Braille to Text Convertor for Sinhala

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Braille to Text Convertor for Sinhala

A dissertation submitted for the Degree of Master of Information Technology

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Declaration

The thesis is my original work and has not been submitted previously for a degree at this or any other university/institute.

To the best of my knowledge it does not contain any material published or written by another person, except as acknowledged in the text.

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Abstract

The instantaneous conversion of written brail symbols to readable text of any language has been a hurdle for many educators specialized in the field of visual disabilities so far. Various solutions have been proposed in this regard and nothing has hitherto been viable and successful. Different Braille converter software for different languages is currently available only by means of one-way conversion capabilities. However, a direct conversion tool that translates Braille to Sinhala is not yet available in mobile and desktop platforms. Hence the visually impaired Academic students of Sri Lanka, who work with Braille, suffer a lot. Their teachers also have faced numerous problems because they can't understand Braille. This conversion engine will easily convert the Braille text into the corresponding Sinhala document and will assist the learning process of visually impaired academic students of Sri Lanka.

A scanning-based input is incorporated in this system because the brail print materials which are expected to be converted through this software need to be subjected to an optical character reading process tailor-made for the purpose. Six dots are used to create brail symbols. This system identifies these distinct symbols using a specially constructed framework and compares them against a database of symbols in compiling the final output which comes as Sinhala Unicode characters.

This system is expected to expedite the paper marking process of the visually impaired students on par with the other ordinary students and therefore shall effectively reduce or abolish the waiting time for those students when receiving their results. It also could work as a more credible method of translation which avoids the inaccuracies caused by human errors in the process of manual translation. Hence the marking which take place based on the answer scripts converted using this tool can be more credible and transparent in the marking process as well.

Keywords: Braille, OCR, OBR, Sinhala, Convertor, Assistive Technologies, Translation

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I sincerely hope the outcomes of this research project will be of benefit for a greater number of users who read and write using Braille system in Sri Lanka as well as the other scholars and researches who are conducting similar studies.

Chapter 1. Introduction

The literacy of the persons with visual impairments has been largely dependent on the tactile reading and writing system called Brail which was invented by Louis Braille. Yet the emergence of new technologies associated with computers and the advancement of information technology posed opportunities as well as challenges for such individuals. Particularly in the realm of education and academic endeavors, persons with visual disabilities found themselves in difficult situation due to the lack of sufficient service providers in terms of translating their write-ups in Braille into ordinary calligraphy.

Various solutions which combined different technologies to solve this issue has been proposed and implemented in different parts of the world by different experts in the field using different methods. This particular endeavor of programming a Braille to Text Convertor for Sinhala intends to look at new methods which could be adopted in this regard to expedite and increase the accuracy of translation of braille into ordinary text and the other way round.

With the advancement of new technology associated with computers and software systems, many tools and applications have been being introduced and developed in order to breach very many communication gaps. Accordingly, the means of written communication such as Braille used by the persons with visual impairments were also inducted into computer systems by means of 'computer Braille' / 'Refreshable Braille'. However, the area that was looked at predominantly in this regard is the assistive technologies which facilitated the conversion of normal text to Braille and not the other way round. This trend has left the process of visual disability inclusion in many sectors such as education, employment and service procurement lopsided because the facilities are only available for one-way communication that enabled normal text to be accessible in Braille while the persons who do not know / use Braille were forced to seek the assistance of experts in Braille to access the scripts written in Braille by the visually impaired users of Braille.

This situation appears like an instance where the people who do not have a disability are handicapped and dependent for a certain extent in terms of understanding / deciphering the communication in Braille. The optical character recognition (OCR) technology which was originally introduced for the benefit of the visually impaired persons and later used for other types of applications became an avenue into which the attention was drawn in order to overcome the aforementioned communication hurdle.

This particular application of the OCR technology is known as Optical Braille Recognition. Therefore, this system is planned to be introduced as a Braille to Text Convertor for Sinhala for the benefit of Sri Lankans with visual disabilities.

1.1 Problem

The visually impaired students studying in various education institutions in Sri Lanka, have faced different issues due to the inadequacy of qualified brail translators. Inclusive education which has enabled them to study in ordinary schools and in universities with other ordinary students is continually disrupted by this barrier.

They are facing various issues due to this situation: the issues vary from inaccurate translations due to human errors, misappropriations of translation in ways that cause undue advantages as well as unjustifiable disadvantages for such students and above all, the intolerable delay of receiving translated examination answer scripts to the respective teachers / lecturers which irritates them and invokes negative impressions about such students.

A system that instantly translates such papers with minimum effort and without the involvement of a skilled translator in this regard will be instrumental in rectifying this issue. In the long run, this system could revolutionize the attitude of the educators towards the bold act of inculcating these students into the mainstream education system under the auspices of inclusive education by means of eliminating the necessity to use hired human translators and the intolerable delay caused in the translation process.

Will the implementation of this system expedite the interactions between teachers and lecturers in the stream of education sector and the students who receive inclusive education by avoiding the need to have human translators and thus eliminating the delay caused during the translation process of brail and by breaching the availability gap between readable text and brail texts.

1.2 Aim of the Study

Develop an application for Braille to text convertor for Sinhala.

1.3 Objectives

The main objective of this project is to develop an application that facilitates the inclusive education sector pertaining to visually impaired students by ways of breaching the delay of translation and the gap between the teachers and such students.

Objectives: -

1. Create an application compatible with mobile and desktop platforms.
2. User can capture the braille text as an image & then it converts automatically to the Sinhala text.
3. The application has identified any braille text & symbols when it written in Sinhala braille.

1.4 Scope

This software application is based on both desktop and mobile platforms. User can capture the image of the document and then App converts it to the Sinhala text. This project that was conducted to create this conversion system only caters to the persons with visual impairment who use Braille system to read and write. As well as this App recognize only standard braille pad's documents only. This system is not expected to be developed to support multilingual text or unrecognized braille symbols.

An image-based input is incorporated in this system because the brail print materials which are expected to be converted through this software need to be subjected to an optical character reading process tailor-made for the purpose. Six dots are used to create brail symbols. This system identifies these distinct symbols using a specially constructed framework and compares them against a database of symbols in compiling the final output which comes as Sinhala Unicode characters.

1.5 Significance and Justification

It is roughly estimated that over 200,000 persons with visual impairment are currently residing in Sri Lanka. This amount to approximately 1% of the entire population. Among these persons there are many who are benefitted by the Braille system.
They require a quick method of translating their brail written scripts efficiently and more accurately in order to be on par with the rest of the society in academic endeavors as well as in daily life where they engage in different white-collar occupations.
Therefore, this technological advancement created by introducing a system that can facilitate the said requirement could be a huge leap that serves a significant minority whose existence could possibly be just another burden for the economy of this country if remained otherwise.

Therefore, this system is planned to be introduced as a Braille-Sinhala converter for the benefit of Sri Lankans with visual disabilities. This system has 2 components which are backend and frontend. Backend is run in the server and its based-on java application. Frontend is run on mobile platform and it’s based on android application. Backend phase can use as a desktop application.

First, a document written in Braille symbols is scanned and the symbols are identified using specific algorithm-based process of image enhancement and optical character recognition. Then the patterns which have been thus obtained are compared with a database of pre-entered standard Braille symbols and are mapped with the Sinhala alphabet where the final task of converting to Sinhala happens.

1.6 Limitations

As an area of interest that's rarely concentrated in the wider spectrum of information technology, the avenue of inter-medium conversion related assistive technologies pose various challenges particularly in terms of the amount of previous research work conducted in this field that has created numerous limitations.

1. The research project that was conducted to create this conversion system only caters to the persons with visual impairments who use Braille system to read and write.
2. The target audience, on whom the needs assessment survey was conducted, had a limitation that remained within the universities which facilitated the higher education of the persons with visual impairments.
3. The limited timeframe for the project was not sufficient to fully implement the system while addressing all the known issues and configurations which had been required to deal with.
4. The conversion that's intended to be carry out through the said system is only limited to Sinhala language as defined in the scope of this research project.
5. The converted output of Sinhala calligraphy has only been researched and implemented to be gained only in Unicode and hence the requirements of converting to other types of Sinhala fonts have not been addressed.

Chapter 2. Background

2.1 Introduction

The World Health Organization (WHO) approximates that the population of persons with disabilities are reported at one billion persons and identifies them as the largest minority in the world. [1] Among them, 285 million people are estimated to be visually impaired. 39 million are blind and 246 have low vision [2].

There are 4 levels of visual function, according to the International Classification of Diseases: [3]

1. Normal vision
2. Moderate visual impairment
3. Severe visual impairment
4. Blindness

Moderate visual impairment combined with severe visual impairment are grouped under the term “low vision”: low vision taken together with blindness represents all visual impairment.

Globally the major causes of visual impairment are:

1. Uncorrected refractive errors, 43%
2. Unoperated cataract, 33%
3. Glaucoma, 2%

An estimated 19 million children are visually impaired. Of these, 12 million children are visually impaired due to refractive errors, a condition that could be easily diagnosed and corrected. 1.4 million are irreversibly blind for the rest of their lives and need visual rehabilitation [2].

Sri Lankan demography highlights that an approximate 1.7 million persons are with disabilities according to the Department of Census and Statistics [4]. This number is estimated to be more with the addition of war affected numbers of citizens who report a disability and disability caused by road accidents and non-communicable diseases. Of these, around 200,000 people are believed to be blind. Another 400,000 are having low vision. The majority of them are blind due to cataract. Refractive errors, glaucoma, diabetic retinopathy and blindness in children are the other causes of vision impairment.

There are currently seventeen schools for the deaf and blind in Sri Lanka. There is also a program of integrated education for the vision impaired which was commenced in 1969 under the aegis of the Ministry of education, based on the recommendation of the Jeane Kenmore report.

More recently in keeping with international development, and particularly with the UN convention on the Rights of the Child, the emphasis has been on Inclusive Education. At present, children with disabilities are educated in government schools either through inclusion in the ordinary classroom or in special education unit attached to ordinary schools. However, a number of students with disabilities continue to attend Special Schools run by NGO’s and the private sector by choice or because they can’t fit in to either of the above streams.

There are number of blind graduates (mostly employed as school teachers), and many blind students are attending university courses. But many vision impaired persons still receive no opportunities for education or employment and are confined to their homes. Even though we have had integrated education for vision impaired children for more than 3 decades, only 71% of today’s adult blind community have received a school education [5].

Although many blind persons learn the use of Braille at school, most are unable to use it later. Only 41% of individuals who know Braille are able to use it. This is due to lack of Braille writing equipment and reading material in Braille. Consequently, vision impaired persons are often excluded from mainstream vocational training programmes not only because of employers’ perceptions that having no sight, they are helpless, but also because vocational training materials and instructions are not available in accessible formats [5].

Hence the creation of a system which facilitates the communication bridge between the persons with visual impairment and the rest of the society is vital and should be facilitated with cutting-edge technology such as the system which was thus implemented. The target beneficiaries of this solution are the visually impaired students who use Braille medium. This system is useful for academic institutions and universities as well as other work places which require quick translation tools for the blind people and the sighted people.

2.2 Components of the System

There are five key components one should take into account when considering the background of this system.

- Sinhala Language
- Braille medium
- Image Processing Technology
- OCR technology
- Conversion algorithms

2.2.1 Sinhala Language

Sinhala is considered a national and official language of Sri Lanka. Many people were of the view that computers will forever function in English and Sinhala will never make it to the list of language in which computer interfaces will be available. Now the tables have been turned and Sinhala is recognized as a well-documented language in computing although it still hasn't gained the international recognition as much as European language. Sinhala was included in Unicode in 1998, but there were no implementations even by 2002.However, the efforts of various academic institutions such as Language Training and Research Labs of University of Colombo and app localization projects of University of Moratuwa paved the way for Sinhala to be elevated to the level of functional interfaces of both Windows and Linux which are considered widely used operating systems all over the world.

Sinhala language is significant for this special system which empowers the students with visual impairments by solving their issue of translation errors and delays because; the primary output will be in Sinhala language.

2.2.2 Braille Medium

Braille is a system of raised dots that can be read with the fingers using tactile sense by people who are blind or who have low vision. Braille is a code, which enables visually impaired persons to read and write. A visually challenged Frenchman, Louis Braille, invented it in 1829 [6]. Braille is comprised of a rectangular six-dot cell on its end, with up to 63 possible combinations using one or more of the six dots. Braille is embossed by hand (or with a machine) onto thick paper and read with the fingers moving across on top of the dots.

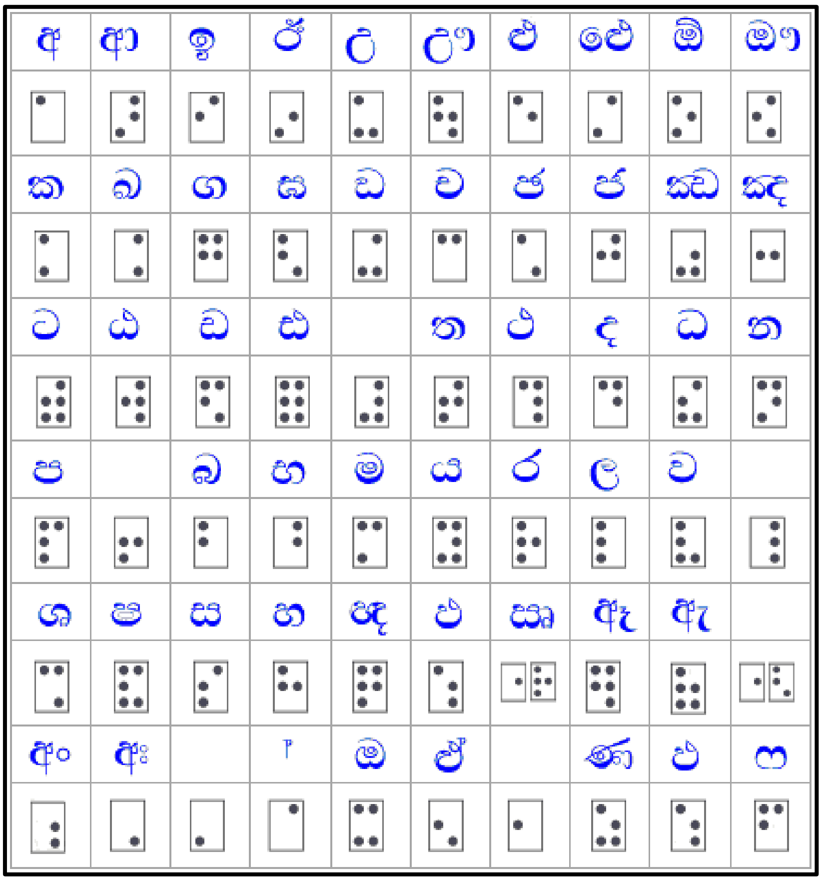


Figure 2.1: Sinhala Braille Alphabet

All over the world, persons who are visually impaired have used Braille as the primary means of accessing information. Also, the concept of Braille has been accepted as a universal approach that works across the boundaries of the world. Different countries of the world have adapted the system of Braille to suit their languages. Although most people have a misconception that brail is another language, that doesn't properly explain the task, performed by brail because this system has methods of writing using all the human languages and numerals.

Therefore, it can be considered a medium utilized by the persons with vision impairments to communicate by means of writing which is similar to calligraphies of various sorts which could be visually deciphered. The only difference of this system is, the visually impaired people can read brail through tactile sense and not visually.

This medium is important for the implementation of this system because the inputs for the system are taken by scanning and deciphering Braille symbols.

Today Braille writing equipment has been modernized. They have been enhanced with the technology to the level of digital Braille. Braille converters which can convert readable text to Braille letters are available for the end-users already. But most of them are limited to the conversion of English or European languages to Braille.

2.2.3 Image Processing Technology

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, like video frame or photograph and output may be image or characteristics associated with that image.

Image processing is required in this system because the scanned images should be further enhanced in order to be able to properly interpret using the optical character recognition technology custom-made for the purpose as discussed above.

2.2.4 OCR Technology

Optical Character Recognition (OCR), is a technology that enables one to convert different types of documents, such as scanned paper documents, PDF files or images captured by a digital camera into editable and searchable data.

This technology should have to be customized to accommodate for the requirement of this system because a separate framework that encapsulates the identification of distinct brail symbols and patterns would have to be conceptualized and implemented in order to accomplish the intended task of this system.

2.2.5 Conversion Algorithm

An algorithm is an effective method that can be expressed within a finite amount of space and time and in a well-defined formal language for calculating a function. Starting from an initial state and initial input (perhaps empty), the instructions describe a computation that, when executed, proceeds through a finite number of well-defined successive states, eventually producing "output" and terminating at a final ending state.

The process of representing continuous graphic object as a collection of discrete pixels is called scan conversion. Converting the geometric definition of a primitive form into a set of pixels that make up the primitive in the image space. This conversion task is generally referred to as scan conversion.

These algorithms will be useful in properly defining and designing the system using OCR technology because rules and limitations as well as validations could be defined using algorithms in both image processing as well as OCR interpretation.

2.3 Similar Systems

The similar research projects in the area of medium-conversion related assistive technologies which provided more insights and divers methods of implementation that enriched certain areas of the system designed as the end result of this project. In the process of researching for literature related to the technologies associated with this specific avenue of OCR-based Braille conversion to different languages, only a few publications were available online which were sufficiently relevant and insightful for reference.

The Braille to Text Convertor for Sinhala is based on Braille system primarily. Numerous resources were instrumental in gaining an in-depth understanding of the evolution of Braille and its various nuances related to the various standards of Braille. Hence it is important at first to look at the basics of Braille.

According to an extensive Indian resource regarding the advancement of Braille titled as "Introduction to Braille", the concept of Braille has been accepted as a universal approach that works across the boundaries of the world. Different countries of the world have adapted the system of Braille to suit their languages. Irrespective of these changes or modifications, visually impaired persons understand standard Braille for the Roman alphabet (English Braille) making it possible to exchange information in a consistent fashion across different countries [6].

As highlighted in the background, the currently used system of Braille has been a result of a continual process initiated by Louis Braille. Braille was a Frenchman who lost his sight from an eye infection caused by an accident with his father's leather working tools in childhood. Louis Braille developed his ideas for a tactile code system adapted from French soldiers who wanted to be able to read notes in the dark. Louis Braille modified this 12-dot system into 6 dots and had written in Braille and taught others by 1832.

Braille was introduced in the U.S. about 1860 and was taught at the St. Louis School for the Blind and other schools later on [6] [7].

There have been many other tactile reading media for people with blindness in the past 200 years. Originally, most reading instruction was done with books made with raised or embossed letters created by wetting paper and printing with an ink printing letterpress. People also learned letters and reading by using carved wooden letters arranged into words, and letters made with bent and twisted wire. It was long thought by educators of blind people that having a tactile code different from letters that sighted people read would separate blind people from the mainstream of society and limits the amount of reading material to which they had access. Special reading codes would also mean teacher training was more demanding and finding teachers able to work with students with blindness more difficult. Around the same time Louis Braille was developing his code, other codes were also being developed. Many blind students secretly learned Braille and other dot-based tactile writing codes when their schools officially taught embossed letters. Ultimately the dot-based letters of Braille became the most widely accepted tactile reading code in English speaking countries, and most of the world [8] [9].

Among those other methods: Boston Line Type developed by Samuel Gridley Howe, the founder of the New England School for the Blind (later Perkins School for the Blind) in Massachusetts, New York Point developed by William Bell Wait, American Modified Braille founded by Joel Smith, a piano-tuning teacher at Perkins School for the Blind in Massachusetts can be identified as most notable[8] [9].

Braille may also be viewed as a script built upon primitive shapes which are dots positioned on a grid. In conventional scripts the letters are drawn using primitive shapes which are stroked. The Braille cells cannot be reckoned as equivalent to the strokes, but each cell corresponds to a letter of the alphabet or a special symbol used in writing a language. Hence Braille cells have to convey different information in different languages. That is, the interpretation of a Braille cell will be language dependent. Generally, countries of the world have assigned the letters of their languages to specific Braille cells according to their local requirements [6].

It must be noted that Bharati Braille (the Braille scheme adopted by India and some South Asian countries) has taken the best approach to presenting Indian language text through conventional Braille by using phonetic equivalents from Standard English Braille to the extent possible [6].

Standard Braille is an approach to creating documents which could be read through touch. This is accomplished through the concept of a Braille cell consisting of raised dots on thick sheet of paper. The protrusion of the dot is achieved through a process of embossing. A cell consists of six dots arranged in the form of a rectangular grid of two dots horizontally and three dots vertically. With six dots arranged this way, one can obtain sixty-three different patterns of dots. A visually impaired person is taught Braille by training him or her in discerning the cells by touch, accomplished through his or her fingertips [7] [9].

Each arrangement of dots is known as a cell and will consist of at least one raised dot and a maximum of six. On a Braille sheet, the dots are created by embossing using a special printer or even a manual machine that simultaneously embosses the dots. Today, there are Braille printers which may be connected to computers on standard printed interfaces. These are generally known as Braille Embossers [6].

Among various tools used for the writing of Braille, there has been a series of mechanical marvels in the form of writers which adopted various sizes and configurations of the Braille cells [7].

Before the development of Braille writing machines, people writing Braille used a slate and stylus. The slate held the Braille paper and provided a template for the dot locations, and the stylus was used to punch holes into the paper. Since the dots are raised, the person had to learn to write in reverse from the back of the paper. Frank Hall, superintendent of the Illinois School for the Blind, developed a personal Braille writing machine in the late 1880's. In the next decades, other inventors developed writers for Braille and New York Point. Since most machines were not mass produced, their reliability and consistency of writing varied widely. In the 1930's, the American Foundation for the Blind commissioned a Braille writer from a typewriter manufacturer. It was heavy and not durable enough for practical use. Later, David Abraham of the industrial arts department of the Perkins School for the Blind worked to develop a Braille writer at the urging of Gabriel Farrell, director of Perkins. He had a model working by the early 1940's but the war year's limited manufacturing. After World War II, Abraham's Braille writer went into production and was on the market in 1951 as the Perkins Brailler [7] [9] [8].

Now the Tatrapoint is available in the U.S. from Maxiaids. It is lightweight and easily portable with some components made of high-impact plastic. The adaptive model allows adjustment to accommodate different hand and finger sizes. Quantum

Technology in Australia recently released a small manual brailler called the Jot-ADot. It uses letter weight paper of a small size and is intended for taking short notes. The same company also makes the Mountbatten Brailler, an electronic Braille writing device which talks. Some models interface with computers and ink printers. The Mountbatten provides good support for people helping students who read Braille, but who don’t read Braille themselves [10] [9].

Using Braille have changed over the years, Braille remains a viable and crucially important medium for communication. Moreover, Braille gives access to text in a manner that allows the reader to read independently and to see the spelling of words, the format of documents, and the symbols used. For these reasons, it’s imperative that the codes are kept up to date, so Braille users can read and write accurately.

For many years, Braille authority of North America which has been functioning as a major stakeholder of developing and keeping the consistency of Braille code has continued to make small changes to the Braille code where absolutely necessary. Out of consideration for the impact on Braille readers, teachers, and transcribers, BANA has acted conservatively in making changes [7].

The first of these efforts was the Unified English Braille (UEB) code project, which was initiated in 1992 by the Braille Authority of North America (BANA). The impetus for this effort was a memorandum sent to the BANA Board in January 1991, by Abraham Nemeth and Tim Cranmer. In this memo, Drs. Nemeth and Cranmer expressed their concern over the “proliferation of Braille codes” with different symbols for common characters. Later in their memo, they cited “the complexity and disarray" of the Braille codes then in use, and they asked BANA to give the Braille code a major overhaul to improve its usability and flexibility [7] [8].

Based on the recommendations in this memo, BANA established a committee to explore the development of a unified code. The original intent of the unified code project was to explore the possibility of bringing together three of the official Braille codes that are used for various purposes: English Braille, American Edition (literary material), Nemeth Code (mathematics and scientific notation), and Computer Braille Code (computer notation). In 1993, the project was adopted by the full International Council on English Braille (ICEB). The project was expanded in scope to explore the possible unification of the Braille codes that are used for those purposes in all seven ICEB member countries: Australia, Canada, New Zealand, Nigeria, South Africa, United Kingdom, and the United States. Work to develop a unified code was conducted primarily by Braille readers in those countries with input from transcribers and educators [7].

However, the codes used for technical purposes in the other ICEB countries were very different from those used in the BANA countries, so that UEB can be regarded as bringing together the Braille codes used in different countries as well as those used for different kinds of notation. The only notation specifically exempted from consideration under the UEB project was the music Braille code, which was already and still is a well-accepted international code [9] [7].

With the advent of computers preparation of Braille documents has been rendered easy and flexible. In the earlier days, Braille had to be printed using special Braille Printing units that worked more like typesetting printing presses. Computers have rendered the process simple where the required text can be typed normally on a computer terminal and automatically transcribed into Braille and printed. Transcription software will be language dependent, but the rules of transcription can be programmed for each language. Bharati Braille may also be transcribed using computer programs by typing in the text in the vernacular. To print Braille using a device connected to a computer, the data corresponding to the cells has to be sent to the device, usually called the embosser. The cells have to be associated with some codes for this purpose. This scheme is known as ASCII Braille. In this scheme, each Braille cell will be specified by an ASCII value which will not be the same as the English character or the symbol the cell represents. When transcribing text to Braille, the Braille codes corresponding to the letters of the alphabet and special symbols are used. But when printing Braille, the transcribed text is mapped again into ASCII Braille before being sent to the embosser [6] [8].

An IT enabled system has been created by an Indian team of researchers for converting the Braille document to Sinhala text, the input is taken in two different formats. In the first method the Braille character is accepted as a sequence of numbers typed through the keypad and in the second method a scanned Braille document is taken as input. The Braille character is extracted in each case and matched with the corresponding alphabet with help of a pre-built Tire structure [11].

The six-dot cell representation of Braille character could be numbered from 1 to 6 starting from top left to bottom right in the order left to right and top to bottom. The numbers 7,4,1,8,5,2 of keypad are mapped to the dots 1,2,3,4,5,6 respectively. With the number pad the number sequences of the Braille characters are typed and used for further conversion. A research has been conducted concerning the conversion of Braille to text in English, Hindi and Tamil languages. This research has been conducted by a team of Indian scholars comprised of S.Padmavathi, Manojna, Sphoorthy Reddy and Meenakshy. They have discussed intensely about conversion software that have thus far been designed to convert various languages to Braille and have found out that there‟s a lack of tools to invert this process I.E. converting specific Braille symbols into normal text in different languages. They have designed the said tool to address the absence of such a software tool to translate Hindi and Tamil Braille contents into normal text of the respective languages [11].

In this method the Braille document is scanned and taken as input, which by a sequence of steps is converted to appropriate text. The scanned document has to be enhanced to identify the dots clearly. The dots are extracted using horizontal and vertical profiling. The Braille cells are identified and converted to binary sequence. The binary sequence is then mapped to the corresponding alphabets or contracted words. These are stored in a text file and given as input to the voice synthesizer [12] [11].

The specific technologies used in this process can be identified as horizontal and vertical projection profiling as well as intensity and contrast stretching. The intensity stretching has been further described as an effective image enhancement technique used in the process and the formula used in the said technique is S=T(r), where S is the grey level after modification T is the enhancement function used and r is grey level before enhancement.

Then the process of image filtering is also explained with the application of Gaussian filter. Then the focus of the methodology is shifted to the edge detection which helps in aligning the document properly before converting into binary. The Prewitt filter has been used in the system explained in this paper. The Prewitt operator uses two 3×3 kernels which are convolved with the image A, to calculate approximations of two derivatives - one for horizontal changes, Gx, and one for vertical, Gy. Where * denotes convolution. The resulting gradient approximations can be combined to give the gradient magnitude, using Eq,When magnitude is greater than the threshold T, it is identified as an edge. The edges mostly correspond to the dots of the Braille cells. The border of scanned document and the stapler pin information if any present in the document are removed through image cropping [12].

The projection profiling methods in both horizontal and vertical forms have been used in Braille dot segmenting. Then the procedure of binary conversion has been carried out and thus the presence or absence of dots in a particular Braille cell is analyzed in order to determine the particular textual symbol of the normal alphabets of Hindi and Tamil languages [11] [13].

More advance approaches have been adopted in, yet another project carried out to implement a similar system for Arabic language.

The Arabic researchers Saad D. Al-Shamma and Sami Fathi have considered many other factors such as dealing with both single sided and double sided Braille papers and re-orienting the skewed papers [12].

They have also cited the findings and implementations of Mennens et al. whose work addressed the problem of false shadows in the image caused by the fact that Braille pages are never perfectly flat due to the tension in the paper's surface, by subtracting a locally averaged image from the original. The said researches also discuss the features of a program to be able to rotate skewed images using the deviation over a vertical projection of the image. Yet another research done by Hermida's et al. has also been cited concerning a system that employed thresholding before the image is passed on to the Braille dot extraction module. Their algorithm converts a digital image of a scanned Braille page into one consisting mainly of black and white spots denoting the dots. The thresholds used were adaptively calculated from the histogram of the input image. Yet another system proposed by Hentzschel and Blenkhorn has been cited which deals with an optical Braille recognition based on twin shadows approach, which subtracts two images of the same Braille page, where each image was taken under different illumination conditions. According to the said research, this helps eliminate blemish and noise in images caused by the texture of the paper used. Unlike Blenkhorn's work presented in 1994 that solely discussed the classification process, his work in association with Hentzschel later addressed the different modules of a pattern recognition system, including image processing. In, the image-processing module encompassed a variety of routines, each serving a different and crucial purpose as using random-noise reduction filter that was necessary to avoid undesired emphasis of noise. In preprocessing consists of two sub operations: noise filtering and edge enhancement [14] [12].

Noise filtering is achieved via a low-pass special Gaussian filter. Edge detection is achieved using convolution Sobel kernels. The approach adopted by Mennens et al. in for extracting Braille dots is based on several assumptions, one of which is that a single dot is represented by two gray level intensities, a light area right above a dark one. Also, their system is designed to recognize a double-sided Braille page. This approach may produce false core regions if two dots are vertically neighbors. The localization and extraction algorithm developed by Hermida et al. takes a thresholder image consisting of couples of white and black spots, where each couple denotes a single Braille dot. Though this method is easy and quick, it is prone to be subjected to faulty interpretation. If some legitimate points are lost, false ones are produced. The dot localization and extraction One of the techniques used in the proposed system consists of two steps; the first is image registration and the second is character segmentation. The final step of dot extraction is normalization, where each Braille character is represented by a 2x3 matrix. Each bit in the matrix denotes a dot in Braille cell. Deciding whether a bit value is either 0 or 1 is based on a threshold used to test 1/6 of the cell area. In 2004, Wong et al. proposed an OBR system that is capable of recognizing a single sided Braille page in addition to preserving the format of the original document in the produced text file. The algorithm processes the image one row at a time reducing the computation time significantly. The dot detection module incorporated in the OBR system proposed by Oyama et al. in 1997 is designed to detect a both recto and verso Braille dot; that is detecting dots on both sides of the page. This was possible due to the difference in light reflectance between recto and verso dots. A hardware circuit configuration that corresponds to the equations and operates in a similar manner was given as well [12].

Mennens et al. adopted Binary Braille cell sets as basis for their classifier, which is grouping the dots and representing each dot by a bit position. The authors have not elaborated on the comparison method used to recognize a Braille cell as a certain letter or digit. The classifier presented by Hermidaetal takes as an input the image produced from the dot extraction module, where characters are represented as a group of dots, each dot is in turn represented by a single bit, with 1 or 0 values. Using this representation, the Braille-to- ASCII conversion is accomplished. The system proposed in this research is based on finite state approach that operates with a finite number of states that perceives the correct state, in addition to its ability to perform both left and right context checking using matching algorithms. This feature is very important in determining characters proceeding wildcards. One of the greatest advantages of this system is that it is designed in a way to perform the conversion from Braille to any of the natural languages depending on the tables provided containing the conversion rules. The work in system has not elaborated on the techniques used for converting an extracted Braille cell into natural language characters. The recognition module in the said system is designed to work with threshold images resulting from the half-character detection module. The classification process is carried out using a probabilistic neural network. For interpretation purposes, authors in the said research determine centriod distances between each dot and its four possible neighbors. Dots are then grouped into cells. Based on the boundary coordinates, information and illumination characteristics, two standard templates were then constructed to represent the front-face dots and backface dots. The Arabic system has been developed under MATLAB environment and divided into two stages: 1-Arabic Braille letters recognition and transcription 2-Arabic Braille words recognition and transcription Both sections are passing through several stages including image capturing or scanning, converting the Image to Gray Level, image Thresholding (converting it to binary), de-skewing the image, edging the Braille dots, filling Braille dots, opening the image by removing all micro scale objects, cropping the cell frames, cropping the dot frames from cell frames, generating binary equivalent of activated Braille dots, generating equivalent decimal Braille code, apply matching algorithm to Braille frames, get equivalent voice and text file of matched Braille cell [14].

Taking this entire process into a whole new level, Dr. Ian Murray and Andrew Pasquale has developed A Portable Device for the Translation of Braille to Literary Text [10].

This devise outputs the translation via voice synthesizers and does not generate a text output. Moreover, it is still limited to English language Braille translation. Since this devise extracts information on Braille dots through a camera, a complex process as explained below is taken place [10].

The image capture of the Braille medium is achieved by a camera system consisting of an illumination source, focusing lens and linear CCD photodiode array. When in operation, the illumination source, constructed of a row of 4 LED's, shines at a right angle to the Braille page causing shadows to form behind the raised dots of the Braille cell. The selfoc [10] lens used consists of a 2*12 array of micro-lens, designed to focus the Braille dot shadows image onto the linear CCD photodiode array. The lens moves above the Braille cell in when the scanner is in motion, and as such causes no wear and tear on the Braille medium.

The software application designed for this devise follows the steps mentioned below using an interrupt-driven algorithm.

1. Quadrature linear motion detection
2. Sampling of camera output frames

3. Fuzzy logic dot detection
4. Camera Angular Misalignment Correction
5. Braille Cell Compilation
6. Braille to text translation

Thus the entire realm of Braille conversion to text has been of greatly interesting in the world of assistive technologies and hence a localized version of this technology as a computer-based application is believed to be a needed and cost-effective solution for Sri Lankans who use Braille and would require to communicate in a more direct way with those who do not use or possess thorough knowledge of Braille [10].

Chapter 3. Methodology

3.1 Introduction

This chapter discusses the project methodology including alternative solutions of this problem, operationalization where the data gathering methodologies are put into trial and obtain results. Finally, the methodology of software implementation including the rough outline of the program using a use case diagram and a flow chart are also presented.

3.2 Operationalization

Both primary and secondary data are equally crucial for the operationalization of this project. Since the project concentrated on both quantitative and qualitative aspects, the primary data provided the former and the secondary data provided the latter. As a reductive research that initially concentrated on the rich picture and subsequently focused on the specifics, the qualitative factor was significant, and the quantitative factor provided more leverage to point out the majority compliance with the assertion. Hence the project regarding this system was conducted based on both primary and secondary data obtained from the beneficiaries as well as the resource persons by means of interviews. The secondary data in particular was obtained through desk research that concerned similar systems developed in the world and locally likewise.

3.3 Sample Population

When choosing the sample population for this research, the university students were given the priority. In order to get the insight of the experience of Braille users over several decades, the inputs of several senior graduates over a few generations earlier also were taken. Overall, the sample population of the research consisted of 30 students.

3.4 Questionnaire

- **Are you a university student who uses Braille?**

The very first question of the questionnaire intends to find out how significant Braille has been for the students with visual impairments in the universities. The results which have been gained in this regard indicate that all the students with visual disabilities have used Braille in their university education. The indication of this result denotes how significant and relevant a system to convert Braille into normal text for the students with visual impairments.

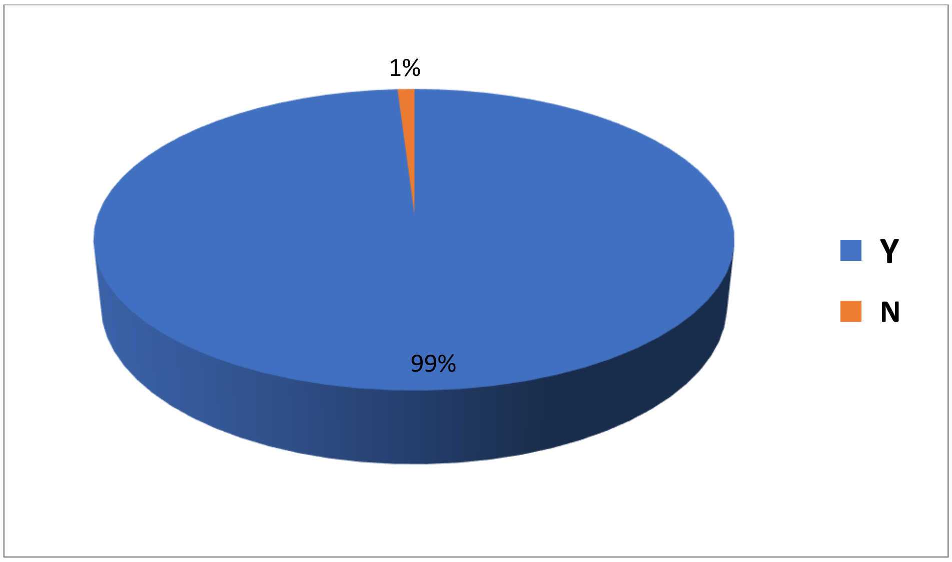


Figure 3.1: Analysis I

- **What's the University you are studying?**

The second question aims to investigate the demography of the students who are benefited through such a technology by taking the various universities into consideration. The result revealed in this regard indicates that a majority of (50%) is from the University of Sri Jayewardenepura and even other universities also consist of students who utilize Braille.

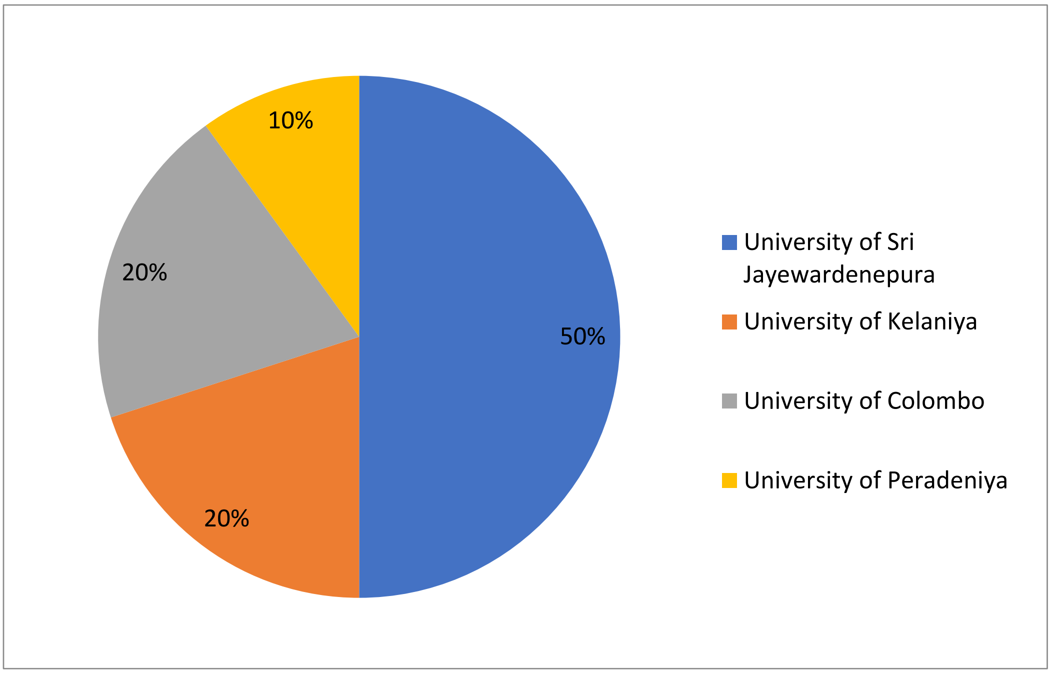


Figure 1.2: Analysis II

- **Do you use any other method apart from Braille to read and write at the university?**

The purpose of the third question is to elicit any other alternative methods used by the students with visual impairments to substitute Braille system in relation to the writing work involved in their university education. While the majority had indicated in their responses that they do use other alternatives, there were some students who had indicated that they use only Braille for all their writing work at the university. This percentage of students makes the requirement of a system like the one that has thus been implemented, all the more vital for their education.

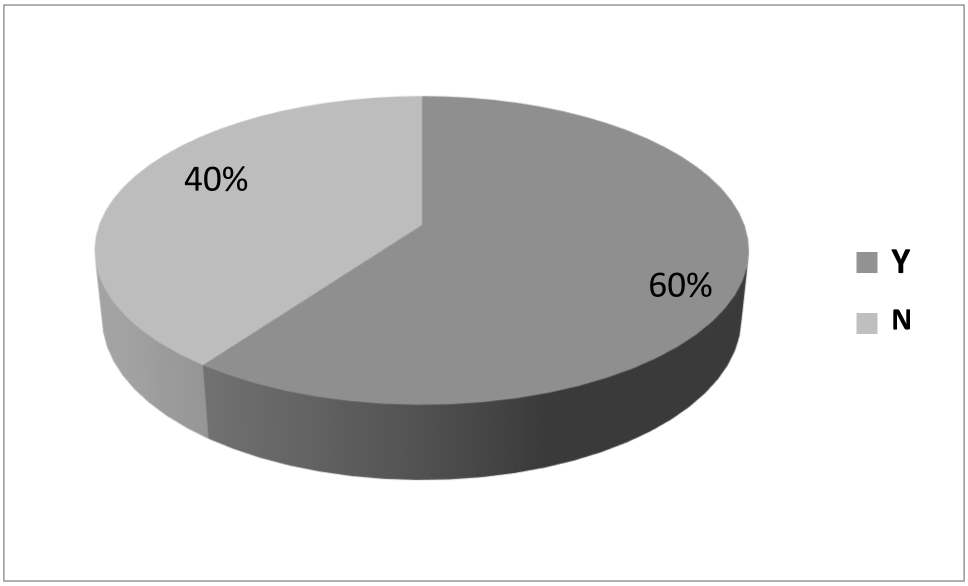


Figure 3.3: Analysis III

- **If there are such other methods you are using, please mention them below.**

In the next question that required the respondents to mention the alternative methods they are using, a considerable amount (80%) of students had mentioned computer-based systems a greater inclination of usage which helps to reaffirm that a system that involves computers, could be handled by them conveniently.

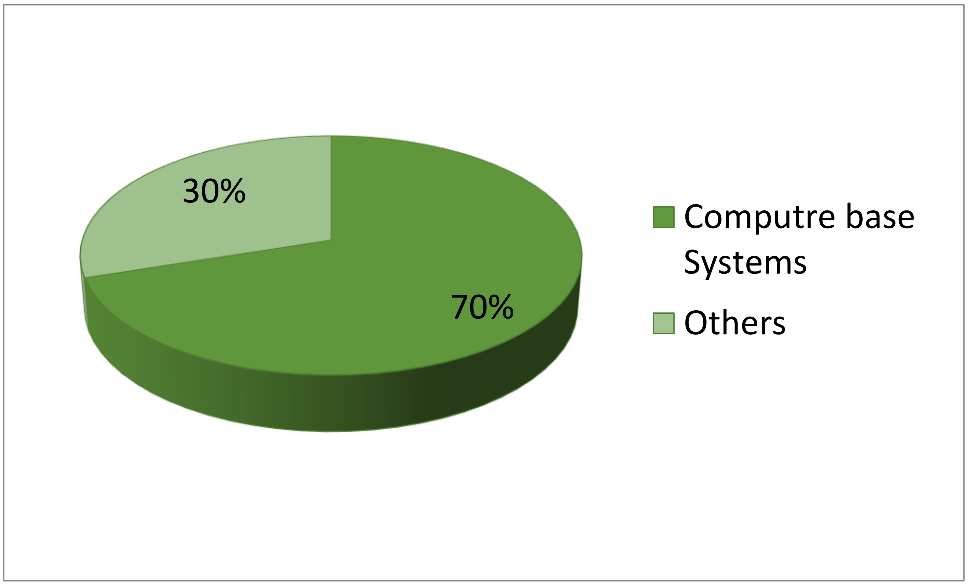


Figure 3.4: Analysis IV

- **Are their qualified professional Braille translators employed by the university to translate your assignments and answer scripts written in Braille?**

The question that investigated the availability of qualified translators garnered a positive response that indicated 90% of availability and still could not disregard the 10 % unavailability as well. Moreover, the students who indicated that they had qualified translators also acknowledged that for certain periods of time in their university career, they did not receive the services of translators and still they will have to state it as available, because there were occasions where they received such services as well.

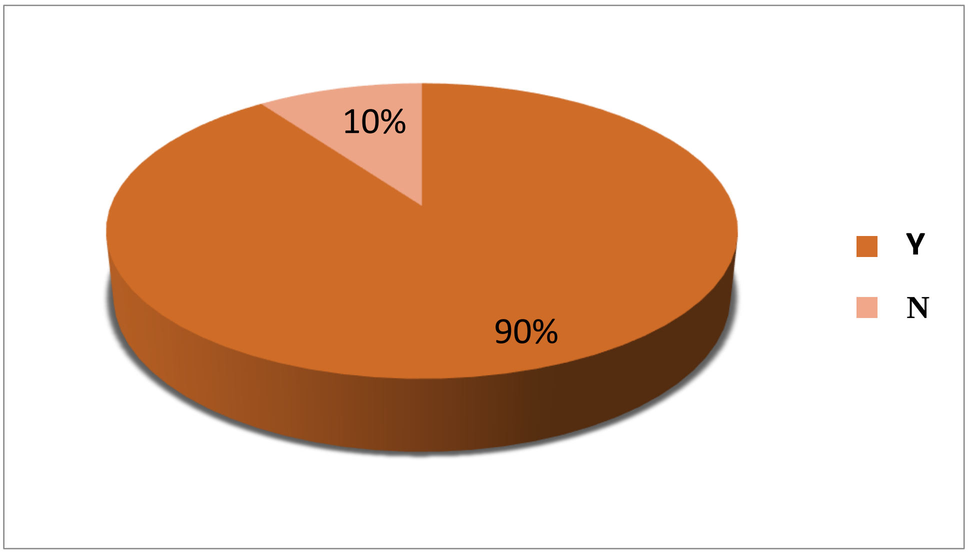


Figure 3.5: Analysis V

- **Have you faced any difficulties due to any delays or unavailability of translation services when you wanted to get a Braille document translated?**

When the question was raised as to whether the respondents have experienced delays or issues with translation services in terms of efficiency and accuracy, 99% have responded in the affirmative while only 1% has not undergone such mishaps. This fact indicates that the available translation method using humans isn't efficient enough to meet the required level of translation demand. Hence the relevance of an automated translation system is further reinforced.

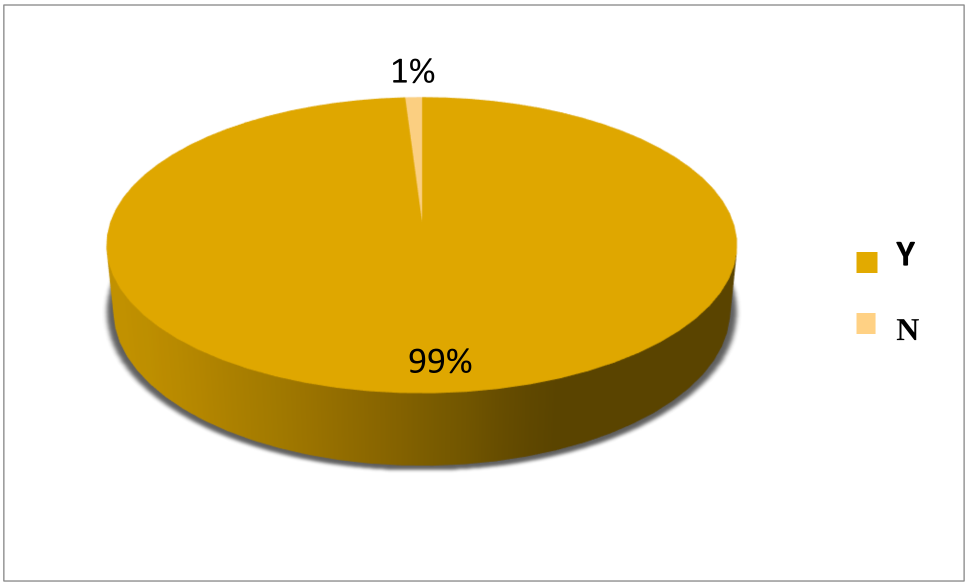


Figure 3.6: Analysis VI

- **While facing examinations or submitting assignments in Braille, have you faced any difficulties or delays in obtaining your examination results?**

This is yet another question that thoroughly investigates whether there had been difficulties for the visually impaired university students who use Braille due to the translation issues that directly affect their examination results and grades. The response of 99% in affirmative indicates that most of the people who took part in this survey had faced problems due to delays in translation at examination results. This discovery further cements the assertion that automating the translation process can be more effective for the efficiency of result release process for the said students and ensure equality of marking grades for them.

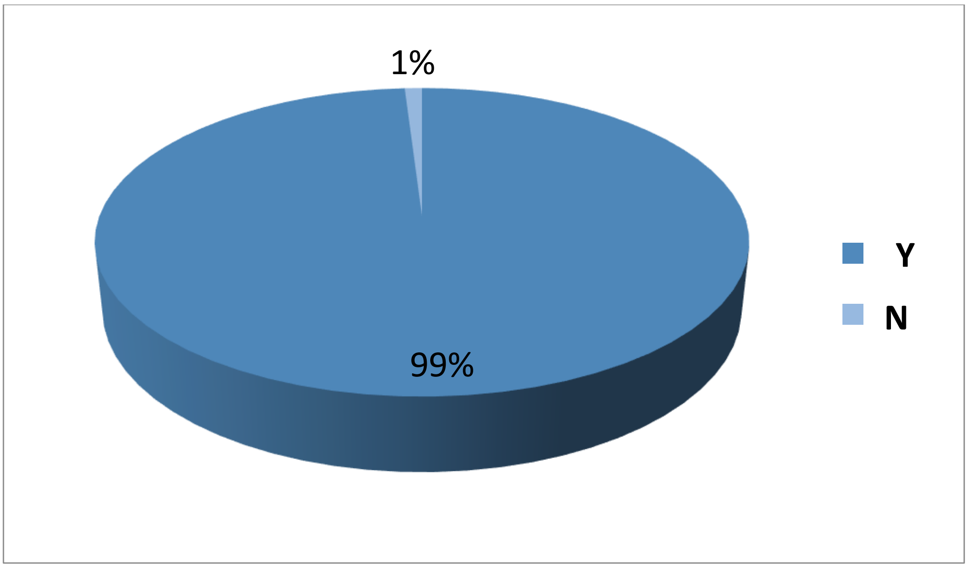


Figure 3.7: Analysis VII

- **Please indicate in the scale below, what level of convenience would be there for you if you would get to use an automated Braille to Sinhala translation tool. Please mark 1 for least usefulness and 5 for most usefulness.**

This question presents the respondents with a scale of one to five in order to rate the usefulness and relevance they feel about the system and all of them have rated as most necessary. Hence the need of such a system has been assessed as utmost high.

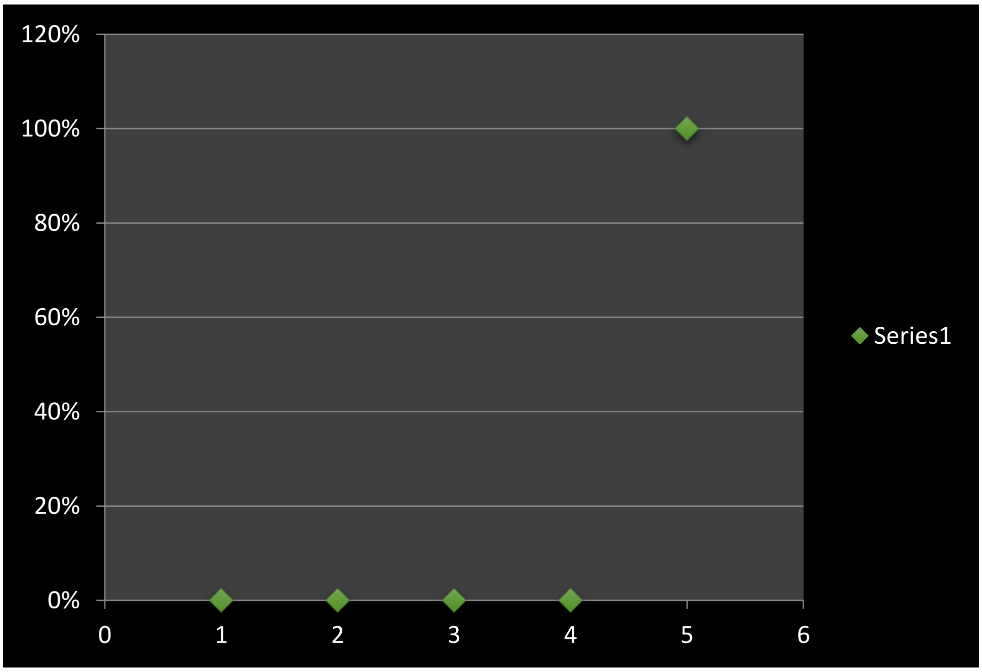


Figure 3.8: Analysis VIII

➢ **Please mention if there are any special features you would like to see in such a system in the space below**

The special features requested by the participants of the survey have been mentioned in the table below.

Feature	**Preferred number of participants**	**Percentage**
Types of symbols	6	20%
Double side Braille scanning	3	10%
Accessibility for blind people	7	23.33%
Accuracy checking ability	10	33%
Support to voice system	3	10%
Compatible with keyboard	1	3.3%

Table 3.1 : Analysis IX

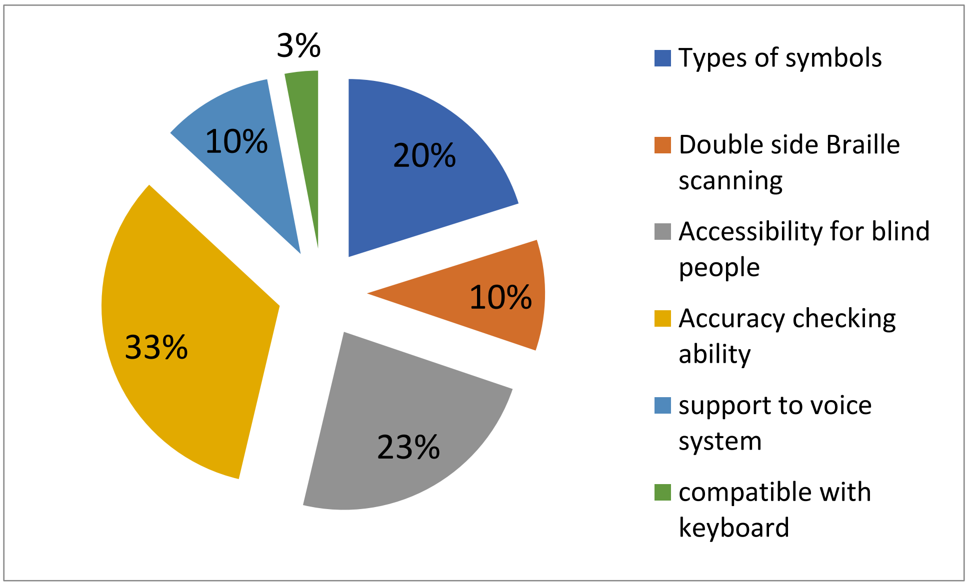


Figure 3.9: Analysis X

The features requested by the respondents include the voice output which could be conveniently implemented by routing the text output to a voice synthesizer and yet, it will be kept as an option to be considered in future development. The requirement of double-sided Braille scanning seems a more pressing issue and hence will be looked at with more attention in the current research and implementation.

Ensuring the accuracy of the system has always been a cardinal requirement of testing and quality assessment and hence the rate of accuracy will be maintained stringently.

3.5 System Implementation

The very first steps of implementing this program was taken with the requirement gathering process which was accomplished through the questionnaire and data collection. The stepwise refinement method was used in developing the system where an agile development approach was followed in order to accomplish the program with minimum errors and maximum efficiency.

Then the following diagrams were developed to define the actors and cases that are possible in the program so that the development is made easier in module decomposition.

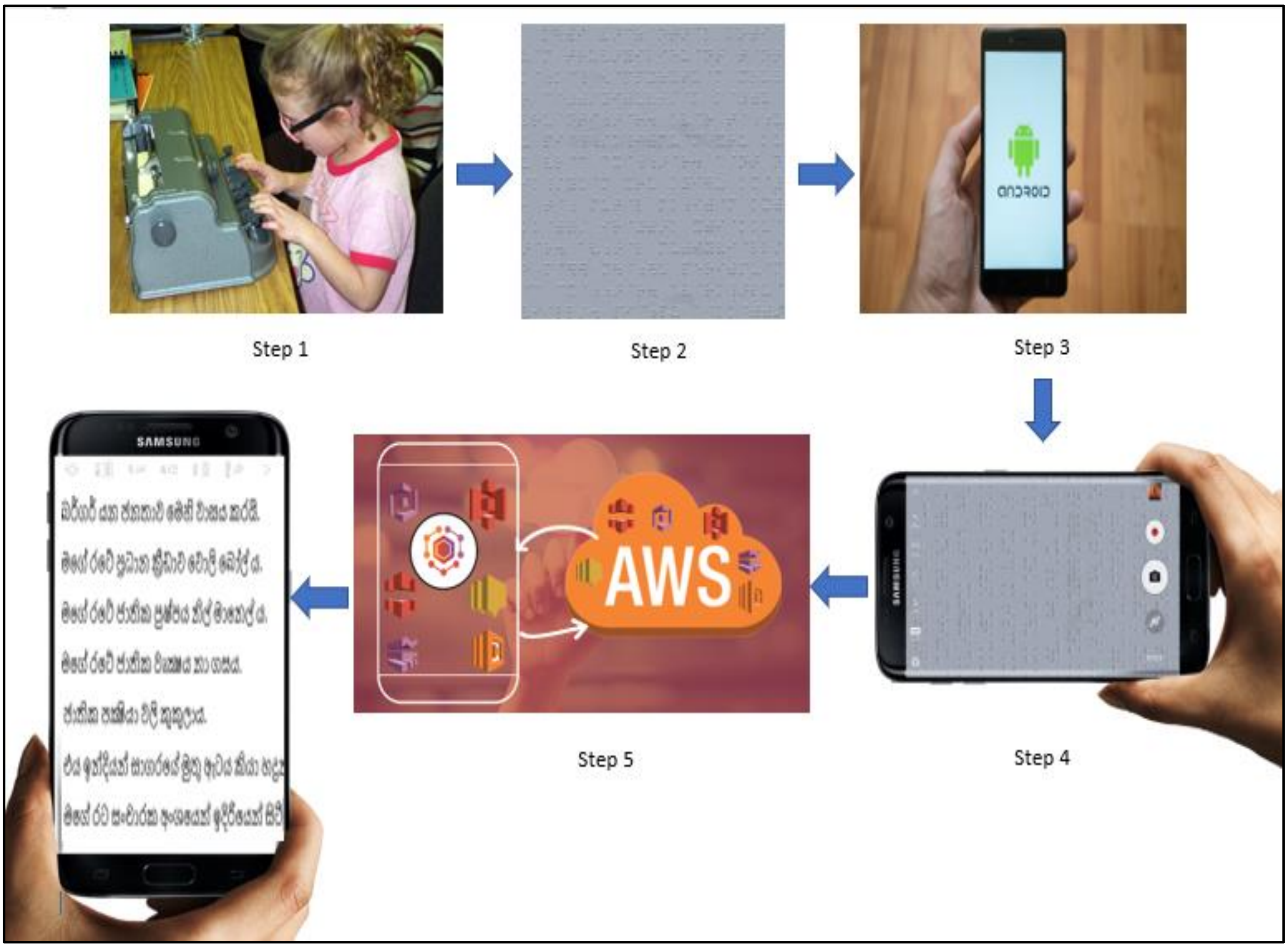


Figure 3.10: System Development Process

Step 1: - Braille document get from the braille typewriter. Blind students can use different type of methods to write their braille letters. In this case get only typewriting documents. Because its dot positions are clear than other braille writing methods.

Step 2: - Identify input braille paper clearly.

Step 3: - Launch the mobile application using android phone.

Step 4: - Capture the braille paper using mobile application. Then identify captured document as an input image.

Step 5: - Then input image uploads to the AWS S3 bucket by the application. AWS EC2 hosted backend API will start series of processes using uploaded image and returning converted text to Mobile application.

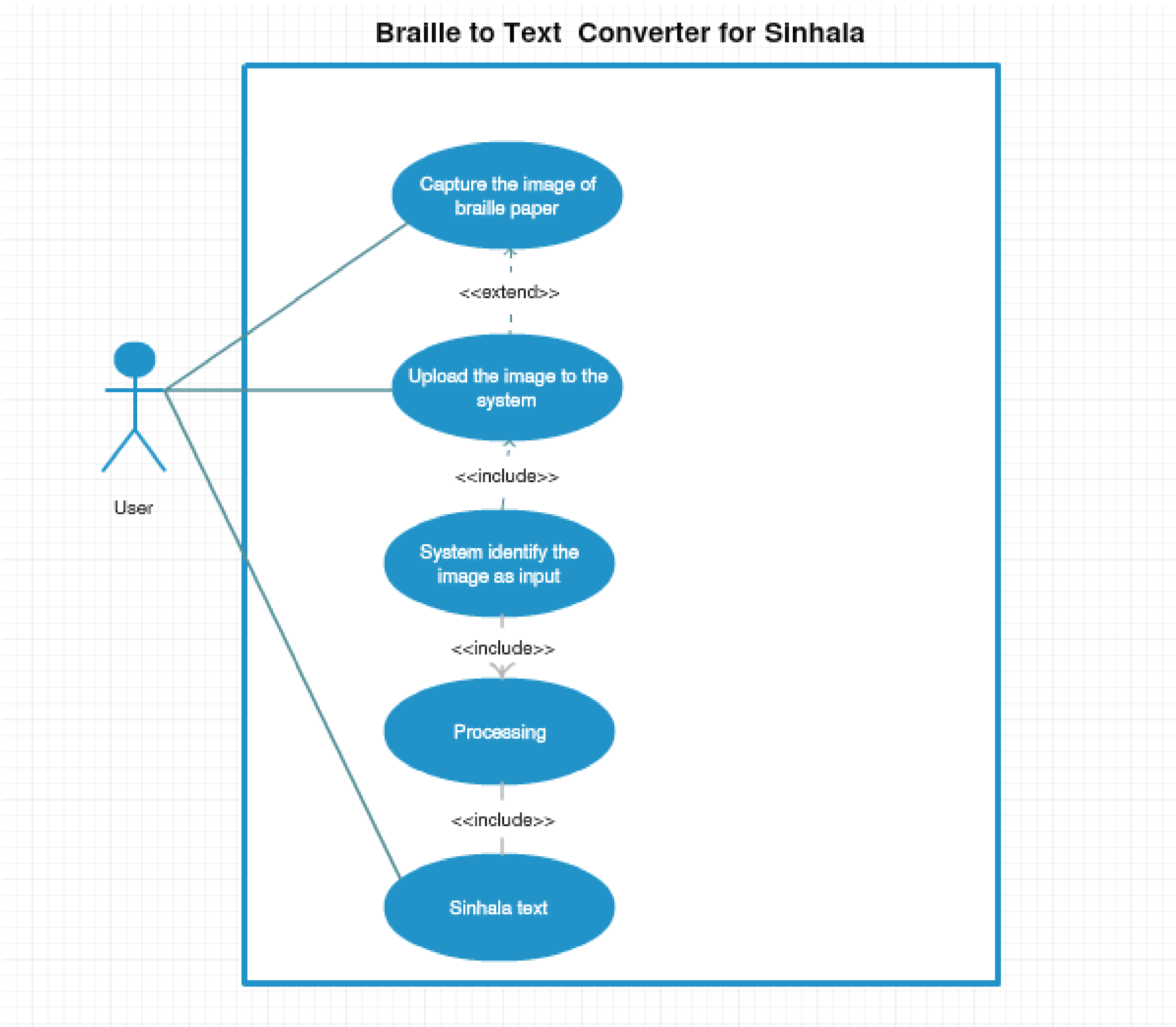


Figure 3.11: Steps of the System

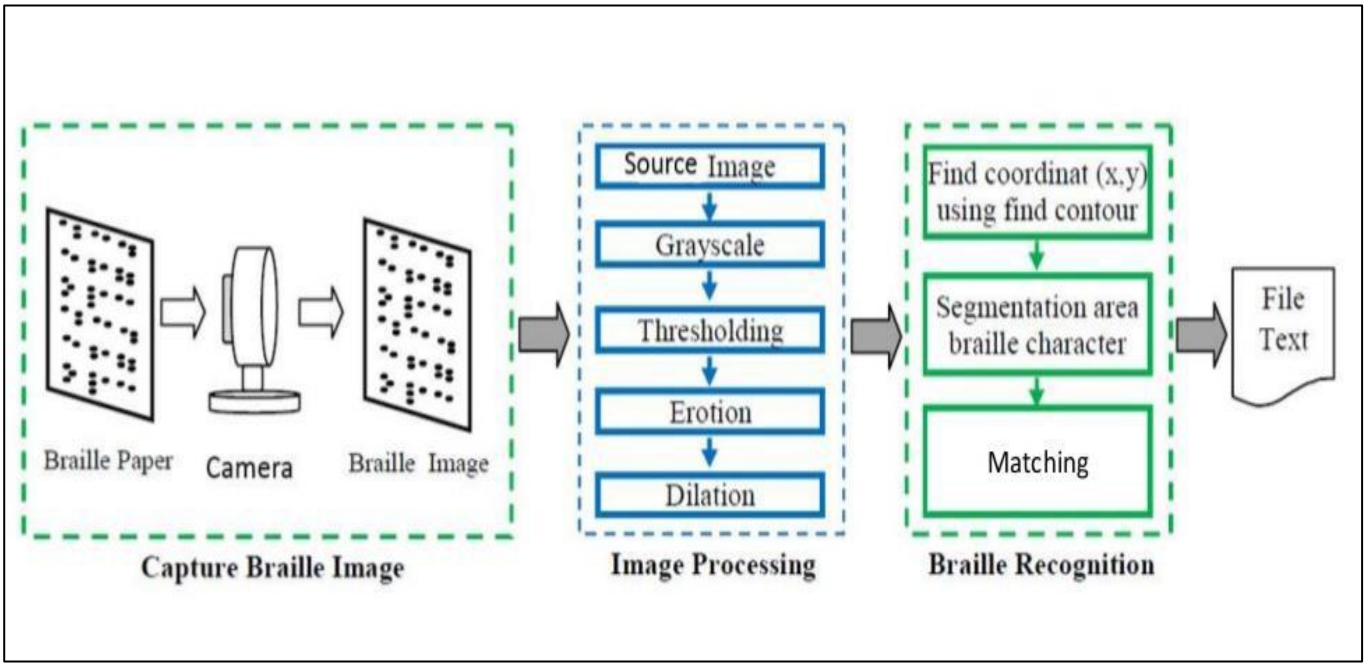


Figure 3.12: User Case Diagram

According to above diagrams we can simply understand what the system was done by this project. Then I identify and classify each step as a task. In my project has backend and frontend development phase. The main project is run on backend phase. It has basic steps. There are

1. Identified an image input model
2. Created an image processing module using
   (a) Gray scaling
   (b) Noise removes
   (c) Thresholding
   (d) Filtering
   (e) Binary conversion
3. Created a module for grid base slicing
4. Identified an issue with different letter sizes
5. Differentiates the Braille dots using the brightness factors of the pixels
6. Identified the Braille dot positions in image
7. Convert to Braille dot positions into Sinhala characters

In this process is run as a Braille Text Processing API and frontend will hope to develop as android application. User can capture the image from android mobile phone and then it converts automatically to the text. In this frontend has only two buttons for capture the image and converts it to the Sinhala text. In this process has some steps. There are

1. User's image sends to the server when click the convert button.
2. Then automatically run the API
3. Output is receiving to the user as a Sinhala text.

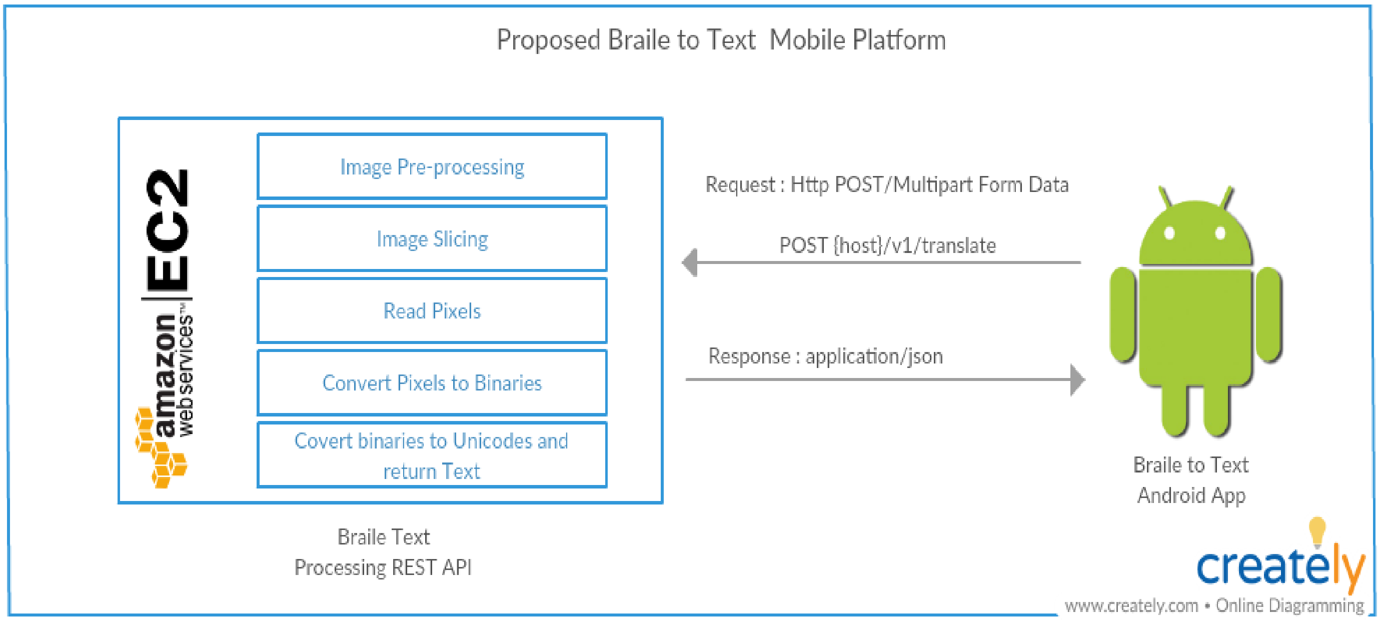


Figure 3.13: Process of the System

3.5.1 Frontend Implementation

In this application's frontend was designed by android application. It selects image of the document and then converts to the Sinhala. In this frontend gives the input for the API. Then it gives a result as a test.

3.5.1 .1 Technology for Android App

- Java 1.8
- Aws SDK S3 – Use to upload the file from mobile app

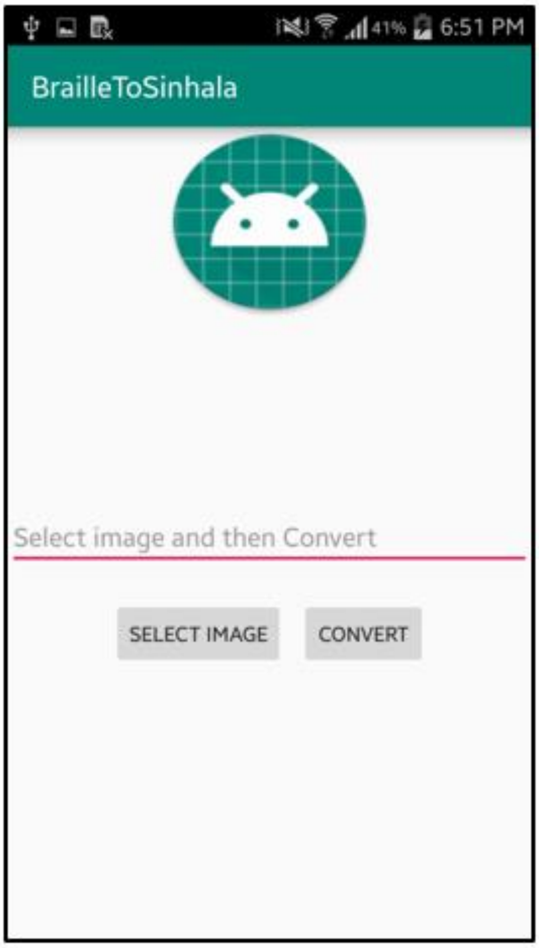


Figure 3.14: Mobile Application GUI I

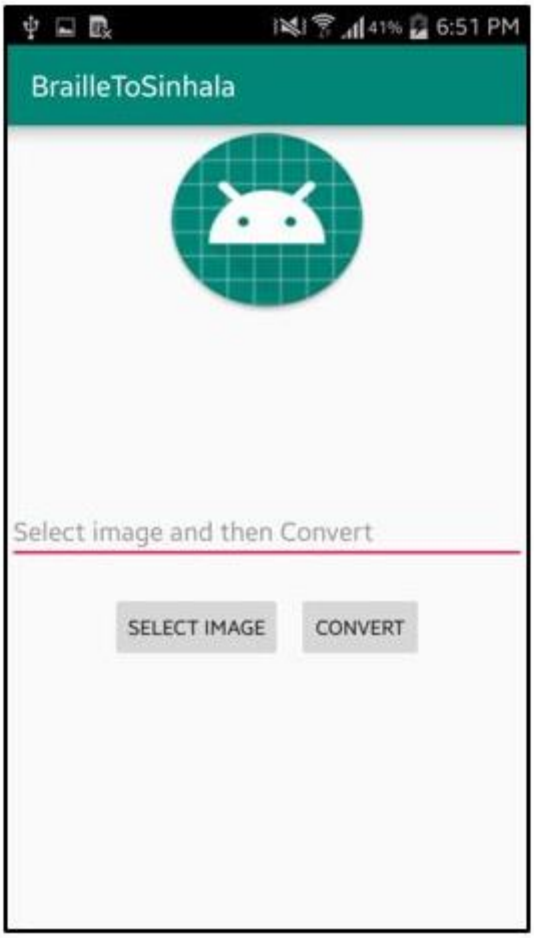
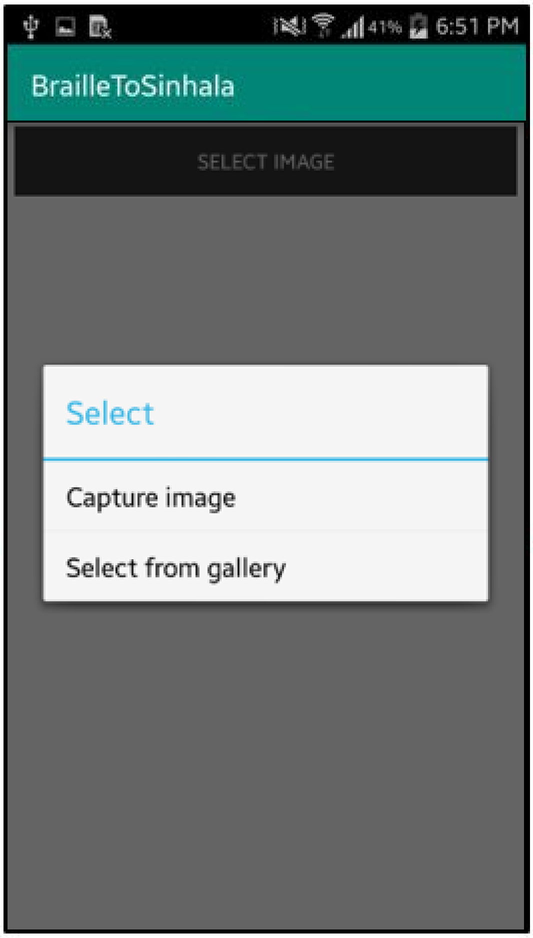
Step 01	Step 02
	

Figure 3.15: Mobile Application GUI II

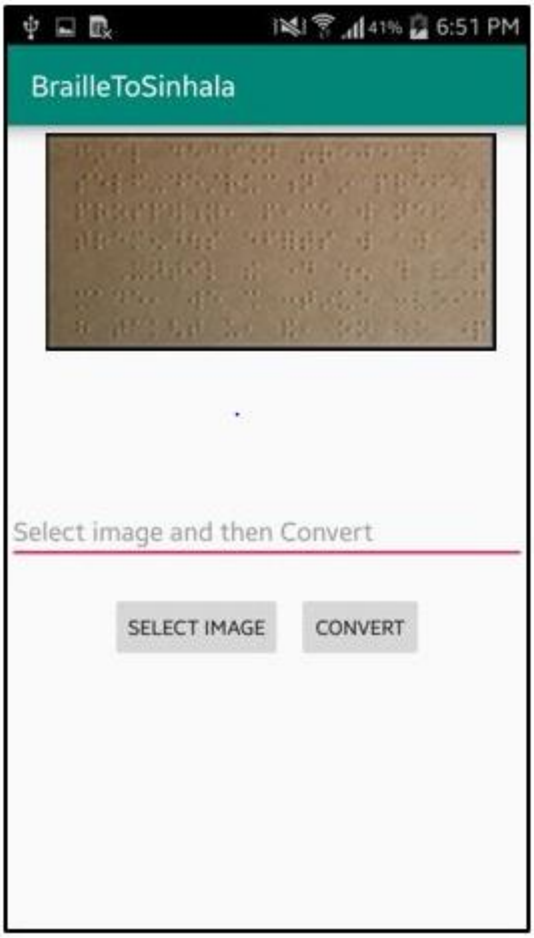
Step 03	Step 04
	

Figure 3.16: Mobile Application GUI III

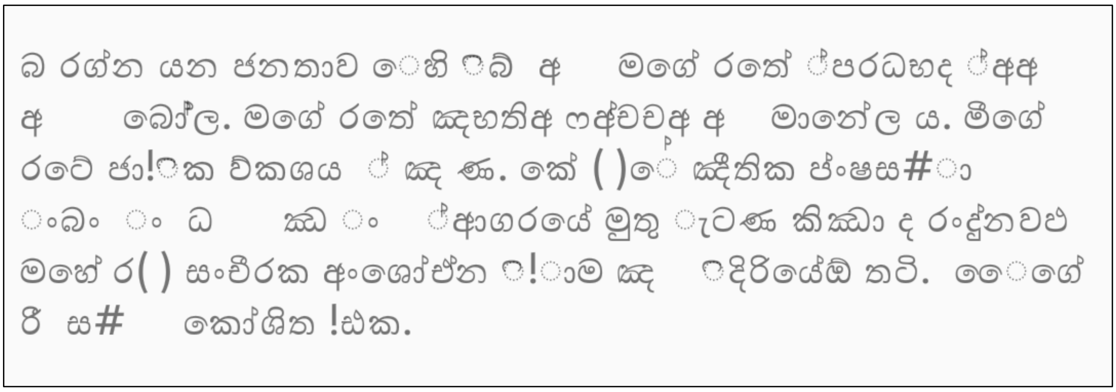


Figure 3.17: Final Output

3.5.2 Backend Implementation

3.5.2 .1 Technology for API

- Java 1.8
- Gradle – Project build tool (package in to jar)
- AWS SDK S3 – Use to get the mobile upload file
- Open cv – Image processing framework
- Aws ec2 – Aws cloud server platform to deploy Brail conversion backend API

The framework called *Opencv 3.00* libraries was used in the core-components of program that involved image processing. A class called *ProcessImage* was defined in which the methods for the conversion were inserted. The said class extends from *javax.swing.JFrame* which is an inbuilt component of java that deals with graphical user interfaces.

Within the said class the method called *InitComponents* is created and it is within that method all the sub components of the program such as (Browse Image, Gray scale image, binary image, crop image, row count, Colum count, slice image) were initialized.

The *BrowseImage* method has been used to import a scanned Braille document as an image file to be subjected to the optical Braille Character Recognition process. The other methods such as *GrayScaleImage***,** *Binaryimage***,** *Cropimage***,** *Rowcount***,** *Columcount***,** *SliceImage* have been used for the preprocessing process.

GreyScaleImage method converts the imported image into a grey scale version so that the rest of the processing does not get affected due to any issues with color differentiation. The image that has been grey-scaled goes through yet another separate method to be filtered and made into binary. After that, it is subjected to a process of counting rows and columns in order to build a virtual grid based on which the Braille dots are recognized.

The image slicing happens based on the results of the above process. The methods known as row count and column count are used for this task while the method *CropImage* is used to crop the unnecessary edges of the image and take the necessary parts where the Braille dots are visible.

In creating the virtual grid to identify the Braille dots, the method process is initiated using *Init* **(***getGridImage*, *getWidth*, *getHeight*, *newBufferedImage***)**. The resulting images of the slicing process were directed to the methods *createSmallImages* and *createDirectoryForSaving* where they were made into small images and saved in a directory for the rest of the process.

Based on the sliced images, the pixel values were counted to detect the presence of Braille dots on those images using X / Y coordinates and for this a calibration method was incorporated.

The reason for this part of implementation was that the inputs can be different from each other since they are scanned images of different quality and finding the range of the Braille cell that consist of 6 (Six) dots need to be correctly identified in order to begin the letter identification process.

For this purpose the code snippet (Ex: *-dataBuffInt = raster.getSample (x, y, 0))* was used where rasterized version of the image is subjected to the pixel identification based on a marginal value 15. When the illumination of the pixel is less than 15, it was identified as a Braille dot and the other values were considered as absence of Braille dots based on X / Y coordinates.

Then the structure defined in that manner is applied to all the other sliced images and thus the dots are indicated as *0* when absent and *1* when present. The binary values which have been taken in this manner are sent to the method *getDecimalFromBinary* where they are put into a database which identify the position of the dots and define the decimal value that's equivalent to a corresponding letter indicated by the dots. Based on the generated decimal value, the relevant letter in Unicode is assigned and displayed accordingly.

A simplified diagram of this entire process is mentioned below.

Step 1: -

- Created an image input module

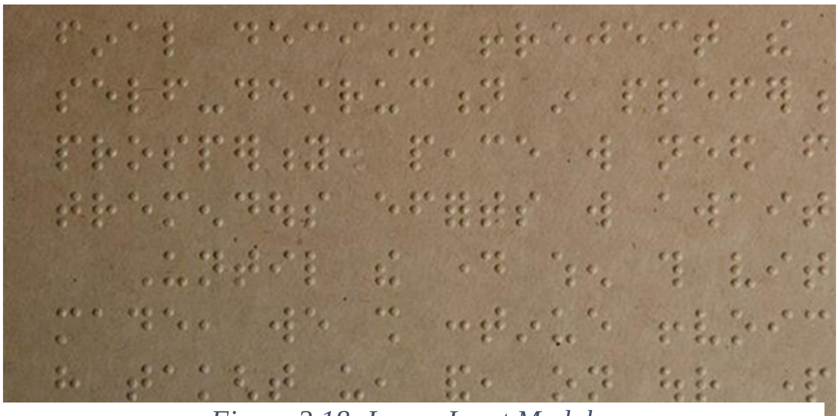


Figure 3.18: Image Input Module

Step 2: -

- Created an image preprocessing module using

  - ✓ Gray Scaling
  - ✓ Noise removes
  - ✓ Thresholding
  - ✓ Filtering
  - ✓ Binary Conversion

- RGB image convert to Gray scale image

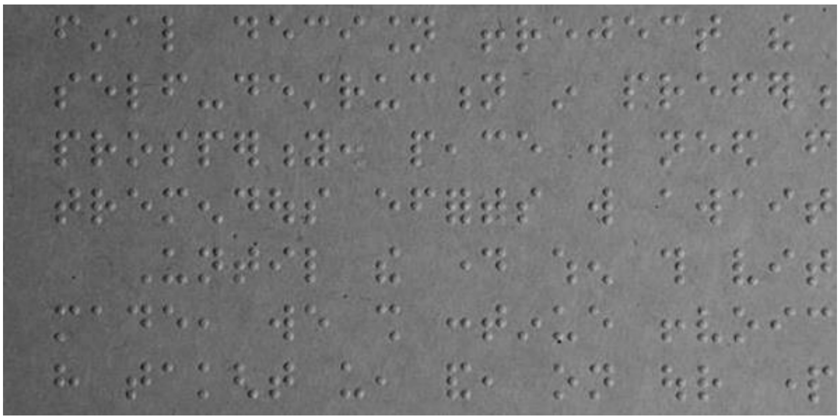


Figure 3.19: Gray Scale Image

Using Opencv
(Imgproc.COLOR_RGB2GRAY)

- Convert to Binary Image

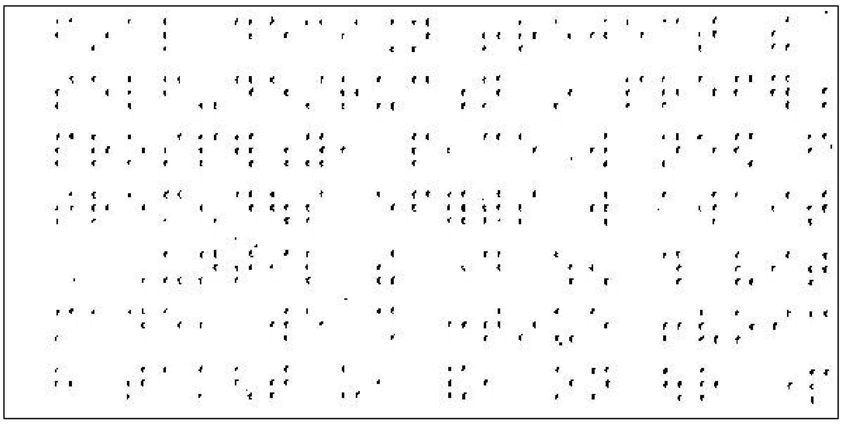


Figure 3.20: Binary Image

Using Opencv
(THRESH_BINARY)

- Cropped image

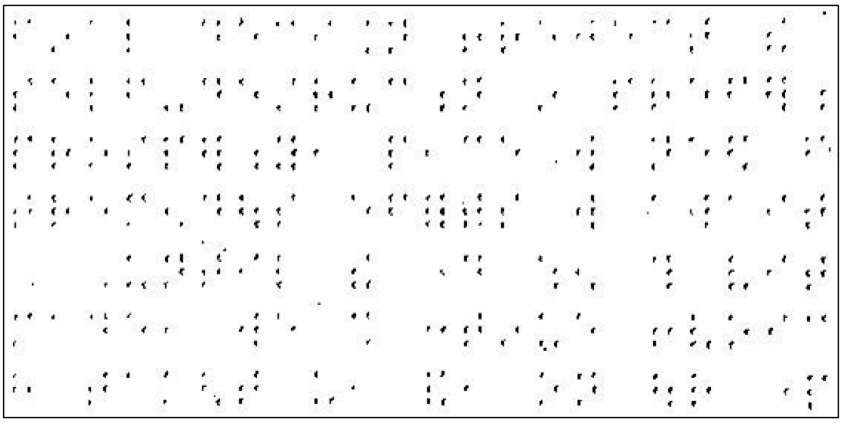


Figure 3.21: Cropped Image

Step 3: -

- Crated a module for grid-based slicing

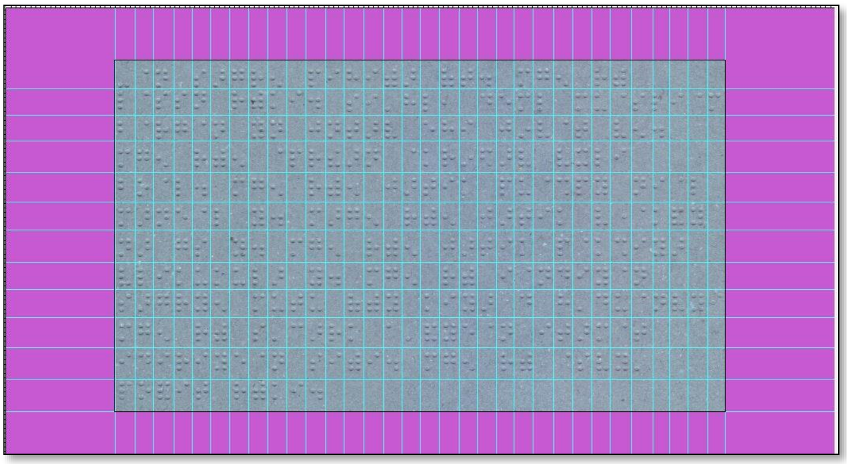


Figure 3.22: Virtual Grid

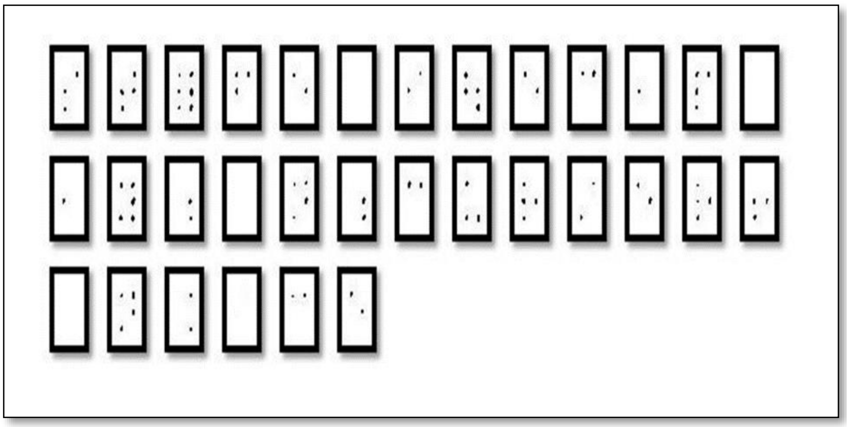


Figure 3.23: Slice Image

Step 4: -

- Identified an issue with different letter sizes.
- Differentiates the Braille dots using the brightness factors of the pixels
    - ❖ 200-255 = White Pixels
    - ❖ 0 - 10 = Black Pixels

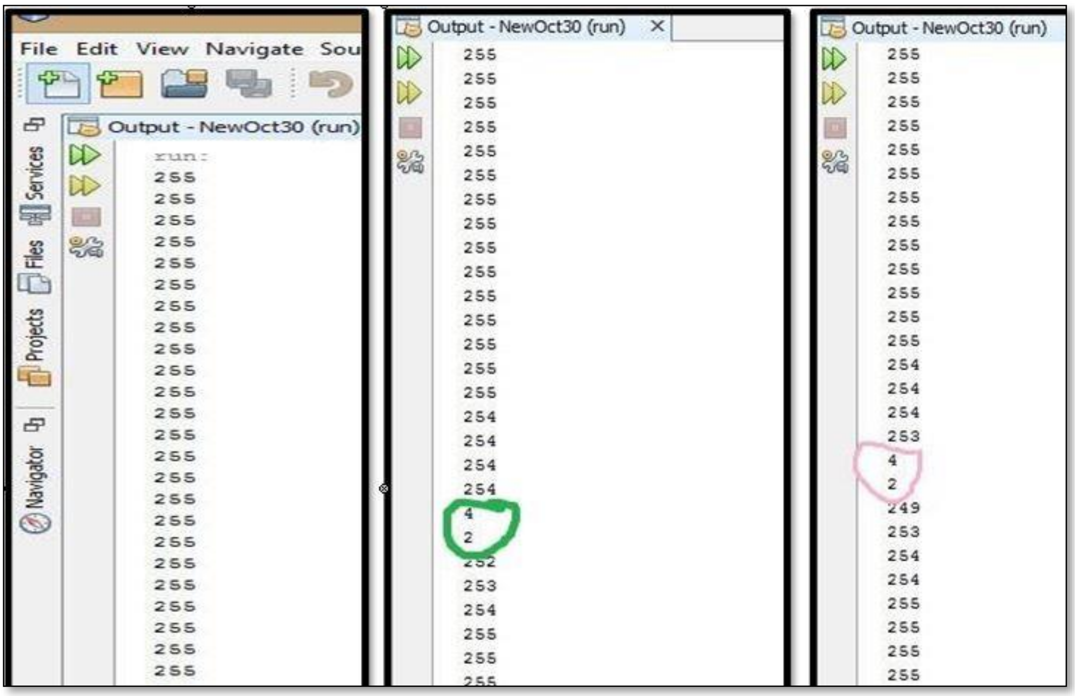


Figure 3.24: Recognize each pixel by its color intensity value

Step 5: -

- Identified the Braille dot positions in image
- Slicing module considering the Braille cell distribution in preprocessed image

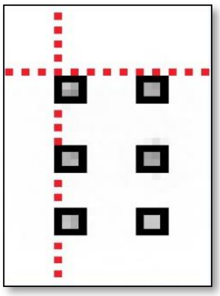


Figure 3.25: Identify Braille dot positions in slicing image

Step 6: -

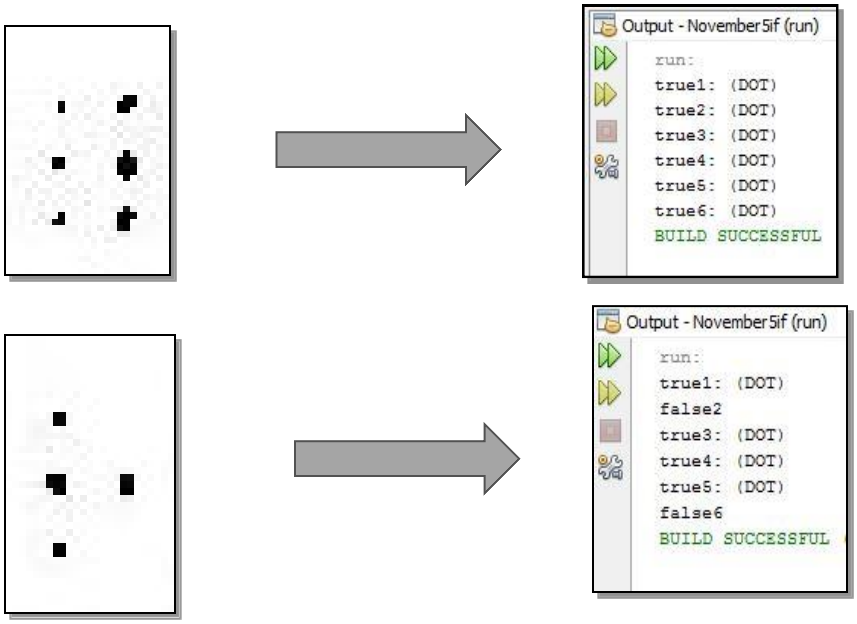


Figure 3.26: Recognize how many dots in the slicing image

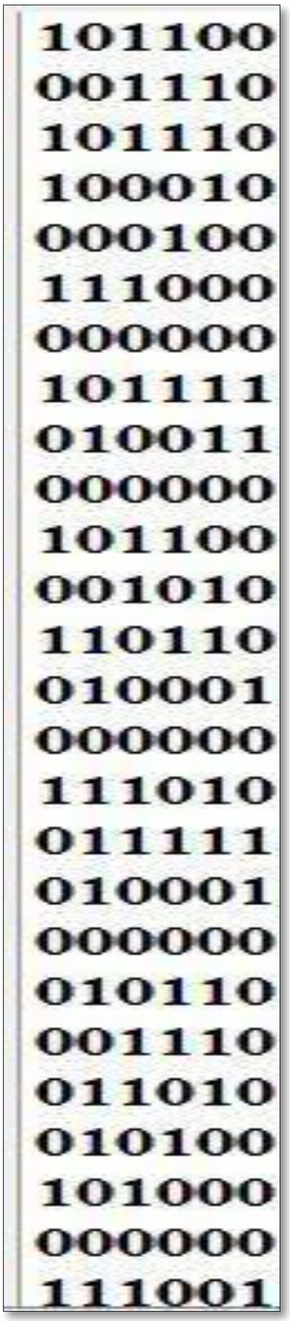
- Crated a module, to identify the first Braille cell position to overcome the problem occur due to the size of sliced cells.

Step 7: -

- Crated binary pattern to match the number of dots in each letter.
- binary patterns convert to decimal.

Step 8: -

- Extracted the relevant decimal values and map them with a Sinhala letters.


101100
001110
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101100
001010
110110
010001
000000
111010
011111
010001
000000
010110
001110
011010
010100
101000
000000
111001

Figure 3.28: Binary Pattern

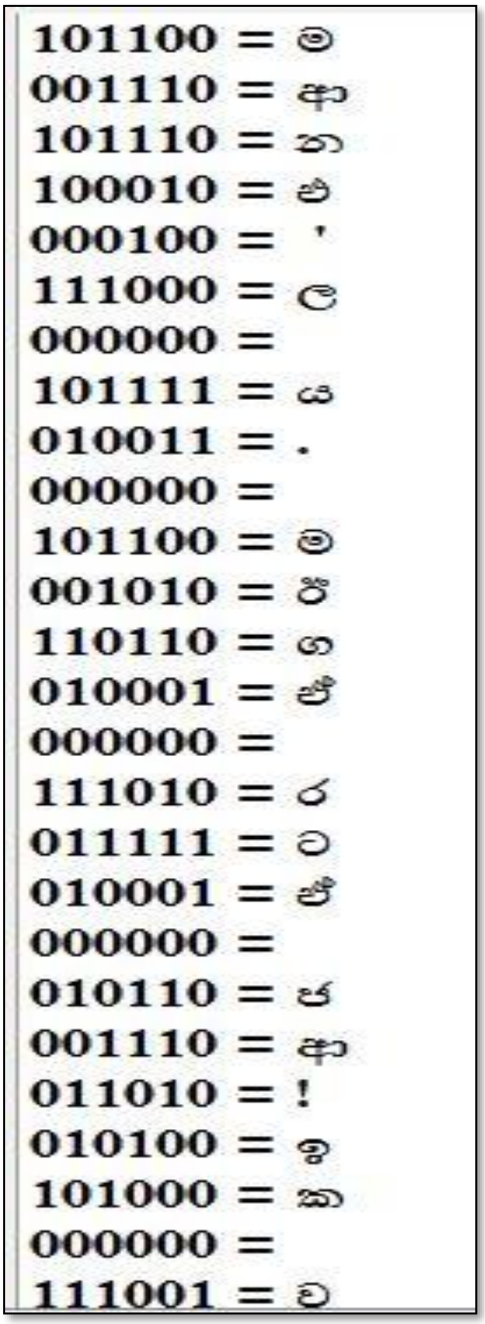
101100 = ම
001110 = ආ
101110 = හ
100010 = එ
000100 = '
111000 = ල
000000 =
101111 = ය
010011 = .
000000 =
101100 = ම
001010 = ඊ
110110 = ග
010001 = ඒ
000000 =
111010 = ර
011111 = ට
010001 = ඒ
000000 =
010110 = ජ
001110 = ආ
011010 = !
010100 = ඉ
101000 = ක
000000 =
111001 = ච

Figure 3.27: Map Sinhala Letters

3.5.3 System Architecture

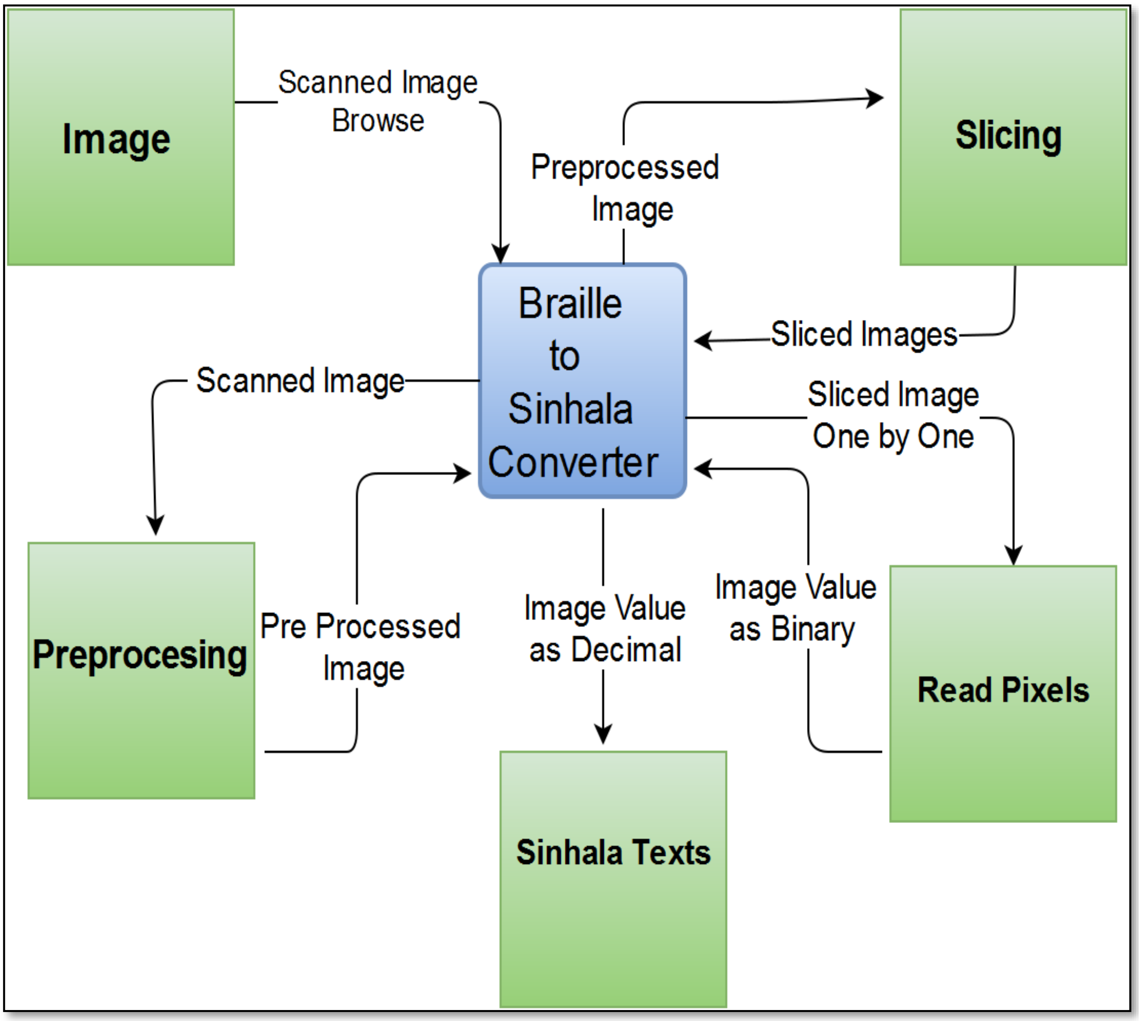

Figure 3.29: Architecture of the System

The screen shots of the operations related to the system are mentioned below.

- Browsed Braille scanned image

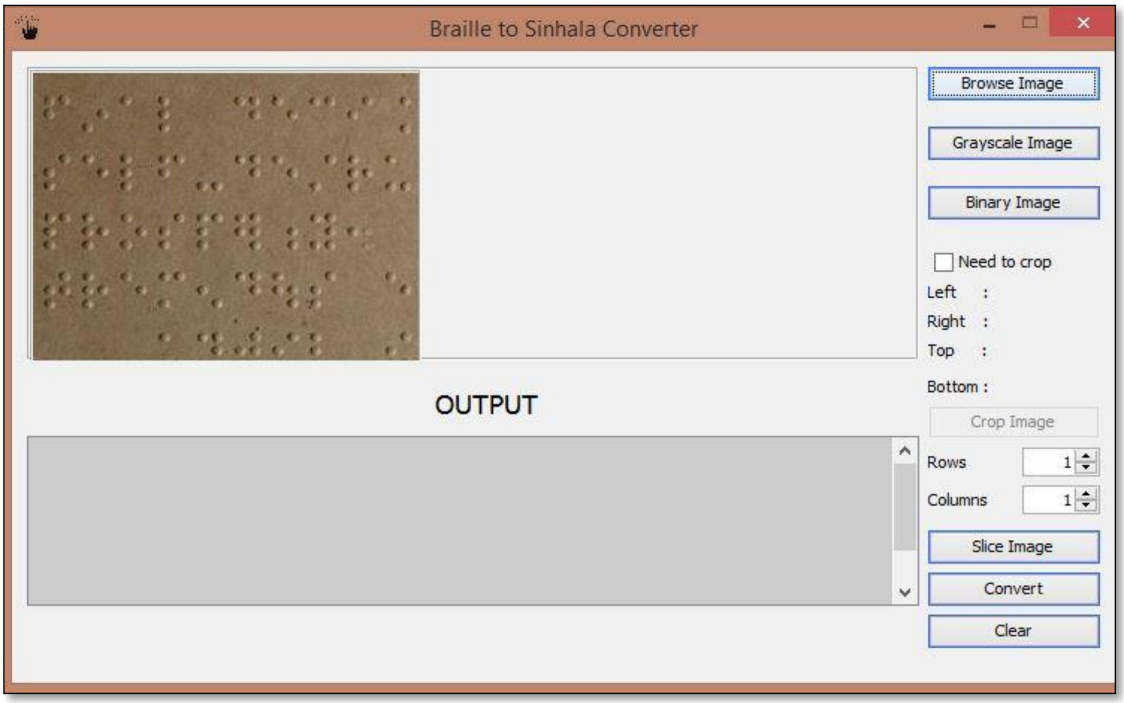

Figure 3.30: System Screen Shot 1

- Gray scale

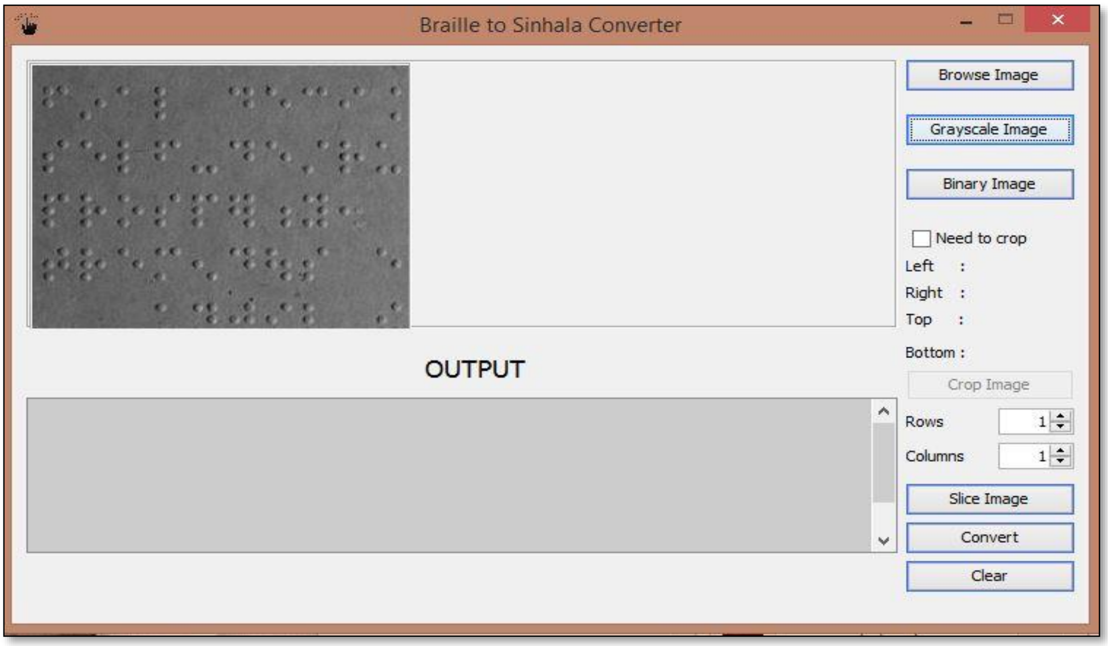

Figure 3.31: System Screen Shot 2

- Binary Image

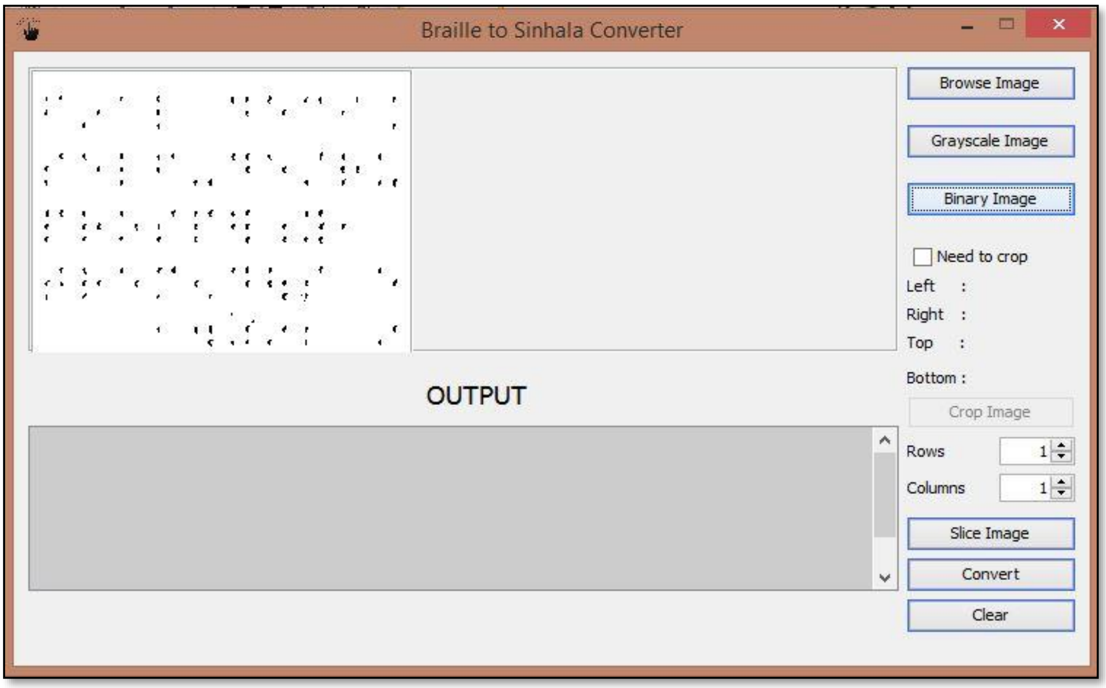

Figure 3.32: System Screen Shot 3

- Convert to Sinhala

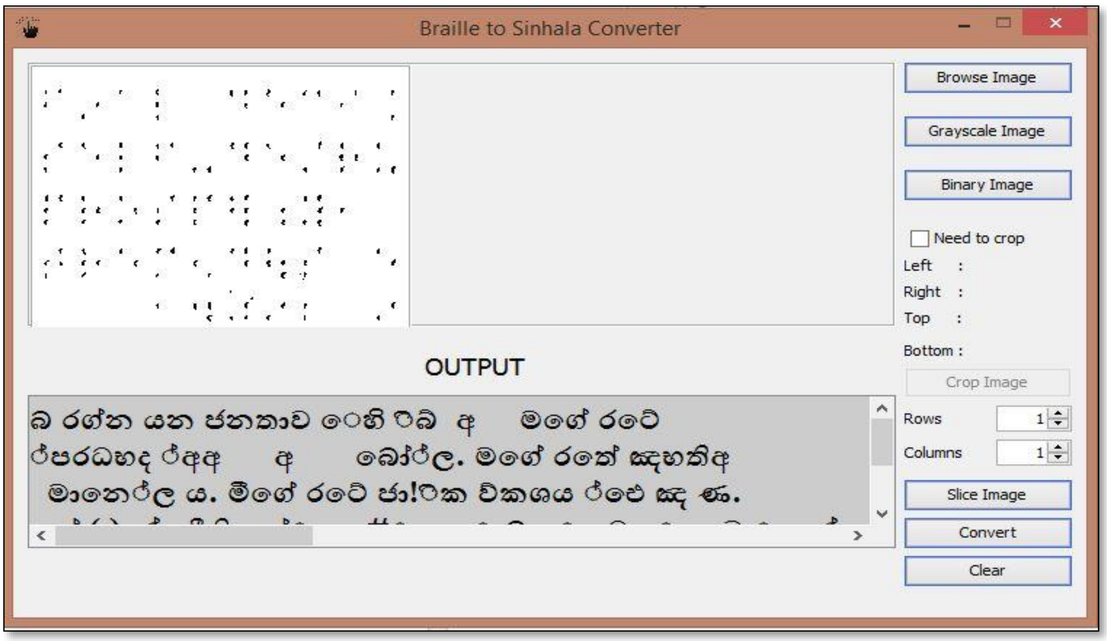

Figure 3.33: System Screen Shot 4

Chapter 4. Evaluation

4.1 Introduction

This involved judgement about the system and identify areas of the further developments. First, evaluation needs to proper test planning. Then we can identify the errors of the system.

Testing Plan

Introduction	
Test Goal	Quality, usability and accuracy of the system
Scope	Fulfill the requirements
Schedule	The progress of the implementation
Objectives	
Unit testing	Take the units independently and test the system. It will be a white box texting.
Integration testing	Check each function of the system. This will be both white box and black box testing.
System testing	Check all the function in a different environment. It will be a black box texting.
Acceptance testing	Check the system with a client before handed over the system. This will be a black box testing.
Recourses	
Hardware	Check the hardware required the implement the system.
Software	The software environment implementation.
Human	Visual impaired students and supervisor

Table 4.1: Testing plan

The testing of the program was carried out using a scanned document written in Braille and the results were as follows.

Test No	**Test Description**	**Expected result**	**Actual result**
1	Letter identification	100% letter identification	50% letter identification.
2	Word identification with single letters	100% identification	30% identification
3	Word identification with combined Sinhala letters	50% identification	20% identification
4	Identification of numbers	100% identification	60 %identification
5	Identification of punctuation	100% identification	50% identification

Table 4.2: Testing

Test Scope	Passed? (Yes/No)	Reasons for failures
Has the system been tested with a scanned image?	Yes	
Has the system been tested with a captured image?	No	Only identify scanned images
Has the setup checked in a fresh machine?	Yes	
Creation of test cases	Yes	
Test cases review	Yes	
Regression testing	Yes	
Functionally testing	Yes	
Environment compatibility testing	Yes	
System integration testing	Yes	
Performance testing	Yes	
UI check	Yes	
Messages	Yes	
Alerts	Yes	
User guides	Yes	
Installation guide	Yes	
Configuration documents	Yes	
Online help	No	Not connect to the help desk yet.
UI consistency	Yes	
Exceptional data handling	Yes	

Table 4.3: Testing II

The screen shots of the above mentions actual results are mentioned below.

- Letter identification

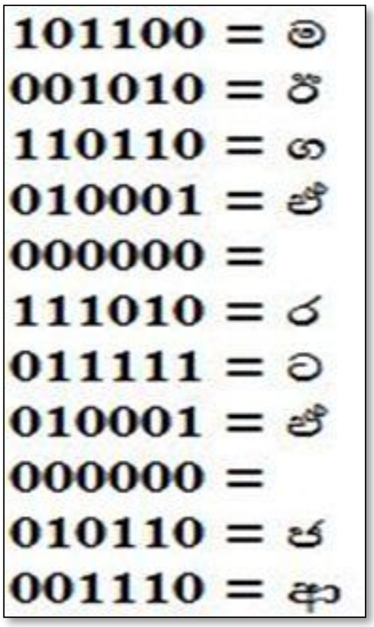

Figure 4.1: Testing 1

- Word identification with single letters

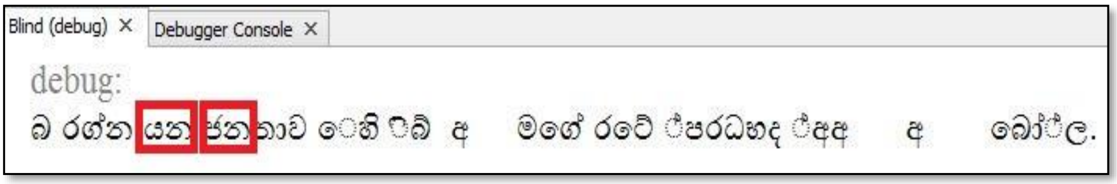

Figure 4.2: Testing 2

- Word identification with combined Sinhala letters

Figure 4.3: Testing 3

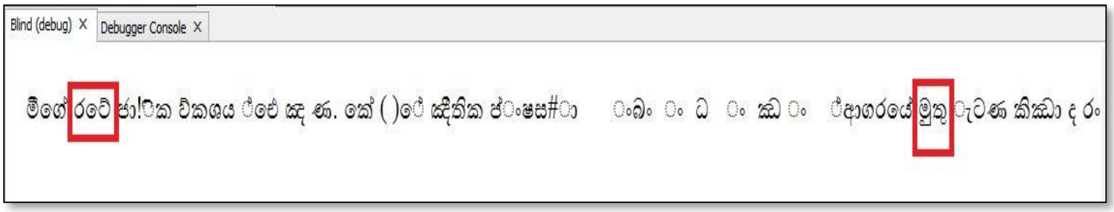

Figure 4.4: Testing 3.1

- ➢ Identification of numbers

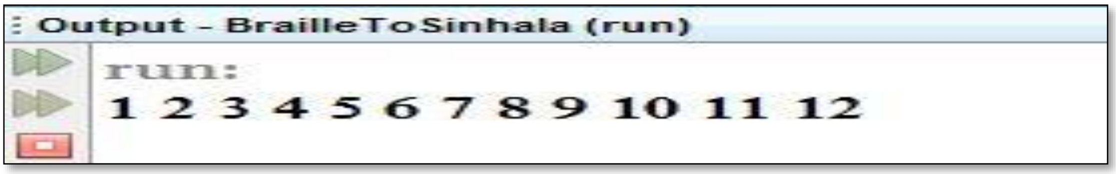

Figure 4.5: Testing 4

- ➢ Identification of punctuation

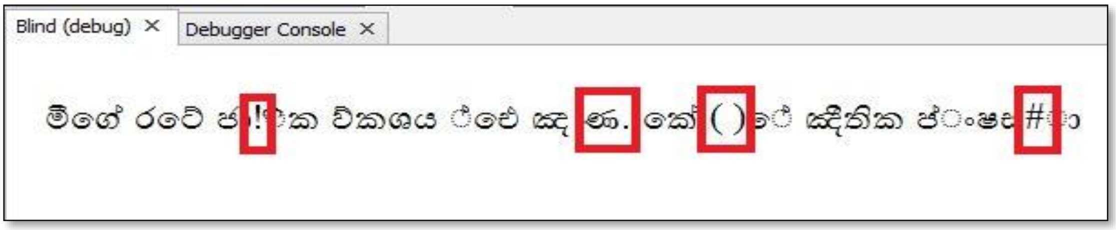

Figure 4.6: Testing 5

Chapter 5. Conclusion and Recommendations for Future Research

The Braille to Text Convertor for Sinhala has been developed based on OCR technology that has been tailored to be inculcated as OBR (Optical Braille recognition) with the view to automating the Braille translation process targeted at the university students in Sri Lanka.

At the first phase of the project, a research was conducted on the visually impaired university students in Sri Lanka including several generations to investigate the need of such a system, the issues faced by the target group due to the absence of such a mechanism, and the usefulness of such a system to the target group using a questionnaire. Additionally, some technological experts in the field of assistive technologies were also consulted in the process of identifying the system requirement and various ways to successfully implement the system.

The initial plan was to design a complete system that includes both API and mobile application within one platform. Both mobile and desktop platforms were successfully implemented.

Accordingly, the development process of the program was carried out based on OpenCV framework libraries of image processing and optical recognition.

In the development process it was identified that the nuances of combinations in Sinhala letters as in the cases of brief consonant letters , combined letters of vowels and consonants and the like were more challenging to be implemented in this system in the ways used by the users of Braille to integrate the said types of letters in their usage.

Consequently, the successful recognition rate was achieved in terms of single letters, numbers and punctuation and yet further developing needs to be done in order to complete this system to become an end-user product by integrating methods to address the issues of using vowels and consonant combinations, brief consonant letters, identification of lines and white spaces based on the interpretation of dots etc.

Another advancement that was noticed in the technologies reviewed throughout the process involved the duel scanning which ensured a verification of the embossed dots by comparing it against a scan of the dots from the engraved side. The inversion process and the modalities of designing the recognition processes should be extensively developed in this process. The result of such a verified translation process will increase accuracy and yet will require special scanning devises which would have to be able to scan papers from both embossed and engraved sides.

Alternatively, the same system can be ported into other mobile operating systems such as IOS where the cameras of the mobile devises can serve as scanning alternatives and makes it more convenient for the users to use the system more portably in their own mobile devises.

The new equipment like raspberry Pi can be used to enhance this process into a computer-independent mechanism that would be felt more intuitive for non-IT professionals such as teachers and other persons who would require the services of the said system.

Overall, it indeed would be an interesting and enthralling proposition to embark on a project that can culminate all the languages used by the Braille users in the world into one system which should be conducted in a broader scale.

Furthermore, one of the features suggested by the target group is to include a module to convert the output of the translation process into voice synthesis. That will enable instant translation and conversion to voice which would enable everyone to understand the contents which have originally made in Braille via auditory input.

It is also important to investigate into different sizes of Braille cells according to the equipment with which they are embossed. In this particular system a method was used to calibrate the size of a Braille symbol based on pixels. Yet further research and development should be put in place to further streamline and enhance that process of size recognition based on the Braille equipment that's used to emboss the letters.

Moreover, it was observed that the colors of the paper used by the users of Braille could be different because the color hardly matters when a Braille reader reads the Braille text in tactile sense. But in the case of scanners, the light absorption factor cans aviate according to the color and hence the accuracy of the result can be severely affected depending on the color of the paper.

A system should be devised to address this issue by trying to calibrate the darkness of the pixels based on a sample of the background color of the paper which is used to write in Braille.

Depending on the thickness of the paper and the gauge of the paper, the level of embossing can vary. Probably also due to the pressing of the embossed Braille that takes place when transporting the Braille scripts here and there can also be identified as significant issues which should be addressed and rectified in the future research and development in this process.

Improving the screen-reader accessibility of this system was another concern and a requirement emphasized by the beneficiaries of the system so that the visually impaired persons themselves could operate the software without outside help when that's required. The Java Accessibility framework can help in order to overcome this challenge. But due to the different ways in which the screen readers interact with the said framework along with their native implementations and associated limitations, a universally accessible tool could not be an apparent possibility.

Overall, this system can be identified as a significant entry point that opens numerous new avenues into the explorations and researches related to conversion-Based assistive technologies and thus minimize the human interaction in frequently required processes of the life of persons with visual impairments while improving the efficiency, accuracy and productivity of the entire process.

In a final and conclusive note, the new assistive technologies are looked at as the disruptors of the old and more reliable systems like Braille for the visually impaired persons and technologies of this nature would challenge such assertions and would contribute to retain the usability of Braille system and would also enable the children who only had the exposure to Braille in order to be adopted into the mainstream education system through the intervention of this tool.

Appendix

Appendix I

Braille Papers

- Paper 01

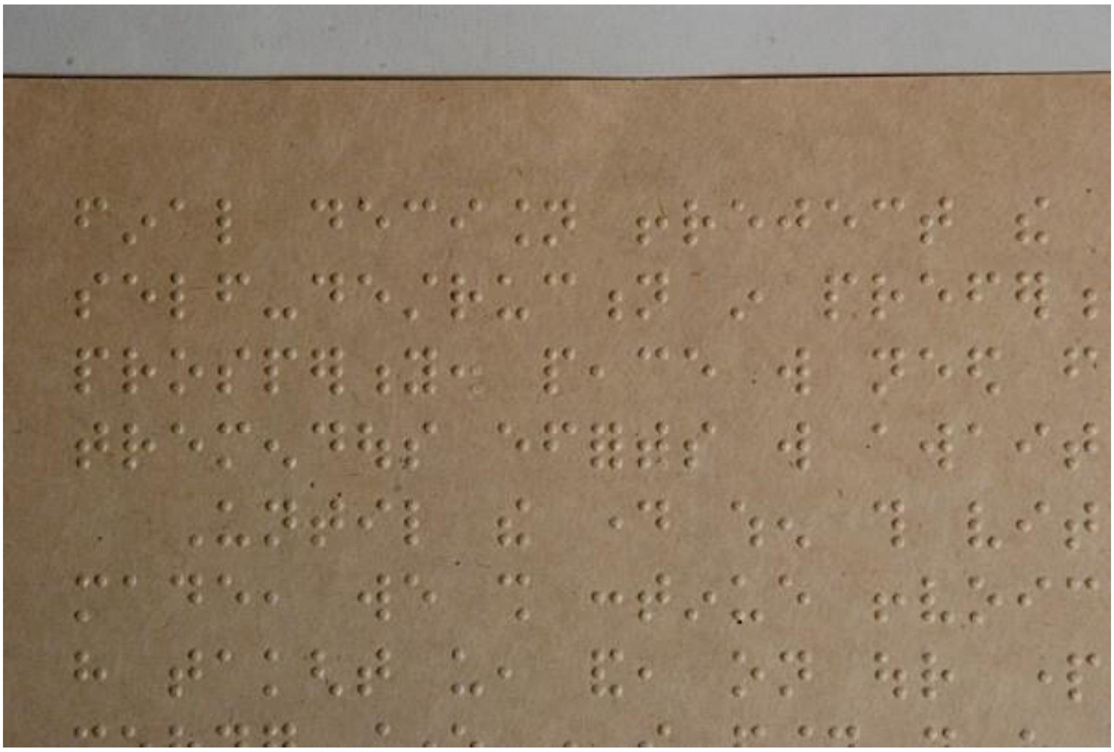

Figure a: Appendix 1.1

- Paper 02

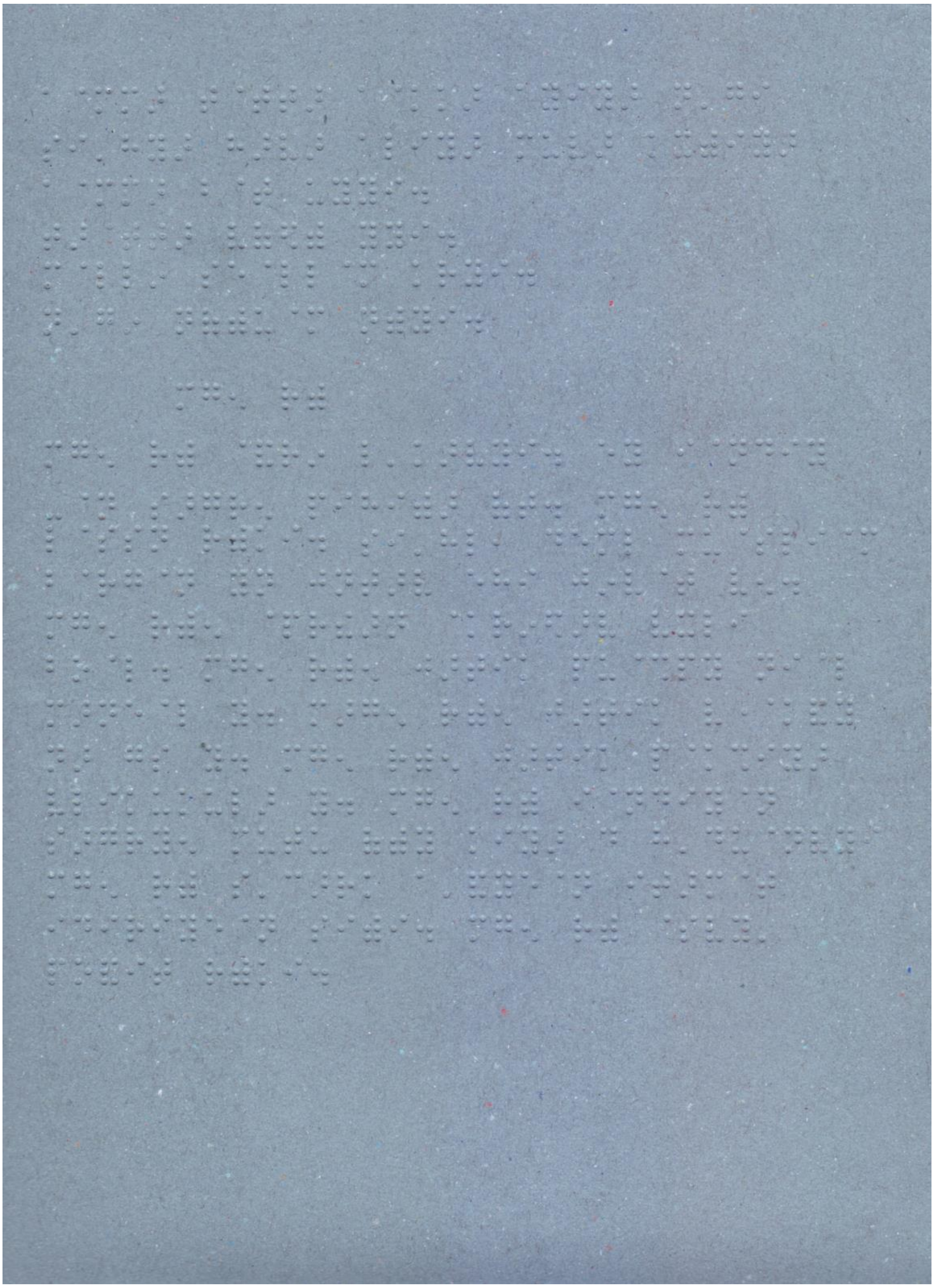

Figure b: Appendix 1.2

Appendix II

Questioner Form

Questionnaire on automated Braille to text convertor for Sinhala translating tool | ස්වයංක්‍රීය බ්‍රේල් සිංහල පරිවර්තකය පිලිබඳ ප්‍රශ්නාවලිය

I'm K. V. S. D. Vithanage, a final year under postgraduate of the Master of Information Technology degree at the university of Colombo School of Computing.
As the final project of my master's degree, I intend to create an application that automates the translation process of Sinhala Braille script to ordinary Sinhala calligraphy.
This questionnaire is presented to you with the hope of obtaining your views on the usefulness and relevance of such a system for your written communication requirements as users of Braille.
I greatly appreciate if you could fill this questionnaire and provide your inputs to assess the need and effectiveness of creating such a system.

මම කේ. වී. එස්. ඩී. විතානගේ නමැති කොළඹ විශ්වවිද්‍යාලයේ පරිගණක අධ්‍යයන අංශයේ තොරතුරු තාක්ෂණ පශ්චාත් උපාධියක් හදාරන අවසන් වසරේ සිසුවියක්මි.
මා විසින් හදාරනුලබන උපාධියේ අවසන් ව්‍යාපෘතිය වශයෙන් සිංහල බ්‍රේල් ලිපි ලේඛන සාමාන්‍ය සිංහල බසට ස්වයංක්‍රීයව පරිවර්තනය කරන මෘදුකාංගයක් නිර්මාණයකිරීමට අදහස්කොටගෙන සිටින්නෙමි.
බ්‍රේල් ක්‍රමය භාවිත කරන ඔබ වෙතින් මෙවැනි පද්ධතියක් ඔබගේ ලිඛිත සන්නිවේදන අවශ්‍යතා සපුරාගැනීමට කොතරම් ප්‍රයෝජනවත් ද කොතරම් අදාළ ද යන්න දැන හඳුනා ගැනීම සඳහා පහත ප්‍රශ්නාවලිය මා විසින් ඉදිරිපත්කරනු ලැබ තිබේ.
ඒ අනුව මෙම පද්ධතිය ඔබට කොතරම් වැදගත්වේද යන්න මා හට හඳුනාගැනීම සඳහා පහත ප්‍රශ්නාවලියට ප්‍රතිචාර දැක්වීමට හැකිනම් එය ඉතා අගයකොට සලකමි.

1. Are you a university student who uses Braille? | ඔබ බ්‍රේල් ක්‍රමය භාවිතකරන සරසවි සිසුවෙක්ද?
    - yes |ඔව්
    - No |නැත

2. What's the University you are studying? |ඔබ ඉගනුම ලබන සරසවිය කුමක්ද?

3. Do you use any other method apart from Braille to read and write at the university? | ඔබ ලිවීමට හා කියවීමට බ්‍රේල් හැර වෙනත් ක්‍රම සරසවියේදී භාවිතකරන්නේද?
    - Yes | ඔව්
    - No | නැත

4. If there are such other methods you are using, please mention them below | ඔබ එසේ වෙනත් ක්‍රම භාවිතකරන්නේනම්, ඒවා පහතින් සඳහන්කරන්න.

5. Are their qualified professional Braille translators employed by the university to translate your assignments and answer scripts written in Braille? | ඔබගේ බ්‍රේල්වලින් ලිවූ පිළිතුරුපත් සහ පැවරුම් පරිවර්තනයට සුදුසුකම් සහිත පරිවර්තකයකුගේ සේවය ඔබ ඉගෙනගන්නා විශ්වවිද්‍යාලය විසින් ලබාගෙන තිබේද?
   - Yes | ඔව්
   - No | නැත

6. Have you faced any difficulties due to any delays or unavailability of translation services when you wanted to get a Braille document translated? | ඔබට බ්‍රේල්වලින් ලියූ යමක් පරිවර්තනයකරගැනීමේදී විවිධ ප්‍රමාදයන් සහ අවහිරතාවලට මුහුණදීමට සිදුවී තිබේද?
   - Yes | ඔව්
   - No | නැත

7. While facing examinations or submitting assignments in Braille, have you faced any difficulties or delays in obtaining your examination results? | බ්‍රේල් මාධ්‍යයෙන් විභාගවලට පෙනීසිටීමේදී හෝ පැවරුම් යොමුකිරීමේදී ඔබගේ ප්‍රතිඵල ප්‍රමාදවීම් සිදුවී තිබේද?
   - Yes | ඔව්
   - No | නැත

8. Please indicate in the scale below, what level of convenience would be there for you if you would get to use an automated Braille to Sinhala translation tool. Please mark 1 for least usefulness and 5 for most usefulness. | සිංහල බසින් බ්‍රේල් මාධ්‍ය භාවිතයේදී වඩා කාර්යක්ෂම ස්වයංක්‍රීය ක්‍රමයකින් පරිවර්තනය සිදුකරගතහැකිනම් එය ඔබට කොතරම් පහසුවක් වනු ඇතිද යන්න පහත පරිමා දර්ශකයේ සටහන්කරන්න. මෙහිදී අවම පහසුව එක ලෙස ද, උපරිම පහසුව පහ ලෙසද දක්වන්න.

   - Least useful | අවම පහසුවක් තිබේ.
   - 1
   - 2
   - 3
   - 4
   - 5
   - Most useful | උපරිම පහසුවක් තිබේ.

9. Please mention if there are any special features you would like to see in such a system in the space below | ඔබ එවැනි පද්ධතියක දැකීමට කැමති විශේෂ පහසුකමක් තිබේනම් එය පහත සඳහන්කරන්න.

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