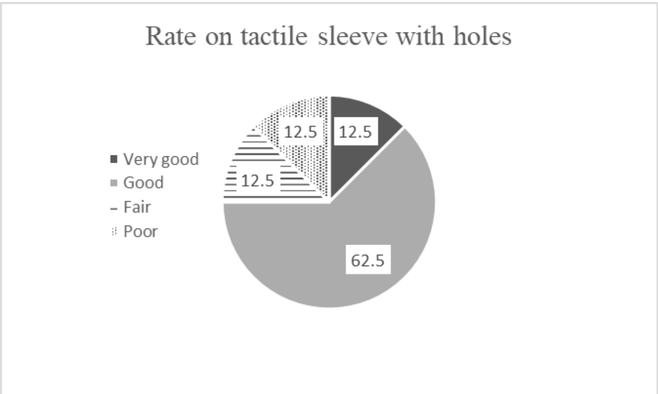

Figure 6.9 : Participant Rating on Tactile Sleeve (Percentage wise)

It was observed that participants required more space on the tactile sleeve without buttons, where they can rest their hand. It was stated that the sizes of the holes are sufficient but the space between holes required to be increased. Two participants stated that having five (5) holes is familiar to them and another participant stated, “it is not hard to identify 5 holes. 5 is easy. I think I can figure out even more”.

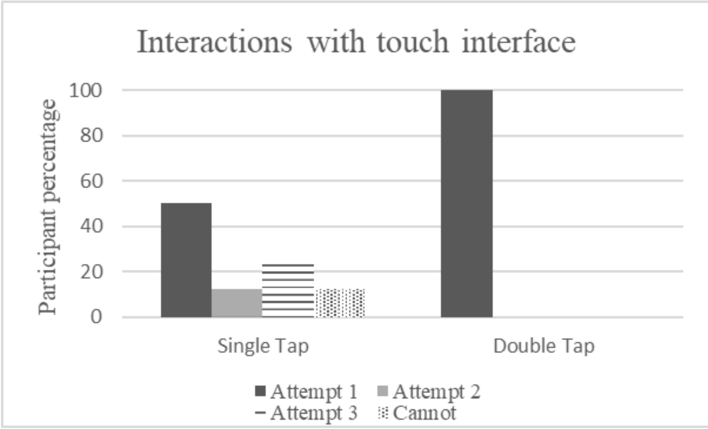

Figure 6.10 : How Focus Group Performed Interactions with Touch Interface

Next participants were asked to vote for a particular political party by giving instructions. The objective behind this activity was to identify their ability to perform single tap and double tap with the touch interface (Figure 6.10). Here the participants were asked, ‘What is the political party represented by the 1st hole?”. They are expected to perform a single tap on the 1st hole which results in playing an audio clip that announces the political party represented by it. Only 50% were able to do a single tap correctly at the first attempt whilst 12.5% could not do it. It was observed that they performed a double tap instead of a single tap.

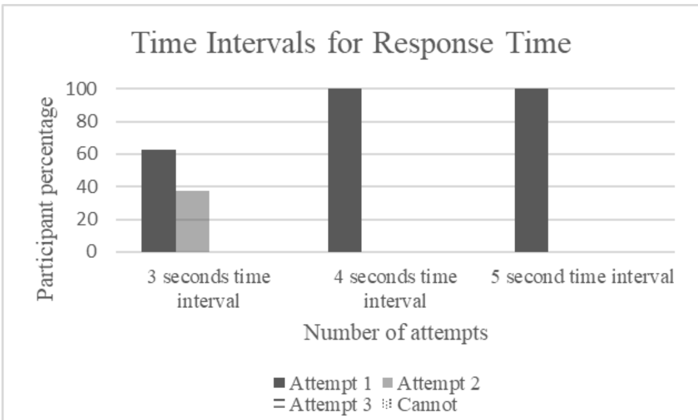

Figure 6.11 : Performance in Different Time Intervals for Response Time

Then participants were asked to vote the same political party. They were expected to double tap to vote. This was successfully performed by all participants at the first attempt. It was observed that all the participants were having the grip on the device by their left hand and were pressing the buttons using right hand only. Same was observed in how they used the tactile sleeve as well.

It was required to find a suitable time interval which acts as the maximum waiting time for a voter response for a given audio instruction. Participants were asked to press the 'select' button when a particular political party is played by the audio clips. These clips were played with 3 seconds, 4 seconds and 5 seconds time intervals (Figure 6.11). All the participants were able to vote within 4 seconds and 5 seconds time intervals in the first attempt but only 62% was able to vote within 3 seconds time interval in the first attempt. From the feedback received 62% mentioned that 3 seconds were enough but remaining stated that at least 4 seconds time interval is required.

6.4 Participant feedback on using both interfaces

They were asked to choose their preference between the two methods of suggested voting (Figure 6.12). It was observed that partial blind voters preferred more in voting using the touch interface with the sleeve and total blind voters preferred more in voting using buttons with time intervals.

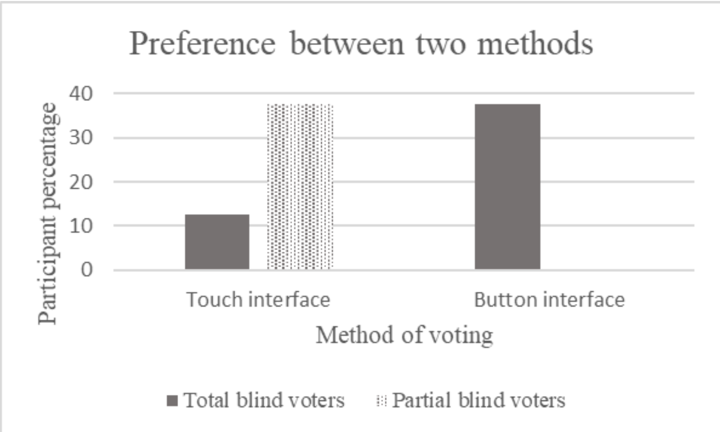

Figure 6.12 : Participant Preference on Ballots (Percentage-wise)

6.5 Prototype Analysis

From the feedback and observations, following interpretations were made that require consideration for modifications. These modifications were addressed in the next stages of the system implementation.

- Buttons for page navigation has to be reconsidered, either in terms of the location or any other way of performing the function.

- Holes are recognizable but there should be a further indication of guidance for them to reach the first hole. And also, an additional feature is required to improve the understanding of the five holes distinctly.
- Double tap is easily performed. Some tend to use double tap instead of single tap when single tap is required. This leads to the consideration of not separating functions based on single or double tap categorization but rather allowing to consider any tap (double or single) as in input.
- Time intervals with at least 4 seconds is enough in general.

From the interviews conducted with voters with visual impairment, it was understood that they all had some sort of experience in using mobile phones compared to other IT related devices. However, their experience in using different types of mobile phones varied. Majority (66%) had an experience of using smart phones but there were persons who had only the experience of using a basic mobile phone with buttons or keypads. Thus, in order to interact with the voting system, voters should be provided with several options such that they will choose the more familiar way, which is bringing in multi-modality concept for voting. The availability of more than one way navigate or use the system is accommodating the 2nd Universal Design principle of Flexibility in Use [84]. Few systems are designed based on this concept whereas certain challenges remain that needs to be addressed. As mentioned in the earlier in introduction section, voice-based voting is claimed accurate only within certain environments with respect to sound distortions. Thus, it leads to the discussion of tactile (using buttons) voting and touch based voting.

Tactile voting is facilitated by a button interface that are in different shapes which are uniquely identifiable in different locations satisfying the underlying 4th universal design principle of Perceptible Information [84]. Button shapes and colours were designed similar to the EZ control keypad, which is used by some existing voting systems as an assistive tool [85]. Based on the evaluation and feedback by the focus group users of the design workshop it was discovered that colours have to be refined because some blind persons have difficulties with respect to colour contrast.

Additionally, this shows that solely depending on colour is also not sufficient. Thus, different shapes were used to improve uniqueness of the buttons. According to the prototype results, ‘next’ and ‘previous’ buttons were identified by trial and error even after providing instructions. Thus, those buttons should be placed together, giving a natural intuitive feeling of going up and down rather than placing on the right and left (Figure 6.13).

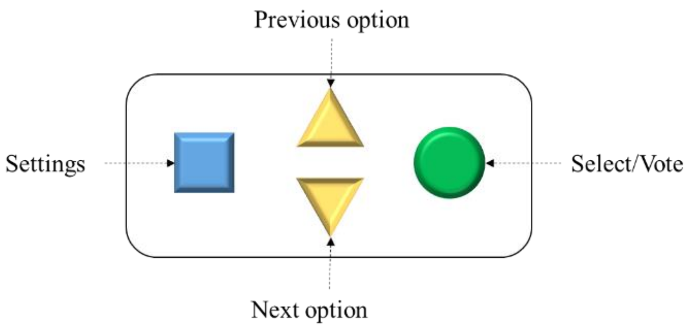

Figure 6.13 : Revised Button Layout

Although it was attempted to make the buttons easily identifiable by keeping the buttons in different locations, results showed it was inconvenient for the blind voters. For an instance ‘settings’ button was far away for the participant to approach. Thus, buttons should be placed at close proximity (Figure 6.13).

Next page and previous page buttons made less sense to the participants. They considered ‘next’ button as ‘next page’ and ‘previous’ button as ‘previous page’ button. Instead of going through pages, the suggested approach is to consider a single page which can be scrolled down from ‘next’ option after each five political parties/candidates. This is more intuitive because it is more similar to the paper-based voting, where only a single long ballot paper is provided for voting in Sri Lankan context.

In existing voting systems with touch interfaces [82] some inefficiencies were reported and identified as in the literature: accidental touch, vote-changing errors, unfamiliar touch interaction, tapping inactive areas. These inefficiencies can be reduced by allowing voters to reach only the active areas in the touch interface by the support of a transparent tactile sleeve with holes aligned with voting options. Thus, to mark the preference voter can listen to the voting list announced via the audio sequentially and vote for the desired by pressing button controls or tapping on the screen. Prototype results show that, users are capable and prefer to use the tactile sleeve. However, it was observed that some participants used trial and error in tracking the holes. Thus, improvements have to be made by including a feature as a guidance to track the holes, so that they do not require to remember the holes or guess.

In order to interact with the touch interface, tapping method was used instead of ‘Slide rule’ [58]. Slide rule was not considered because an existing voting system that has used slide rule interaction reports that it is less natural for blind voters [82] and also, interview results and workshop pre-survey shows the same results. Even though single tap is performed when using smart phones to listen to a description, prototype results showed that majority of the blind persons are familiar with double tap more than single tap. But there were also some participants who were familiar with single tap gesture. Thus, to listen to a description or make any kind of selection (selecting settings options, vote, confirm, etc) either tap should be allowed, where no restriction is placed. Here, after any tap gesture (single or double), a description of the selected area is described and the voter is asked to tap (single or double) again if it requires to be selected.

6.6 Chapter Summary

Results obtained from the design workshop with the prototype showed that design features have to be modified in some areas in order to improve the voting experience of the voters with visual impairment. Sizes and functions of some buttons have to be reconsidered. Tactile interface with holes requires further consideration in order to increase usability. The design was modified and is explained in the *Section 5.1 Revised Design Concept and Design Features*.

7 Chapter Seven: Implementation

This chapter explains how the system was developed based on the analysis of the prototype results and modified design concept. The architecture of the voting solution including software and hardware aspects are described. Factors considered when developing user interfaces and other design considerations are also explained in this chapter.

7.1 Architecture of the system

Figure 7.1 displays the architecture of the system comprising of software components (bottom box) and hardware components (top box).

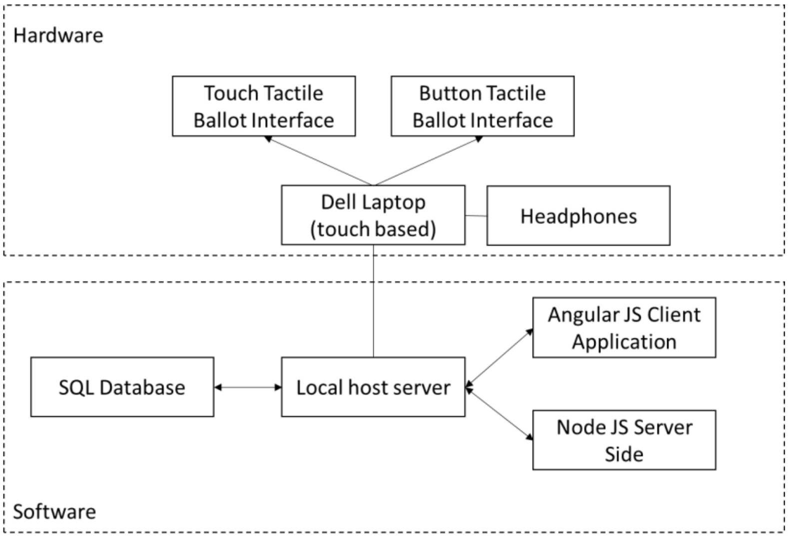

Figure 7.1 : System Architecture

7.1.1 Hardware

In this study, we used a Dell Inspiron 13-5378 SE with touch support, which is appropriately sized in conducting an election. Dimensions of the device in system implementation is shown as in Figure 7.3. Changes in dimensions are due to the response received for the prototype device.

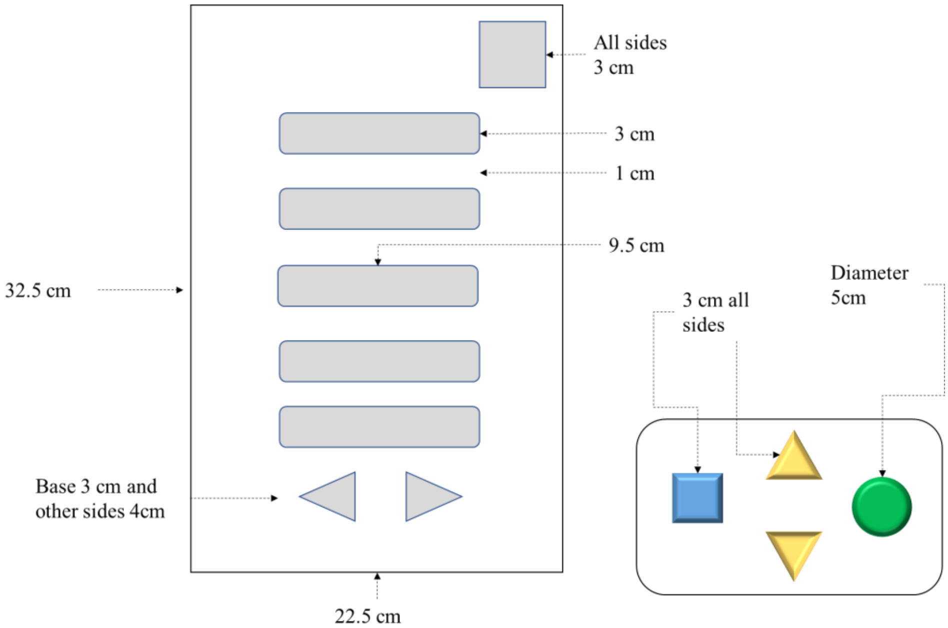

Figure 7.2 : Final System Device Dimensions

7.1.2 Software

Front end was developed using Angular Java Script. Node Java Script was used for capturing data and keeping logs. Although the design is not related to Internet voting technologies, scripting languages were used only for the purpose of preparation of the prototype ballots.

System timeout was set based on the Voluntary Voting System Guidelines [86]. System stays active without any user actions for 3 minutes. System waits for 4 seconds till voter makes a selection and confirmation, which was decided based on the prototype results.

7.2 Audio Instructions

By following guidelines of American Council of the Blind, audio instructions were written for the journeys of the two interfaces separately [87]. The instructions can be found in Appendix G.

7.3 Functionalities

This section explains the functionalities in brief. Further explanations of these functionalities with voter user flows can be found in *Section 5.3 User flows.*

7.3.1 Language selection

This functionality allows the voter to choose the preferred language since the local context is a multi-ethnic community (Figure 7.3).

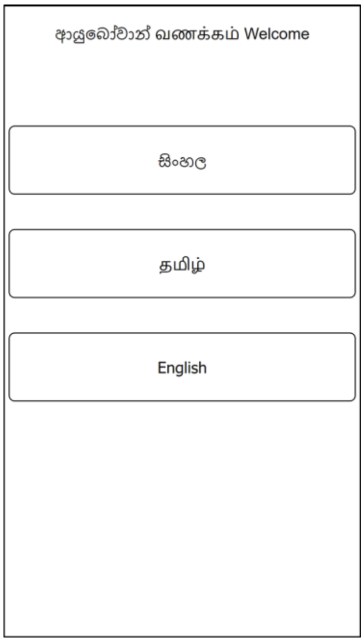

Figure 7.3 : User Interface for Language Selection

7.3.2 User training

First time voter can make use of this functionality to learn the system controls such as identifying the locations and the functions of the Button Tactile Ballot, identifying the holes of the Touch Tactile Ballot. This is not a mandatory step in voting and can be skipped.

7.3.3 Changing system settings

Voter has the liberty to adjust the system according to their preferences and pace (Figure 7.4). The available adjustable settings are to change language, change colour contrast, change audio speed and volume.

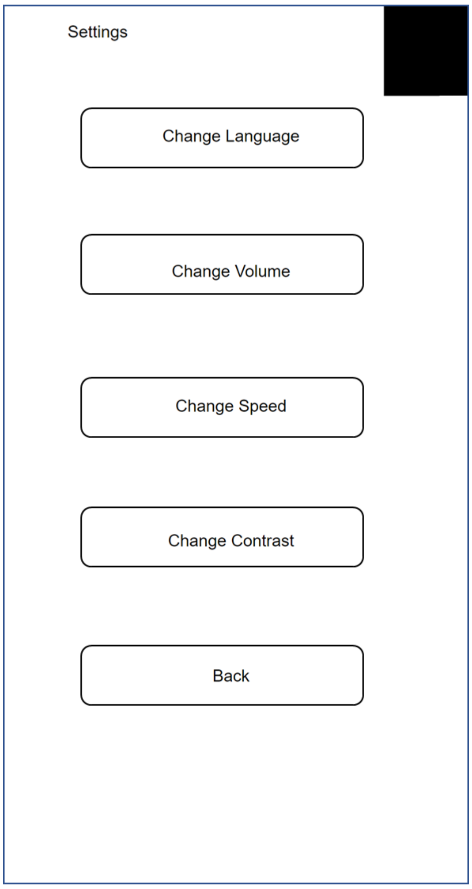

Figure 7.4 : Settings

7.3.4 Casting vote

The most important functionality of the system is the ability to mark the vote and confirm the vote. Figure 7.5 and Figure 7.6 shows the two pages provided in the system that lists the political parties (countries names considered are here). Figure 7.7 shows how the confirmation screen appears to be.

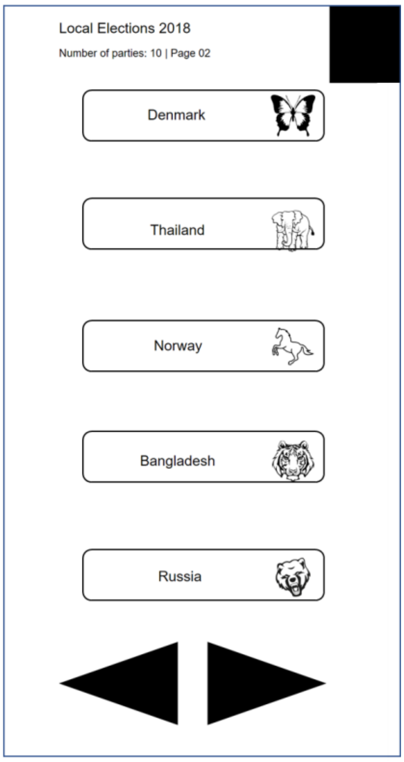

Figure 7.5 : Voting Page 1

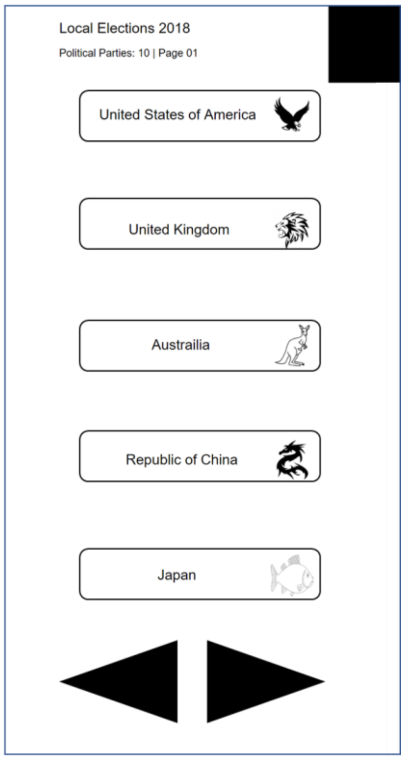

Figure 7.6 : Voting Page 2

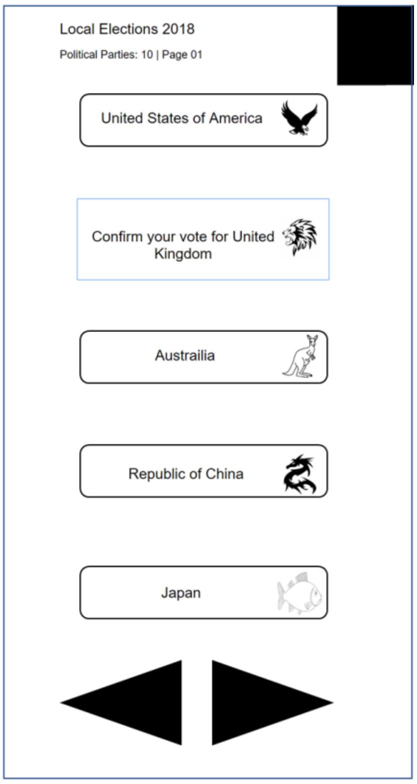

Figure 7.7 : Confirmation

8 Chapter Eight: Design Evaluation

As explained in methodology chapter (See chapter 3), evaluation tasks were conducted after obtaining consent of participants. Figure 8.1 and 8.2 shows participants using TT Ballot and BT Ballot respectively.

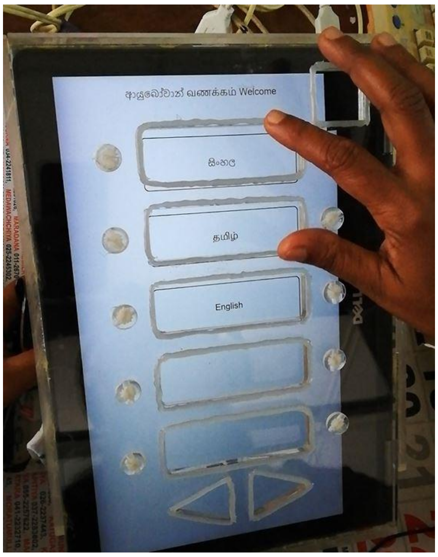

Figure 8.1 : A participant using the Touch Tactile Ballot

Figure 8.2 : A participant using Button Tactile Ballot

8.1 Participants

A total of 10 participants with visual disabilities were selected (7 men and 3 women, 20–71 years old, mean age 44.7 ± 5.9 years). There were 7 participants with total blindness (5 men and 2 women, 20–71 years old, mean age 50.1 ± 7.2 years) and 3 with partial blindness (2 men and 1 woman, 22–46 years old, mean age 32 ± 7.2 years).

Experience in using mobile phones or Automatic Teller Machines (ATM), is considered as a potential to use an electronic voting solution with ease implying that similar interfaces are incorporated [21]. Thus, participants were questioned of whether they have prior experience of using digital devices such as an ATM, computer, mobile phones and for how long they have experienced the usage.

Eight participants have used touch based smart phones (average of nearly 2 years of experience). Remaining participants have used phones with keypads (average of nearly 3 years of experience). All participants had an experience of using screen reader assisted computers. Some participants had an experience of using an Automated Teller Machine (5 participants).

8.2 Tasks

Participants were given an introductory training for both ballot interfaces (BT Ballot and TT Ballot). Participants were randomly assigned to use one of the ballots first and the other second.

8.2.1 Training

The training program of BT (Button Tactile) Ballot explained the button placements and its functions. The training for TT (Touch Tactile) Ballot explained the holes placements and its functions.

8.2.2 Trials

Before using any ballot interface, participants were instructed to listen to voting instructions. If linear navigation was considered instead of page wise navigation, participants were instructed to vote for the 7^{th} political party. Each page displays only five candidates. If page wise navigation is considered, participants were instructed to vote for the 3^{rd} political party in 2^{nd} page. Here, ballot interfaces used names of countries instead of names of actual political parties.

8.3 Data collection and Metrics for Analysis

Usability of both Button Tactile (BT) Ballot and Touch Tactile (TT) Ballot were measured using metrics recommended by International Organization for Standardization (ISO 9241-11, 1998) and previously conducted studies in a similar research [44] (See chapter 2). Thus, effectiveness, efficiency and user satisfaction were measured. Usability issues observed were noted separately.

8.3.1 Effectiveness

Participant voting choices were captured using logs.

8.3.2 Efficiency

Time stamps were logged when the language selection page was loaded, when the voting list was loaded and when the participant arrives the vote completion page. Ballot completion duration was considered the time between the loading of voting list and loading of vote completion page since initial language selection and instructions were common for all. The durations were marked in seconds.

8.3.3 Satisfaction

The System Usability Scale was adopted and score was calculated by considering the values from 0 to 4. Calculation procedure was followed as explained in literature [88] (See section 3.5.3). For items 1,3,5,7 and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Then the sum was multiplied by 2.5 to obtain the overall value which have a range of 0 to 100 [60].

8.4 Evaluation Results

Most participants (n = 8) completed all tasks including training and trials of using ballot interfaces. Two participants (n = 2) were not able to complete the voting task using the Button Tactile (BT) Ballot because they did not confirm the vote. One participant (n = 1) avoided and did not want to test the Touch Tactile (TT) Ballot due to personal preferences. Thus, the total number of completed ballots was 17 ballots (TB Ballot interface x 1 trial x 8 participants plus TT Ballot interface x 1 trial x 9 participants).

8.4.1 Effectiveness

Of the total number of completed ballots (n = 17 ballots), 10 ballots (58.82%) were completed without error: 50% (n = 4 ballots) of ballots with the BT Ballot and 66% (n = 6 ballots) of ballots with the TT Ballot (see Table 8.1).

Table 19 : Ballot completion with and without errors

		No error	With Error	Total
Button Tactile Ballot	Total blind	3	3	6
	Partial Blind	1	1	2
	All	4	4	8
Touch Tactile Ballot	Total Blind	4	2	6
	Partial Blind	2	1	3
	All	6	3	9

Of the total number of completed ballots (n = 17 ballots), 7 ballots (41.17%) were completed with an error of not marking the intended political party: Overall, 50% (n=4) of ballots with the BT Ballot contained the stated error. The number of ballots containing this error also varied by group: the total blind group (38%, n = 3) had the highest number of ballots containing the stated voting error, followed by the partially blind (13%, n = 1). Overall, 33% (n = 3) of ballots with the TT Ballot contained the stated error. The number of ballots containing this error also varied by group: the total blind (22%, n = 2) had the highest number of ballots containing at least one voting error, followed by partially blind (11%, n = 1).

8.4.2 Efficiency

It was identified that ballot completion was faster with the Touch Tactile Ballot (M = 92.55 seconds, SD = 24.40) than with the Button Tactile Ballot (M = 105.5 seconds, SD = 49.63). The ballot completion time varied also by the disability of the participants (see Figure 8.3). For the total blind participants, ballot completion time was lesser in Touch Tactile Ballot (M = 89.33 seconds, SD = 28.57) than with the Button Tactile Ballot (M = 107.16 seconds, SD = 58.61). For the partial blind participants, ballot completion time was lesser in Touch Tactile Ballot (M = 99 seconds, SD = 15.71) than with the Button Tactile Ballot (M = 100.5 seconds, SD = 2.12).

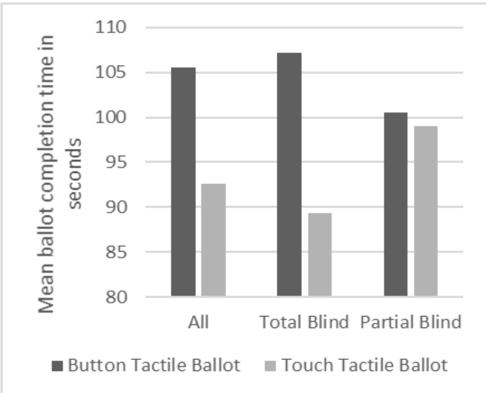

Figure 8.3 : Mean Ballot Completion Time Varied by Ballot Type and Blind Context

8.4.3 Usability with Satisfaction

The mean SUS score of both ballots (Button Tactile Ballot: M = 88.25 and SD = 7.91, Touch Tactile Ballot: M = 84.44 and SD = 6.09) was above the average score (68) [88]. Figure 8.4 presents how the mean of the SUS score varies for each ballot by the blind disability.

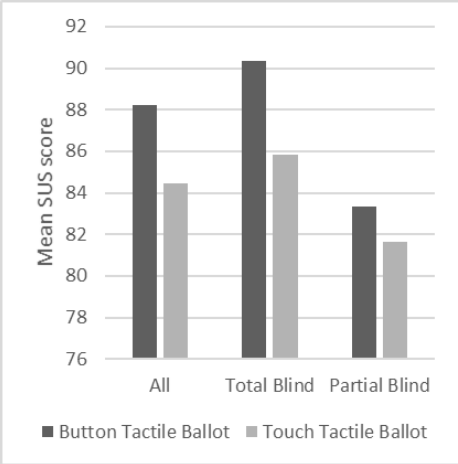

Figure 8.4 : Mean SUS Score for Two Ballots Varied by Blind Context

8.4.4 Preference

Participants preferred using Button Tactile Ballot interfaces (50%, n = 5) than using Touch Tactile Ballot interfaces (20%, n = 2) irrespective of the variation in visual disability (Figure 8.5). Also, some participants did not like choosing the most preferred and stated that they prefer both (30%, n = 3).

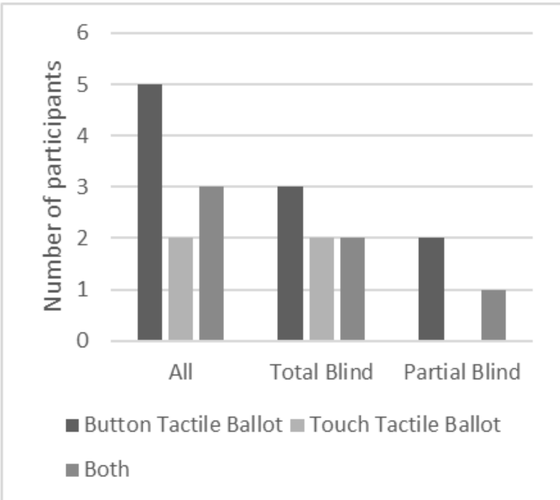

Figure 8.5 : Preference of the Ballot Interface Type Varied by Blind Context

Most of the total blind participants (30%, n=3) preferred the Button Tactile Ballot to the Touch Tactile Ballot (20%, n = 2). The reasons why they preferred the Button Tactile Ballot to the Touch Tactile Ballot included the following: easier to use compared to touch (n = 2), identifying the buttons was easier (n = 2), only few buttons were there to learn (n = 2), pressing buttons felt more in touch sensory (n = 1).

The reasons why they preferred the Touch Tactile Ballot to the Button Tactile included the following: they were familiar with using touch phones, so it was easier than using buttons (n =

2), it was quicker (n = 1), no accidental touch when compared to usual touch phones that need whole screen scanning to identify locations (n = 1).

The reasons for provided by the participants who preferred both ballots (n = 3) included: Both are equally easy (n = 2), 'it was easy to use the touch tactile, even if the touch concept is given in a different way here' (n = 1), 'buttons were easy to handle but using touch tactile allowed to vote in a different contrast colour setting, so I like both' (n = 1).

8.4.5 Usability Issues

It was observed that, 40% of the participants (n = 4) started touching the holes from the bottom instead of top using the Touch Tactile Ballot. Some stated that this issue could have been avoided if audio instructions stated that the hole numbers start from top (n = 2), one suggested that design can be modified to begin hole number from the top and another stated 'this won't be an issue if we are given more time to be familiar with the device physically'. Another issue noted was that two participants accidently used double tap which led to skipping options ahead. Some participants (n = 4) stated that since they are familiar with touch phones, they tend to double tap to do a selection although this design is catered to avoid double tap. One participant stated that the gap is not enough between the holes located in the middle which listed the political parties. Another participant stated that holes sizes are too large and that can lead to accidental touch of holes.

Using the Button Tactile Ballot, 50% of participants (n = 5) faced a technical issue of hearing response alerts and instructions (dual sound clips playing) together in some situations which was disturbing to them.

In both ballots, two participants reported that language selection and vote ready pages also require response feedback when a selection is made, and it should not be limited to the voting list page. Some participants mentioned that waiting period (4 seconds) was too long (n = 3). However, using Button Tactile Ballot interface, two participants voted mistakenly to the following political party (political party listed after 'Norway') because the waiting period was not enough. One person stated that instead of having separate training interface, it is better to combine training and voting instructions for both ballots.

8.5 Summary of Results

The research was aimed at designing usable ballot interfaces having aligned with Principles of Universal Design [84] supporting voters with visual abilities (total blind and partial blind). Results of the study indicate that participants did not perform equally on the two ballots when considering usability metrics of effectiveness, efficiency, and satisfaction.

Effectiveness is achieved when the voters can cast their vote for the intended political party/candidate. Only 85% ballots were completed with or without errors because the remaining did not confirm the vote as instructed. However, a majority of 58.82% were able to complete it without error. Participants marked the ballot incorrectly in Button Tactile Ballot slightly than in Touch Tactile Ballot irrespective of the blind category they belonged to. It was observed that few of them were late to press the button when the political party was announced. Errors were reported using Touch Tactile Ballot were mainly due to participants double tapping rather than single tap because of their prior experience in using smart phones. This can be addressed by adjusting the touch with de-bounce feature [82].

When considering the efficiency measure, participants were slightly faster using Touch Tactile Ballot than using Button Tactile Ballot. This can be due to Touch Tactile Ballot displays candidates all at once and participants can go through it. However, the difference is not high because participants made well use of the 'up' and 'down' buttons of Button Tactile Ballot to go through the voting list quickly.

Although effectiveness was not significant, satisfaction in terms of the SUS score showed beyond average and excellent results (BT = 84.44 and TT = 88.25) according to the grading scales [88]. According to Nielsen Norman Group, '*Users generally prefer designs that are fast and easy to use, but satisfaction isn't 100% correlated with objective usability metrics*' [89]. Thus, it is clear that effectiveness and satisfaction can show no correlation as the results gained from the test prototype.

In existing voting systems with touch interfaces [82] the major inefficiencies reported were accidental touch and tapping inactive areas. These inefficiencies can be reduced by allowing voters to reach only the active areas as in the Touch Tactile Ballot.

Prototype results show that, users are capable and preferred to use the tactile sleeve (Touch Tactile Ballot preference only = 20%, both ballot preference = 30%), which is also evident by the SUS Score gained (84.44). However, it was observed that some participants used trial and error in tracking the holes. Thus, improvements have to be made by including a feature as a guidance to track the holes, so that they do not require to remember the holes or guess. Majority of the participants preferred the Button Ballot Interfaces (Button Tactile Ballot preference only = 50%, both ballot preference = 30%) due to its minimalist design of few unique buttons made with known shapes. It was stated by one the participants that, irrespective of any prior knowledge on touch or other technologies, they can easily use this.

9 Chapter Nine: Discussion

In the simplest form with respect to persons with visual disabilities, the way to accommodate for secrecy is initially to provide them the interfaces with accessibility to vote independently with ease. However, it is vital to ensure that voting systems made usable and not just only being accessible.

9.1 Voting Process

If paper-based voting systems are continued to be used, optical scanning methods have to be applied to make it accessible for blind voters. However, it does not solve the problem of the fact that the scanned papers were initially designed to be marked by pen or pencil, not for screen reading [10]. Also, ability to change the vote and the redundant confirmation voting strategy are major advantages of using electronic voting machine over traditional paper-based voting.

The voting process can be identified as a journey of 3 stages: Initiating the process, learning the controls of the system and marking the vote. To initiate the process instead of inserting a card as in existing voting systems, our solution seeks a simpler procedure to initiate the voting system by using sensor-based triggering. The voter wears the headphone and the system sense it. Then voter is instructed to select a region or press button which starts the voter journey.

Even though overall statistics shows high literacy of Sri Lankans as a country, there are geographical variations among the literacy levels within the context. It is discussed that all voters are not having English literacy, and language preference option was given concern.

9.2 Ballot Designs

In Sri Lanka, braille literacy is significantly low where only 41% of individuals who know Braille are able to use it [25]. Also, it is being less learnt by new generations because of new assistive technologies. Thus, IT literacy and language literacy are the key literacy factors that required attention when designing the solution.

9.2.1 Touch Tactile Ballot Design

The initial studies conducted showed that ability of persons with blindness to use smart phones with touch capability is a good indication of their favourable IT literacy. Thus, adapting familiar smart phone features was considered by using touch inputs (Touch Tactile Ballot).

Existing touch-based voting designs have reported a critical usability issue of voters touching unintended areas on the touch interface [44] due to lack of guidance.

The TT Ballot (Touch Tactile Ballot) we provided is addressing this issue by using a transparent sleeve with holes (made out of glass). The holes are aligned with the options to be selected on the touch screen (See section 5.2.4). This TT Ballot has gained a mean SUS (System Usability Score) of 88.25% which can be interpreted as our solution has made an impact in solving the issue. Also, participants do not indicate the issue of unintended touch selections.

'Slide Rule', a set of multi-touch interaction techniques that improve the accessibility of touch screen-based devices, has been used in existing voting designs [58]. For an instance, when the user drags and releases his/her finger, a selection is made. This rule is used for several actions as to browse lists, to select items, to flip between pages of items and to browse the hierarchy [58]. However, use of this rule in touch interfaces for voting has reported as a less natural interaction for voter [44]. Instead of using 'Slide Rule' interaction we used the tap selection method since it is more natural and frequently used in smart phones. Results showed that some voters tend to double tap in situations where single tap is necessary. This can be addressed by using de-bounce feature and reducing sensitivity of the touch.

9.2.2 Button Tactile Ballot Design

Although majority of the participants showed experience in using smart phones, few others were there who had no experience in using touch devices. It is necessary to provide flexibility in voting method by providing another method. Thus, buttons (Button Tactile Ballot) were used as an input additional to the touch input. This is the underlying concept of Multi-modality where several types of modes of inputs and outputs are provided to facilitate user interactions [80].

In general, existing voting systems use a combination of buttons and audio support voters with visual disabilities. Most of these systems (e.g. AutoMark VAT, AVC Edge, E-slate, See section 2.2.2) are designed with braille embossments. As discussed earlier due to low Braille literacy, depending on Braille embossments is not sufficient. Thus, buttons were designed with unique shapes and colours enabling to identify them uniquely satisfying 'Perception' of Universal Design Principles [90].

9.3 Audio Accessibility

Providing audio facility was the suggested way to guide the blind voters through the voting process if braille reading option is ignored. A study shows that in many existing voting systems, although audio guidance is provided for the voters with visual disabilities, they are lacking in providing introductory instructions of using voting device or equipment [69]. In Sri Lankan context, voting using electronic means is a scenario faced for the first time. Thus, a training module was provided in our solution as a guidance about using the voting device.

Audio instructions plays a major role in this kind of voting system. The users of our system were satisfied with the audio instructions provided by our solution. However, there were some issues reported in the audio instructions relevant to TT Ballot: not stating that the holes of the TT Ballot start from the top and misinterpretation of shapes of the holes.

Considering audio feature gives the raise to further concerns such as the accent of the speaker, speed adjustments, volume and more. A report shows that some voting systems simply provide audio facility [10] with less concern on other factors that contribute to quality of audio instructions. Thus, our solution provides the facility to adjust volume and speed.

9.4 Colour Contrast Feature

Designing a voting solution for voters with visual disabilities including voters with partial blindness requires attention to be given for colour contrast feature [44] [91] [10]. Also, existing voting designs have rarely given concern to this feature [10] [92]. Thus, we have allowed the voters using our solution to change contrast. From the user study it was reported that two participants used this feature which can be used to interpret the necessity of this feature.

9.5 Navigation

Interface navigation is a key consideration in designing voter journey [93]. There are several researches conducted in creating different ways to have the voting interface layout: linear layouts [73] and random direct selection layouts [44] [93]. Those have shown better results when voters were given both navigation layouts. Thus, our solution also provided both linear layout and random layout. Navigation while managing long lists was a key consideration because currently in the local context a high number of political parties are existing.

9.6 Design Principles

In designing interfaces that can accommodate for persons with disabilities including visually impaired voters, it is important to consider the necessary functionalities in the initial stages of the designing process rather than adapting assistive tools after the design stage. This is the underlying design concept of Universal Guidelines.

There is a lack of information and available evidences on how voting systems were designed. Only few instances are reported with stating the design methodologies that have been followed. Among those voting systems, UCD methods and UD guidelines were followed for designing features, and SUS has been used for evaluating those features more frequently.

However, it is vital to understand that these guidelines can be applicable across various domains generally, but to fit into a specific context should be given more attention, whilst also ensuring that the designers and developers working towards the building of voting systems are with the skills and experience in the relevant principles.

In initial expert discussions, it was stated that the voting solution designed should be very simple and easy to understand because the vote should be marked quickly and it can be done only once at a time. Thus, it should be an intuitive design which can be easily informed or taught to blind voters before the voting day or at the voting moment. It was stated by the users of our solution that they can easily learn the voting procedure and the device is user friendly.

9.7 Privacy

In terms of ensuring privacy of the vote, some voting systems consider it as a security aspect. Certain other systems have considered privacy both as a security aspect and interface aspect by having applied cryptography-based security mechanisms and interface level privacy design features respectively. Few systems have addressed interface level privacy by turning off the screen when a blind voter uses the system but voters are not pleased with this feature [92]. Thus, our voting solution does not switch off the screen but instead displays the content while audio instructions are synced to improve usability.

10 Chapter Ten: Conclusion and Future Work

Sri Lanka currently uses a paper-based voting system for conducting elections. In this system, voters with visual disabilities have to depend on the assistance of another to vote. This research is an approach to design a voting solution with the intention of addressing the difficulties faced by voters with visual impairments in Sri Lanka. The research goal aimed by this research was, "*Designing usable ballot interfaces to provide an independent voting experience for Sri Lankans with visual impairment*". These interfaces were aimed to enable an accessible vote, which also supports to maintain the secrecy of the vote. The usability is defined and measured according to metrics of International Organization for Standardization (ISO 9241-11, 1998), which lists effectiveness, efficiency and user satisfaction as key factors of usability in a design.

Persons with visual disabilities are more accustomed to use mobile phones because inbuilt accessibility features exist. All the participants also had some sort of experience in using mobile phones compared to other IT related devices. However, their experience in using different types of mobile phones varied. Majority (80%) had an experience of using smart phones but there were persons who had only the experience of using a basic mobile phone with buttons or keypads. And also, there can be blind voters without any mobile device experience. Thus, in order to interact with the voting system, voters should be provided with several options such that they will choose the more familiar way, which is bringing in multi-modality concept for voting. Such concept is also aligned to facilitate the 2nd Universal Design principle of Flexibility in Use [84]. Few systems were already designed based on this concept whereas certain challenges remain that needs to be addressed. Aim of this research was to design ballot interfaces that fit into the Sri Lankan context.

In this study, two ballot interfaces were designed and examined that are capable of providing an independent voting experience for voters with visual disabilities: Button Tactile Ballot with button controls, Touch Tactile Ballot based on a touch interface. The design features of the interfaces were based on multi-modality and universal design guidelines. A test prototype was provided to a group of users and usability metrics were used to measure the results. Feedback received for the test prototype could be interpreted that voters with visual disabilities prefer to use this multi-modal voting solution that provided mean SUS Scores of 88.25 and 84.44 for Button Tactile Ballot and Touch Tactile Ballot respectively. Users preferred the Button Tactile Ballot (50%) more than Touch Tactile Ballot (20%) while some preferred both (30%).

However, in terms of efficiency Touch Tactile Ballot (Mean of 92.55 seconds) was slightly ahead that of Button Tactile Ballot (Mean of 105.5 seconds). Effectiveness wise also Touch Tactile Ballot was slightly higher (66%), which was measured by the number of completed ballots without errors.

Results obtained were promising and provided a greater SUS score as explained above. However, few usability issues were identified that requires certain modifications to improve the voting experience: Adjusting touch sensitivity to accommodate double tap errors, improving audio instructions, changing how the training is provided. After modifications are made, again the ballots have to be tested by voters with visual disabilities and without visual disabilities both.

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Appendix A: Requirement analysis interview structure

1. Demography related information.
    a. Date of birth
    b. Gender
    c. Electoral district
    d. Residential district
2. Visual disability related information.
    a. Blind category (Total blind or partial blind)
    b. Blind from which age
3. Occupation and education related information.
    a. Occupation
    b. If no occupation asking whether they are still studying
    c. Otherwise
4. Devices used out of the following and the activities that has been performed using them.
    a. Mobile phone
        i. Type of phone (Smartphone or feature phone)
        ii. If it is a smart phone, usage of any accessibility tools
        iii. Activities performed using the mobile phone
    b. ATM machine/ Cash Deposit Machine?
        i. Activities performed (Withdrawal, Balance Inquiry, Deposit)
5. Verbal proficiency (speaking and listening)

Language	Native	Strongly knows	Fairly knows	Slightly knows	Null

a. Sinhala					
b. Tamil					
c. English					
d. Braille					

6. Preference to use an electronic voting machine at the polling.

    a. Preference

    b. Reasons for above answer

    c. Expectations

Appendix B: Thematic Analysis

Thematic Codes

Interview 1

1. Current voting needs support of another
2. Current voting has no technology applied
3. Current voting has no Braille ballot papers
4. Indian voting did not help blind
5. Indian voting has technology applied
6. Hiring Indian voting machines cheaper that current voting
7. Current law does not address electronic ballot
8. Low literacy can be overcome by electronic voting
9. India has low literacy compared to us
10. Compared to India's literacy we too can have electronic voting
11. Ability to use ATM machines means ability to use EVM
12. Overall literacy is high in Sri Lanka
13. Up country literacy is lower than overall literacy of Sri Lanka
14. Up country people can remember pictures
15. Ability to use mobile phones means ability to use EVM
16. Upcountry people know how to use mobile phones
17. Current law should change to address electronic voting
18. Young people are capable enough to use EVM
19. Electronic voting can be implemented
20. Customizing after hiring EVM
21. Customizing hired EVM for VVPAT feature

22. VVPAT feature shows vote on a printed paper

23. Customizing hired EVM for braille column feature

24. Hiring EVM does not need to buy EVM

25. Demonstration to parliamentarians on using an EVM

26. Vendor fairs to show EVM for politicians

27. Electronic voting initiation in 2020

28. Book published on voter registration in braille

29. Current law should change to print braille ballots

30. Braille ballots is feasible for all island elections

31. Braille ballots less feasible for elections that needs political party listing

32. Tactile voting can be used with paper ballots for the blind

33. Indonesia uses tactile voting

34. Braille ballot paper print is avoided

35. Low braille literacy

36. SPA needs obtaining a medical certification proving blindness

37. Polling officials asking voters to prove blindness at polling stations

38. Polling officials does not mark as intended in assisted voting

39. SPA process is expensive

40. Waiting lines at polling stations gives priority for blind voters

41. Privacy is the main concern in a secret vote

42. Voter cannot be traced back during counting

43. Voter cannot be traced back during voting

44. In postal voting voter cannot be traced back

45. EVM does not store whether a blind person marked the vote

46. Same voting experience for a non-blind voter and blind voter

47. Waiting lines at polling stations gives priority for blind voters

48. Same voting experience for a non-blind voter and blind voter

49. Blind voters might not like assistance in voting

50. Privacy is main voting concern

51. Accuracy is a main voting concern

Interview 2

1. Voting should address illiterate voters
2. Voting should be accessible for blind
3. Voting should be accessible for voters with low vision
4. Information about vote should be accessible
5. Low vision voters need large print
6. Low vision voters can be given magnifying glass
7. Spectacles cannot address blindness
8. Availability of accessible polling stations
9. SPA violates fundamentals of universal franchise
10. AVBAP has a chance of not voting as intended by blind voters
11. AVBAP has no way to verify voted as intended by blind voters
12. AVBAP violates privacy of blind voter
13. Election PO are not aware of SPA
14. Election PO are not allowing AVBAP
15. SPA process is complicated
16. SPA needs obtaining a medical certification proving blindness
17. Doctors are not supportive in SPA need for obtaining a medical certification
18. Information about vote should be given to blind voters

19. Internet voting has security issues

20. Tactile voting can be used with paper ballots for the blind

21. Philippines uses tactile voting

22. Blind people are becoming familiar with computers

23. Electronic voting is preferred by blind voters

24. Does not rely on blind statistics

25. People can hide disability when finding statistics

26. Statistics of voters depends on attitude of enumerators

27. Secrecy is a voting concern

28. Accessibility is a voting concern

29. Addressing the illiterate is a voting concern

Interview 3

1. Preferential voting will be considered again
2. Current law should change to address electronic voting
3. SPA act passed for voters with disabilities
4. Issues in obtaining a medical certification proving blindness
5. Issues in obtaining a grama niladari certification approving person taken for AVBAP
6. SPA issues are discouraging blind voters
7. Election PO are not aware of SPA
8. Election PO are not allowing AVBAP
9. SPA process is expensive
10. Braille ballots less feasible for elections that needs political party listing
11. Blind voters are familiar with touch phones
12. Blind voters are familiar with computer keyboards

13. Practice on symbols and using symbols to vote
14. IT literacy about all blind voters is not assured
15. All blind persons do not have touch phones
16. Blind persons with touch phones need initial support from another
17. Voters should be given language preference option
18. All voters are not English literate
19. Voice accent is a concern in audio
20. Braille is less liked and used by blind persons
21. Braille needs touch always which is not easy
22. Listening is easier over braille reading
23. Listening is easier over braille reading
24. Braille reading cause fatigue
25. No proper definition on blindness
26. Mobile phones have text books reading in English but not in Sinhala
27. 17 lakhs persons with disabilities
28. 2-3 lakhs persons with blindness
29. Ability to understand the operations of EVM is a voting concern
30. Voters should be given language preference option
31. Ability to understand the operations of EVM is a voting concern
32. Information about vote should be given to blind voters

Interview 4

1. Secrecy is a voting concern
2. AVBAP has no way to verify voted as intended by blind voters
3. Degree of disability

4. Total blind B1 is light can be seen slightly but directions are not visible where they cannot walk independently
5. Partially Blind B2
6. Partially Blind B2 Poor low vision is might be able to see directions and walk but cannot see other things clearly
7. Partially Blind B2 Good low vision might be able to read if things are magnified
8. Mild blindness B3 medium might be braille or not
9. Legally blind means ones who cannot be transformed into having normal vision and cannot make use of spectacles
10. SPA needs obtaining a medical certification proving blindness
11. SPA process is complicated
12. AVBAP violates privacy of blind voter
13. AVBAP is ethically wrong
14. 2001 reports 24% to be with visual disabilities
15. 2011 and 2012 stat are not reliable as it says ‘seeing’ disabilities
16. Blind definition Sri Lanka, for a short term of total period if a person cannot do work in the normal ways due to physical or mental weakness
17. UN Blind definition, is not person related. Disability is due to some environmental or social conditions.
18. International, definition is context related
19. Sri lanka, definition is person related
20. Braille is considered as the primary communication medium of the blind
21. Braille is less liked and used by blind persons
22. Audio based option preferred by blind persons
23. Screen readers types: NVDA, open source
24. Screen readers types: JAWS, expensive, more features

25. Localization issues in screen readers

26. Android system has a Sinhala screen reader

27. Low English literacy

28. Screen reader makes inclusive

29. Audio based option preferred by blind persons

30. Blind voters are familiar with computer keyboards

31. Blind readers using audio books of Daisy organization

32. Digital design is the only option for equal voting rights

33. Accessibility here means, it should be either audible or visual.

34. Usability is voting concern

35. Low vision voters can be given magnifying glass

36. Colour contrast options

37. Physical buttons for input functions

38. Touch interfaces are not convenient

39. Touch interfaces take time

Searching Themes Phase

Table B.20 Searching Themes

Theme	Codes
Current Voting Process	• Current voting has no technology applied • Current voting needs support of another • Current voting has no Braille ballot papers • Book published on voter registration in braille • Availability of accessible polling stations
SPA	• SPA act passed for voters with disabilities • Issues in obtaining a grama niladari certification approving person taken for AVBAP • SPA needs obtaining a medical certification proving blindness • Doctors are not supportive in SPA need for obtaining a medical certification • Polling officials asking voters to prove blindness at polling stations • Polling officials does not mark as intended in assisted voting • SPA process is expensive • SPA violates fundamentals of universal franchise • AVBAP has a chance of not voting as intended by blind voters • AVBAP has no way to verify voted as intended by blind voters • AVBAP violates privacy of blind voter

	• Election PO are not aware of SPA • Election PO are not allowing AVBAP • SPA process is complicated • SPA issues are discouraging blind voters • AVBAP is ethically wrong
Indian Voting Process	• Indian voting has technology applied • Indian voting did not help blind
Internet Voting	• Internet voting has security issues
Tactile Voting	• Tactile voting can be used with paper ballots for the blind • Indonesia uses tactile voting • Philippines uses tactile voting
Braille ballots	• Current law should change to print braille ballots • Braille ballots is feasible for all island elections • Braille ballots less feasible for elections that needs political party listing • Braille ballot paper print is avoided • Braille is less liked and used by blind persons
Hiring EVM	• Hiring Indian voting machines cheaper that current voting • Customizing after hiring EVM • Customizing hired EVM for VVPAT feature • Customizing hired EVM for braille column feature • Hiring EVM does not need to buy EVM

Touch Interfaces	• Touch interfaces are not convenient • Touch interfaces take time
Using EVM	• Current law does not address electronic ballot • Current law should change to address electronic voting • Digital design is the only option for equal voting rights • Young people are capable enough to use EVM • Electronic voting can be implemented • Demonstration to parliamentarians on using an EVM • Vendor fairs to show EVM for politicians • Electronic voting initiation in 2020 • Blind people are becoming familiar with computers • Electronic voting is preferred by blind voters • Blind voters are familiar with touch phones • Blind voters are familiar with computer keyboards
Relationship between Literacy and Electronic Voting	• Up country people has low literacy • Low literacy can be overcome by electronic voting • India has low literacy compared to us • Compared to India's literacy we too can have electronic voting • Overall literacy is high in Sri Lanka • Up country literacy is lower than overall literacy of Sri Lanka • Up country people can remember pictures
IT Literacy	• Ability to use ATM machines means ability to use EVM

	• Ability to use mobile phones means ability to use EVM • Upcountry people knows how to use mobile phones • IT literacy about all blind voters is not assured • All blind persons do not have touch phones • Blind persons with touch phones need initial support from another
Braille Literacy	• Braille is considered as the primary communication medium of the blind • Low braille literacy • Braille is less liked and used by blind persons • Braille needs touch always which is not easy • Listening is easier over braille reading
Language Literacy	• All voters are not english literate • Low English literacy
Voting system should address	• Usability is voting concern • 340 political parties are present • Privacy is the main concern in a secret vote • EVM does not store whether a blind person marked the vote • Same voting experience for a non-blind voter and blind voter • Blind voters might not like assistance in voting • Accuracy is a main voting concern • Voting should address illiterate voters • Voting should be accessible for blind • Accessibility here means, it should be either audible or

	visual. • Secrecy is a voting concern • Preferential voting will be considered again • Voters should be given language preference option • Ability to understand the operations of EVM is a voting concern • Colour contrast options • Physical buttons for input functions • Voting should be accessible for voters with low vision • Low vision voters need large print • Low vision voters can be given magnifying glass • Spectacles cannot address blindness • Voter cannot be traced back during counting • Voter cannot be traced back during voting • In postal voting voter cannot be traced back • VVPAT feature shows vote on a printed paper • Voice accent is a concern in audio • Listening is easier over braille reading • Audio based option preferred by blind persons
Screen Readers	• Localization issues in screen readers • Screen reader makes inclusive • NVDA, open source • JAWS, expensive, more features • Android system has a sinhala screen reader

Blind Variations	• Degree of disability • Total blind B1 is light can be seen slightly but directions are not visible where they cannot walk independently • Partially Blind B2 • Partially Blind B2 Poor low vision is might be able to see directions and walk but cannot see other things clearly • Partially Blind B2 Good low vision might be able to read if things are magnified • Mild blindness B3 medium might be braille or not
Blind Definitions	• No proper definition on blindness • Legally blind means ones who cannot be transformed into having normal vision and cannot make use of spectacles • Blind definition Sri Lanka,For a short term of total period if a person cannot do work in the normal ways due to physical or mental weakness • Sri lanka, definition is person related • UN Blind definition,is not person related. Disability is due to some environmental or social conditions. • International, definition is context related
Statistics related to Blind Persons	• Does not rely on blind statistics • People can hide disability when finding statistics • Statistics of voters depends on attitude of enumerators • 17 lakhs persons with disabilities • 2-3 lakhs persons with blindness • 2001 reports 24% to be with visual disabilities

	• 2011 and 2012 stat are not reliable as it says ‘seeing’ disabilities
Voting Education	• Information about vote should be accessible • Information about vote should be given to blind voters
Voting Ethics	• Waiting lines at polling stations gives priority for blind voters
	Mobile phones have text books reading in English but not in Sinhala
	Blind readers using audio books of Daisy organization
	Practice on symbols and using symbols to vote

Reviewing Themes Phase

Table B.21 Reviewing Themes

Main Theme/ Sub Theme	Codes
Main:Current Voting Process	• Current voting has no technology applied
Sub: Issues of Current Voting	• Current voting needs support of another • Current voting has no Braille ballot papers
Sub: Actions taken to improve voting by blind	• Book published on voter registration in braille • Availability of accessible polling stations
Main: Issues of SPA	• Issues in obtaining a grama niladari certification approving person taken for AVBAP • SPA needs obtaining a medical certification proving blindness • Doctors are not supportive in SPA need for obtaining a medical certification • Polling officials asking voters to prove blindness at polling stations • Polling officials does not mark as intended in assisted voting • SPA process is expensive • SPA violates fundamentals of universal franchise • AVBAP has a chance of not voting as intended by blind voters • AVBAP has no way to verify voted as intended by blind

	voters • AVBAP violates privacy of blind voter • Election PO are not aware of SPA • Election PO are not allowing AVBAP • SPA process is complicated • SPA issues are discouraging blind voters • AVBAP is ethically wrong
Main: Available voting options	
Sub: Internet Voting	• Internet voting has security issues
Sub: Tactile Voting	• Tactile voting can be used with paper ballots for the blind • Indonesia uses tactile voting • Philippines uses tactile voting
Sub: Braille ballots	• Current law should change to print braille ballots • Braille ballots is feasible for all island elections • Braille ballots less feasible for elections that needs political party listing • Braille ballot paper print is avoided • Braille is less liked and used by blind persons
Sub: Hiring EVM	• Hiring Indian voting machines cheaper that current voting o Indian voting has technology applied o Indian voting did not help blind • Customizing after hiring EVM

	• Customizing hired EVM for VVPAT feature • Customizing hired EVM for braille column feature • Hiring EVM does not need to buy EVM
Sub: Touch Interfaces	• Touch interfaces are not convenient • Touch interfaces take time
Main: Using EVM	
Sub: Challenges for using EVM	• Current law does not address electronic ballot • Current law should change to address electronic voting
Sub: Support for using EVM	• Digital design is the only option for equal voting rights • Young people are capable enough to use EVM • Electronic voting can be implemented • Demonstration to parliamentarians on using an EVM • Vendor fairs to show EVM for politicians • Electronic voting initiation in 2020 • Blind people are becoming familiar with computers • Electronic voting is preferred by blind voters • Blind voters are familiar with touch phones • Blind voters are familiar with computer keyboards
Main: Relationship between Literacy and Electronic Voting	• Up country people has low literacy • Low literacy can be overcome by electronic voting • India has low literacy compared to us • Compared to India's literacy we too can have electronic

	voting • Overall literacy is high in Sri Lanka • Up country literacy is lower than overall literacy of Sri Lanka • Up country people can remember pictures
Sub: IT Literacy	• Ability to use ATM machines means ability to use EVM • Ability to use mobile phones means ability to use EVM • Upcountry people knows how to use mobile phones • IT literacy about all blind voters is not assured • All blind persons do not have touch phones • Blind persons with touch phones need initial support from another
Sub: Braille Literacy	• Braille is considered as the primary communication medium of the blind • Low braille literacy • Braille is less liked and used by blind persons • Braille needs touch always which is not easy • Listening is easier over braille reading
Sub: Language Literacy	• All voters are not english literate • Low English literacy
Main: Voting system should address	• Privacy is the main concern in a secret vote • EVM does not store whether a blind person marked the vote • Same voting experience for a non-blind voter and blind voter • Blind voters might not like assistance in voting

	• Accuracy is a main voting concern • Voting should address illiterate voters • Voting should be accessible for blind • Accessibility here means, it should be either audible or visual. • Secrecy is a voting concern • Preferential voting will be considered again • Voters should be given language preference option • Ability to understand the operations of EVM is a voting concern • Colour contrast options • Physical buttons for input functions • Voter cannot be traced back during counting • Voter cannot be traced back during voting • In postal voting voter cannot be traced back
Sub: Addressing Blind Variations	• Voting should be accessible for voters with low vision • Low vision voters need large print • Low vision voters can be given magnifying glass • Spectacles cannot address blindness
Sub: Vote Verification	• VVPAT feature shows vote on a printed paper
Sub: Audio Option	• Voice accent is a concern in audio • Listening is easier over braille reading • Audio based option preferred by blind persons

Sub: Secrecy & Privacy	• Voter cannot be traced back during counting • Voter cannot be traced back during voting • In postal voting voter cannot be traced back • Privacy is the main concern in a secret vote
Main: Screen Readers	• Localization issues in screen readers • Screen reader makes inclusive
Sub: Screen Reader Types	• NVDA, open source • JAWS, expensive, more features • Android system has a sinhala screen reader
Main: Facts related to Blindness	
Sub: Blind Variations	• Degree of disability • Total blind B1 is light can be seen slightly but directions are not visible where they cannot walk independently • Partially Blind B2 • Partially Blind B2 Poor low vision is might be able to see directions and walk but cannot see other things clearly • Partially Blind B2 Good low vision might be able to read if things are magnified • Mild blindness B3 medium might be braille or not
Sub: Blind Definitions	• No proper definition on blindness • Legally blind means ones who cannot be transformed into having normal vision and cannot make use of spectacles • Blind definition Sri Lanka,For a short term of total period if a

	person cannot do work in the normal ways due to physical or mental weakness • Sri lanka, definition is person related • UN Blind definition,is not person related. Disability is due to some environmental or social conditions. • International, definition is context related
Sub: Statistics related to Blind Persons	• Does not rely on blind statistics • People can hide disability when finding statistics • Statistics of voters depends on attitude of enumerators • 17 lakhs persons with disabilities • 2-3 lakhs persons with blindness • 2001 reports 24% to be with visual disabilities • 2011 and 2012 stat are not reliable as it says 'seeing' disabilities
Main: Voting Education	• Information about vote should be accessible • Information about vote should be given to blind voters
Main: Voting Ethics	• Waiting lines at polling stations gives priority for blind voters
	Mobile phones have text books reading in English but not in Sinhala
	Blind readers using audio books of Daisy organization
	Practice on symbols and using symbols to vote

Final Themes

Table B.22 Final themes

Theme	Sub Theme

Factors to consider when designing a voting solution for the blind	• Usability
	  ○ Navigation
	  ○ Managing Long lists (Political Parties)
	• Addressing Blind Variations (which comes under **Facts related to Blindness**)
	• Secrecy & Privacy factors
	• Vote Verification & Accuracy
	• Literacy Factors
	• Same voter journey (which comes under **Current Voting & SPA Issues**)
	• Vote without assistance (which comes under **Current Voting & SPA Issues**)

Available design options	• Audio Option ○ Screen Readers • Language Literacy • Tactile Voting • Touch Interfaces

Appendix C: Use cases

Language Selection Use Case

Table C.23 Use Case: Provide Instructions

Use case name	Language Selection
Actors	VVD, System
Preconditions	● Polling official (Typically third official) examines the eligibility to vote (i.e. examine little fingers for ink marks) and if eligible, mark little left little finger with indelible ink. ● VVD wears headphones successfully.
Basic course	1. System prompts an explanatory message explaining language selection. 2. Voter selects the preferred language.
Outcome	● Voter has chosen the language in which he/she prefers to vote.
Alternate course	● Voter makes no choice, system repeats once more or system is timed out.

Provide Training Use Case

Table C.24 Use Case: Provide Instructions

Use case name	Provide training
Actors	VVD
Preconditions	● VVD has chosen the language.
Basic course	1. System prompts explanatory messages explaining controls of system and how-to-use system. 2. Voter follows instructions successfully. 3. System explains key commands to customize system features (audio volume, audio speed, language switch) 4. Voter makes necessary adjustments. 5. System proceeds to next step.
Outcome	● Voter has learnt the controls on how to use the system
Alternate course	● Voter skips the training ● Voter skips settings adjustment

Provide Instructions Use Case

Table C.25 Use Case: Provide Instructions

Use case name	Provide instructions
Actors	VVD
Preconditions	● VVD has selected the language ● VVD has gained the system training
Basic course	1. System instructs how to navigate and how to mark the vote. 2. System asks the voter if he/she ready to mark the vote. 3. Voter proceeds
Outcome	● Voter has learnt the instructions to use the system and is ready to caste the vote.
Alternate course	● Voter skips the instructions. ● Voter does not proceed and decides to go through the system instructions again. ● Voter makes no action and system is timed out.

Voting Use Case

Scenario 1: Voting for Presidential Election

Table C.26 Use Case: Voting for Presidential Election

Use case name	Voting
Actors	VVD

Preconditions	Voter has proceeded after system asked the voter if he/she ready to mark the vote
Basic course	1. System displays the page with the list of political parties 2. System starts narrating political parties in sequential order. 3. Voter selects his major preference 4. System notifies voter about the selection he/she has made 5. System prompts a confirmation message for the preference. 6. Voter confirms his/her preference a. [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] 7. System prompts to confirm vote b. [Refer Alternative flow of user selecting a second preference instead of confirmation vote] 8. Voter confirms his/her vote. 9. System provides a success notification
Outcome	● VVD has voted successfully
Alternate course	a. user changing his selected preference instead of confirmation of preference a-i. Voter selects his major preference a-ii. System notifies voter about the selection he/she has made [Merges with basic course 6]

	b. Flow of user selecting a second preference b-i. Voter selects his/her second preference b-ii. System prompts a confirmation message for the preference. b -iii. Voter confirms his/her preference [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] b-iv. System prompts to confirm vote [Refer Alternative flow of user selecting a third preference instead of confirmation of vote]. System prompts to confirm vote b-v. Voter confirms his/her vote. b-vi. System provides a success notification c. Flow of user selecting a third preference instead of confirmation of vote. c-i. Voter selects his/her third preference c-ii. System prompts a confirmation message for the preference. c -iii. Voter confirms his/her preference [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] c-iv. System prompts to confirm vote c-v. Voter confirms his/her vote. c-vi. System provides a success notification

Scenario 2: Voting for Local Election

Table C.27 Use Case: Voting for Local Election

Use case name	Voting
Actors	VVD
Preconditions	Voter has proceeded after system asked the voter if he/she ready to mark the vote
Basic course	1. System displays the page with the list of political parties 2. System starts narrating political parties in sequential order. 3. Voter selects his/her preference for political party. 4. System notifies voter about the selection he/she has made 5. System prompts a confirmation message for the preference. 6. Voter confirms his/her preference a. [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] 7. System prompts to confirm vote 8. System provides a success notification
Outcome	● VVD has voted successfully
Alternate course	a. user changing his selected preference instead of confirmation of preference

	a-i. Voter selects his major preference a-ii. System notifies voter about the selection he/she has made [Merges with basic course 6]

Scenario 3: Voting for Parliamentary Election/Provincial

Table C.28 Use Case: Voting for Parliamentary Election/Provincial

Use case name	Voting
Actors	VVD
Preconditions	Voter has proceeded after system asked the voter if he/she ready to mark the vote
Basic course	1. System displays the page with the list of political parties 2. System starts narrating political parties in sequential order. 3. Voter selects his/her preferred political party. 4. System notifies voter about the selection he/she has made 5. System prompts a confirmation message for the preference. 6. Voter confirms his/her preference a. [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] 7. System prompts to confirm vote b. [Refer Alternative flow of user selecting first preferential candidate instead of confirmation vote] 8. Voter confirms his/her vote. 9. System provides a success notification
Outcome	● VVD has voted successfully
Alternate course	a. User changing his selected preference instead of confirmation of preference

	a-i. Voter selects his preference a-ii. System notifies voter about the selection he/she has made [Merges with basic course 6 OR b-iv, OR c-iv, OR d-iv] b. Refer Alternative flow of user selecting first preferential candidate instead of confirmation vote b-i. Voter selects his/her first preferential candidate b-ii. System prompts a confirmation message for the preference. b -iii. Voter confirms his/her preference [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] b-iv. System prompts to confirm vote [Refer Alternative flow of user selecting a second preferential candidate instead of confirmation of vote]. System prompts to confirm vote b-v. Voter confirms his/her vote. b-vi. System provides a success notification c. Refer Alternative flow of user selecting a second preferential candidate instead of confirmation vote c-i. Voter selects his/her second preferential candidate c-ii. System prompts a confirmation message for the preference. c -iii. Voter confirms his/her preference c. [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] c -iv. System prompts to confirm vote [Refer Alternative flow of user selecting a third preferential candidate

	instead of confirmation of vote]. System prompts to confirm vote c -v. Voter confirms his/her vote. c-vi. System provides a success notification d. Flow of user selecting a third preferential candidate instead of confirmation of vote. d-i. Voter selects his/her third preference d-ii. System prompts a confirmation message for the preference. d -iii. Voter confirms his/her preference [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] d-iv. System prompts to confirm vote d-v. Voter confirms his/her vote. d-vi. System provides a success notification

Scenario 4: Voting for Referendum Election

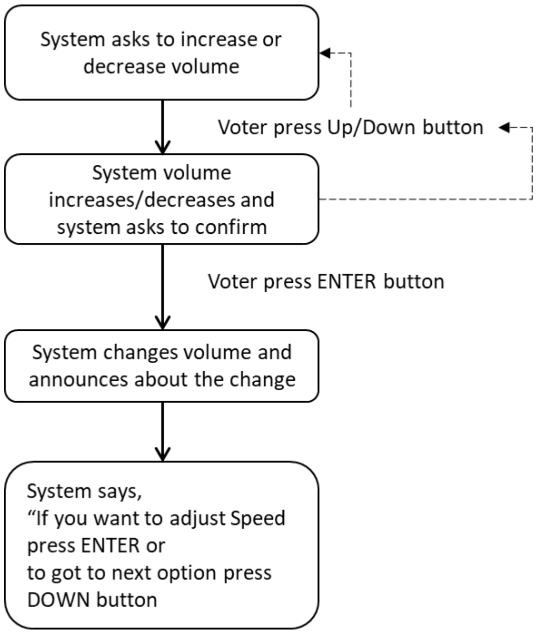
Table C.29 Use Case: Voting for Referendum Election

Use case name	Voting
Actors	VVD
Preconditions	Voter has proceeded after system asked the voter if he/she ready to mark the vote
Basic course	1. System displays the page with the list of preferences 2. System starts narrating preferences. 3. Voter selects his/her preference.

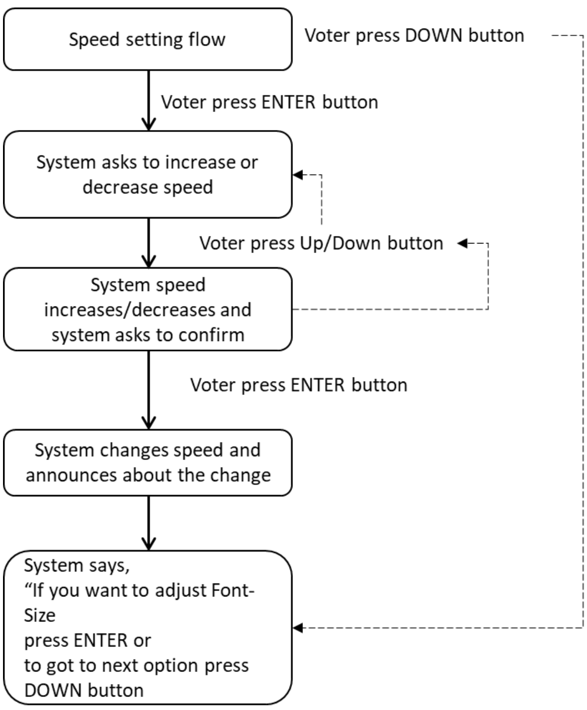
	4. System notifies voter about the selection he/she has made 5. System prompts a confirmation message for the preference. 6. Voter confirms his/her preference a. c. [Refer Alternative flow of user changing his selected preference instead of confirmation of preference] 7. System prompts to confirm vote 8. System provides a success notification
Outcome	● VVD has voted successfully
Alternate course	c. user changing his selected preference instead of confirmation of preference c-i.Voter selects his major preference c-ii.System notifies voter about the selection he/she has made [Merges with basic course 6]

Appendix D: User flows

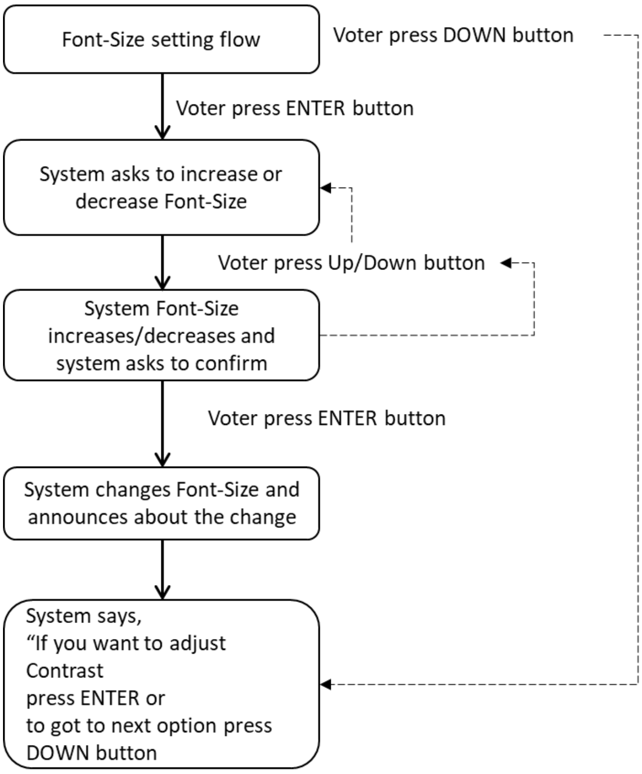
Volume Setting Flow



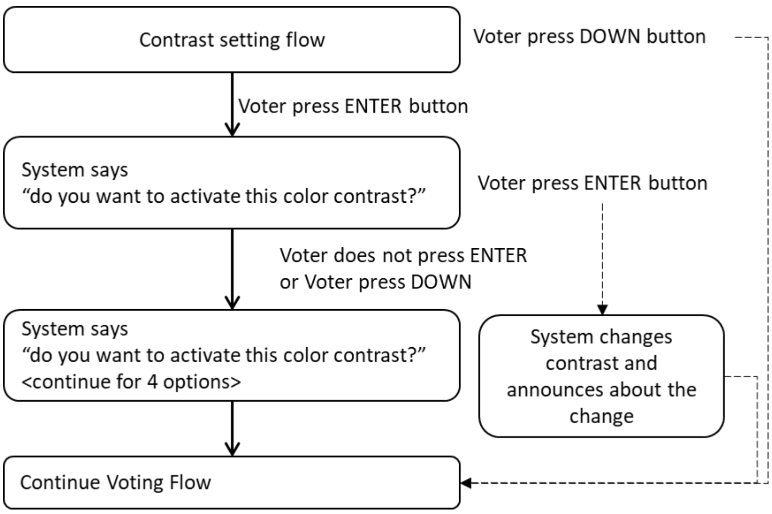
Speed Setting Flow



Font-Size Setting Flow



Contrast Setting Flow



Appendix E: Audio Instructions

Audio instructions for using Button Tactile Ballot

Page	Instructions/ Audio Descriptions	
	Item	Instruction/ Description
Language selection	Header	We warmly welcome you to the voting system (Repeated in Sinhala and Tamil).
	Language options	There is circle shaped button on your right side. If you want to vote in English language, press the circle shaped button in your right side. (This is repeated for Sinhala and Tamil language selections)
Settings	Header	There is a square shaped button on your left side. You can go to settings by pressing it. Settings allow you to change the language, volume, speed, and colour contrast. If you want to go to settings, press the square shaped button on your left side.
Voting instructions	Header	Now the voting instructions will be announced. The voting list will be announced to you. When you hear the political party you prefer, press the circular shape button on your right side within 4 seconds. There are triangular shaped buttons to the left side of the circular button. By pressing them you can go up and down the voting list. Voting list is announced only twice. If you do not vote in either round, your vote will be rejected.
	Ready to vote	Are you ready to vote? Then press the circle shaped button in your right side within 4 seconds.
	Instructions	Do you want to listen to voting instructions again? Then press the circle shaped button in your right side within 4 seconds.
Voting list	Page 1 header	Local Elections 2018. The number of political parties is ten. First page.
	List	• United States of America, symbol is eagle. • United Kingdom, symbol is Lion. • Austrailia, symbol is Kangaroo. • Republic of China, symbol is Dragon. • Japan, symbol is Fish.
	Page 2 header	Second page.
	List	• Denmark, symbol is Butterfly. • Thailand, symbol is Elephant. • Norway, symbol is Horse. • Bangladesh, symbol is Tiger. • Russia, symbol is Bear.
	Confirmation upon selection	You have selected <political party name>. To confirm the vote press the circle shaped button on your right side within 4 seconds.

End	Header for successful vote	You have voted for <political party name>. Thank you for voting. Please replace the headphones.
	Header for vote rejection	Your vote was rejected. Please replace the headphones.
Settings Menu	Header	Now you are in settings menu.
	Options	If you want to change the language, press the circle shaped button on your right side within 4 seconds. If you want to change the audio speed, press the circle shaped button on your right side within 4 seconds. If you want to change the audio volume, press the circle shaped button on your right side within 4 seconds. If you want to change the colour contrast, press the circle shaped button on your right side within 4 seconds. If you want to return to voting press the circle shaped button on your right side within 4 seconds.

Table E.30 : Audio instructions for using Button Tactile Ballot

Audio instructions for using Touch Tactile Ballot

Page	Instructions/ Audio Descriptions	
	Item	Instruction/ Description
Language selection	Header	We warmly welcome you to the voting system (Repeated in Sinhala and Tamil).
	Language options	In this voting system, there is a window with holes on top of the screen. This window has square shaped five main holes in the middle region. If you want to vote in English language, touch the third hole. (Repeated in Sinhala and Tamil).
Settings	Header	There is a square shaped hole on the right top of the screen. You can go to settings by tapping on it. Settings allow you to change the language, volume, speed, and colour contrast. If you want to go to settings, tap on the square-shaped hole on the right top of the screen.
Voting instructions	Header	Now the voting instructions will be announced. The voting list will be announced to you. When you hear the political party you prefer, press the relevant hole. There are triangular shaped holes on the bottom of the screen. By tapping them you can navigate among pages. Voting list is announced only twice. If you do not vote in either round, your vote will be rejected.
	Ready to vote	Are you ready to vote? Then tap the first hole within 4 seconds.
	Instructions	Do you want to listen to voting instructions again? Then tap the second hole within 4 seconds.
Voting list	Page 1 header	Local Elections 2018. The number of political parties is ten. First page.
	List	• United States of America, symbol is eagle. • United Kingdom, symbol is Lion. • Austrailia, symbol is Kangaroo.

		• Republic of China, symbol is Dragon. • Japan, symbol is Fish.
	Page 2 header	Second page.
	List	• Denmark, symbol is Butterfly. • Thailand, symbol is Elephant. • Norway, symbol is Horse. • Bangladesh, symbol is Tiger. • Russia, symbol is Bear.
	Confirmation upon selection	You have selected <political party name>. To confirm the vote press the relevant hole within 4 seconds.
End	Header for successful vote	You have voted for <political party name>. Thank you for voting. Please replace the headphones.
	Header for vote rejection	Your vote was rejected. Please replace the headphones.
Settings Menu	Header	Now you are in settings menu.
	Options	If you want to change the language, tap the first hole. If you want to change the audio speed, tap the second hole. If you want to change the audio volume, tap the third hole. If you want to change the colour contrast, tap the fourth hole. If you want to return to voting tap the fifth hole.

Table E.31 : Audio instructions for using Touch Tactile Ballot

Appendix F: Evaluation form structure

Age		
Education level		
Type of vision disability		
District		
Previous IT usage	ATM	
	Computer	
	Basic phone	
	Smart phone	

Preferred interface	
Why? Any particular reason?	
Other feedback	