CHAPTER 1

INTRODUCTION

1.1 Background of Study

It has always been a challenging task for the visually impaired people (VIP) to navigate in unfamiliar surroundings and finding desired location or public utility (Vashisht, 2013). Most of the time, they are not able to see the texts displayed on the signage clearly. With the loss of all that important message from the displayed signage, it may result in dangers especially when they are alone. For example, a visually impaired person would not able to read a signage that specifies warnings or hazards.

An Android application to solve this navigation problem faced by the VIP had already existed called Text Signage Recognition (TSR) prototype application. According to Foong (2013) the TSR prototype was developed to address the problems faced by the VIP upon their independent navigation by using Tesseract OCR engine and implemented on Android mobile devices for better portability. Based on the previous research, TSR prototype applied Morphological transformation and Otsu algorithm to convert original signage image to a binary image.

However, text detection and recognition occurred to have faced many challenges in the development process. The major drawback of the text recognition application lies on its recognition performance and ability to fully identify the capture image despite of its environment. The main contributing factors of poor detection and recognition performance includes cluttered or complex background, small font size, inappropriate font style, skewed or embossed images, and poor lighting.

Therefore, the project aims to address the problems faced by the visually impaired by informing them what the nearby text signage says. In this study, the main focus is to propose a noise filtering TSR prototype for VIPs. The project will focus more on improving the text recognition process of the captured images which allows the visually impaired access to the signage information just like a normal people experience. Thus, the project is hoped to give a better navigation experience for the
visually impaired and reduces the chances of them facing dangers when navigating alone.

1.2 Problem Statement

The existed TSR prototype application had encountered some problems in the recognition process. The prototype unable to recognize signage image correctly. This happened because of the presence of noise in the signage image captured. When visually impaired captured the signage, they tend to capture the background of the image or scenery as well instead of just captured the text in the signage. This is an unwanted noise to the captured image which will make the text of the image more difficult to read. Not just that, presence of noise in the image can potentially skew the character recognition accuracy.

1.3 Objective

- To assess the usability of the existing Text Signage Recognition (TSR) prototype application with the visually impaired.
- To propose a noise filtering technique for TSR which filter noise from image captured by VIP.
- To evaluate the performance of the TSR noise filtering technique by estimating the recognition rate.

1.4 Scope of Study

In this study, project focused on evaluating and analysing how the TSR prototype application support the targeted user which is low visually impaired people. From this, the author can defined whether it is feasible to have the TSR application in the real environment experienced by users. The study continued by analysing the problems faced by the VIP upon using the existing TSR prototype application and how it reflects the recognition performance of the TSR prototype. In the second phase of this study (FYP2), the author deployed the noise filtering technique based on the proposed system architecture to overcome one of the problems identified during the analysis phase. Unlike the existed TSR prototype application, this project focused on implementing TSR technique for noise filtering in standalone system
using Matlab Release 2015a. The prototype developed are meant to filter the noise in the signage image captured by VIP. The completed prototype are then tested by the targeted user which is low visually impaired people (VIP).

1.5 Relevancy and feasibility of the Project within Scope and Time Frame

The relevancy of this project is that it will give solution to the low visually impaired who find it difficult to find places during their independent navigation because of the inability to read signage. This project will focusing on low visually impaired user in order to help overcome the limitations that they faced during independent navigation. This project is feasible as there are many references and recent research relating to text recognition available.

Next, the research and development of the project will be conducted within two semesters, approximately in seven months’ time. The research phase will be carried out during the first semester, whereas the development of the prototype will be initiated immediately at the end of the first semester. The research phase will be focusing on the planning, researching, analysing the system requirements, feasibility study and documentation. While the development phase is allocated for prototype development, system testing and system implementation. Thus, based on the division of activities, the project is believed to be completed within the allocated time.
2.1 IPhone accessibility features for the Visually Impaired

In the early phase of technology advancement, most of the smartphone developed did not have much of the features that can help the visually impaired. However, in June 2009 Apple opened up a whole new opportunities for the visually impaired people with their new developed VoiceOver screen reader on the IPhone 3GS. VoiceOver screen reader provides a way for blind and low-vision users to use iOS devices – iPhones, iPads, and iPod touches without seeing the screen (Burton, 2009). VoiceOver is the world’s first “gesture-based screen reader” assistive technology which allows the visually impaired interact with their devices using multitouch gestures on the screen. As an example, when a visually impaired slide their finger around the smartphone screen surface, the IPhone will read aloud the name of each application.

In addition to that, for a reading app like online newspaper, swiping two fingers down the screen will prompt the smartphone to read the text aloud. When turning the fingers in a circle like opening a padlock after taking two fingers and holding them an inch apart will calls the menus, including ones with the ability to change VoiceOver’s rate of speech or language. According to Bilton (2013) in his article, he interviewed one of the visually impaired user using iPhone which is also a professional photographer, Mr. Perez stated that:

“With the iPhone I am able to use the same technology as everyone else and having a product that does not have a stigma that other technologies has been really important to me. Now, even if you are blind you can still take a photo.”
According to Hansen (2014), over the years Apple continually improve the VoiceOver capabilities starting with the iPhone 3GS then it also had been added in the iOS starting from iOS3 until recently the latest is iOS8. Aquino (2014) mentioned that in the latest version of iOS8, Apple Inc. introduce new features to its accessibility capabilities for the visually impaired which includes:

- **Alex** – a substitute for the robotic – voice that controls VoiceOver by providing a natural spoken audio voice for all of iOS technologies.
- **Speak Screen** – a simple gesture which able Alex to read anything on the screen. In simple, Speak Screen will read out everything displayed.
- **Guided Access** – enable users to exit Guided Access using their fingerprint.
- **Enhance Braille Keyboard** – Includes a braille keyboard that can convert 6-dot chords into word.

From this, we can examine that Apple will keep on developing and uncovering new features to help their user through this accessibility features. The iPhone, of course is not the only smartphone that helps the visually impaired but Apple shows a consistent focus on making its products and features more accessible to those with disabilities especially the visually impaired throughout the years.
2.2 Categories of disabilities

A disability is a condition or function to be recognized as fundamentally impaired in respect to the regular standard of an individual or a group. It include several types of functioning disabilities which are physical impairment, cognitive impairment, sensory impairment and various types of chronic disease. This impairments will affect and reduce the person ability to do their day to day activities. One of the impairments that we can commonly see in the community is visual impairment. According to Mandal (2012), Centers for Disease Control and Prevention (CDC) defined vision or visual impairment as functional limitation of the eye or both eyes and the vision system which cannot be corrected back to their “normal level”. CDC further explained that there are numbers of people that suffer from this impairment because of injuries and disease such as cataracts, glaucoma and many more.

World Health Organization (WHO) (n.d.) stated in their website that 285 million people are estimated to be visually impaired worldwide whereas 39 million of them are blind and 246 million have low vision. It is also estimated that the number of adults with visual impairment to double as the elderly population increase over the years. By referring to WHO, the classification of visual impairment was identified based on visual acuity or visual field limitation which also defines blindness as profound impairment. Below are the level of visual impairment with their classification defined by WHO International Classification of Disease, 9th Revision.
<table>
<thead>
<tr>
<th>Classification</th>
<th>Levels of Visual Impairment</th>
<th>Additional Descriptors That May Be Encountered</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Legal” WHO</td>
<td>Visual Acuity (VA) and/or Visual Field (VF) Limitation (Whichever is Worse)</td>
<td></td>
</tr>
<tr>
<td>(NEAR-) NORMAL VISION</td>
<td>RANGE OF NORMAL VISION 20/10 20/13 20/16 20/20 20/25 2.0 1.6 1.25 1.0 0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NEAR-NORMAL VISION 20/28 20/30 20/40 20/50 20/60 0.7 0.6 0.5 0.4 0.4</td>
<td></td>
</tr>
<tr>
<td>LOW VISION</td>
<td>MODERATE VISUAL IMPAIRMENT 20/70 20/80 20/100 20/125 20/160 0.29 0.25 0.20 0.16</td>
<td>Moderate low vision</td>
</tr>
<tr>
<td></td>
<td>SEVERE VISUAL IMPAIRMENT 20/200 20/250 20/320 20/400 0.10 0.08 0.06 0.05 VF 20 degrees or less</td>
<td>Severe low vision, “Legal” blindness</td>
</tr>
<tr>
<td>BLINDNESS (WHO) one or both eyes</td>
<td>PROFOUND VISUAL IMPAIRMENT 20/500 20/630 20/800 20/1000 0.04 0.03 0.025 0.02 CF at: less than 3m (10 ft.) VF: 10 degrees or less</td>
<td>Profound low vision, Moderate blindness</td>
</tr>
<tr>
<td></td>
<td>NEAR-TOTAL VISUAL IMPAIRMENT VA: less than 0.02 (20/1000) CF at: 1m (3 ft) or less HM: 5m (15 ft) or less Light projection, light perception VF: 5 degrees or less</td>
<td>Severe blindness, Near-total blindness</td>
</tr>
<tr>
<td></td>
<td>TOTAL VISUAL IMPAIRMENT No light perception (NLP)</td>
<td>Total blindness</td>
</tr>
</tbody>
</table>

CF = counts fingers (without designation of distance may be classified to profound impairment)

HM = hand motion (without designation of distance may be classified as near-total impairment)

VA = visual acuity (refers to best achievable acuity with correction)

VF = visual field (measurements refer to the largest field diameter for a 1/100 white test object)

Figure 2: Levels of visual impairment (American Optometric Association, 2007)
As shown in the Figure 2, there are 5 level of visual impairment with their classification as well as the visual acuity level. The classification of visual impairment varies for each organization, each descriptors have their own measurement in classifying the visual impairment. However, the most accurate would be WHO International Classification of Disease which categorizes impairment as moderate visual impairment, severe visual impairment, profound visual impairment, near-total visual impairment, and total visual impairment. The WHO further classifies that moderate and severe visual impairment as low vision while profound, near-total and total visual impairment as blindness.

Within each of these classification, there are many variations in term of disabilities and barriers that people with visual impairment will faced. Those with profound visual impairment may find enlarging image on the screen as no use and need mechanism or braille to read something. While someone with moderate visual impairment or low vision may need mechanism to enlarge the image on the screen. According to M. Scheiman and M. Scheiman (2007), low vision which visual acuity is 20/70 or poorer was caused by eye disease and cannot be corrected with regular eyeglasses. In other words, low vision is noncorrectable reduced vision which interferes their daily activities and it is vary from person to person.

Those having low vision is considered as not legally blind. Since low vision is a slightly less severe visual impairment, some of the people affected can still read printed text or image if it is large or view through magnifier. Therefore, many of the technologist have created and developed gadgets or application to help these type of people in living their days.

2.3 Navigation Issues for the visually impaired

In today’s world, we are becoming a part of “do it yourself” era. The visually impaired faced a number of navigating challenges in their daily lives from reading the label on a food packaging label to figuring out they are at the right bus station. They often have a difficult time in self-navigating, traveling or simply walking down a crowd street especially in the unknown environments. They are having hard times in places that are not designed for their special condition. Most of it become real obstacles for them and putting risk at their physical integrity. These include places
like bus station, public offices, university and etc. In this project, author will focus on three main issues faced by the visually impaired in navigation.

2.3.1 Public signage

Many of us take for granted the aids that have been provided in the public places such as markings or tactile surface on the ground at the pedestrian crosswalk, traffic lights for pedestrian which inform when it is safe to cross, maps that shows the schedules and routes of buses and train and not to forget the sign that notify our location as well as advertise what’s ahead. Even though it is useful for the normal sighted people but not really helpful for the visually impaired because they cannot see making everyday lives very challenging for them. This is one of the biggest issues faced by the visually impaired in navigation.

2.3.2 Misunderstood the concept of using a guide dog.

In an interview conducted by Mau and Melchior (2008), it was found that about 90% of blind people are not able to travel independently in which 7% of them are using white cane, 3% using a guide dog. However, only half of them choose to use a guide dog because of the burden they faced when carrying it. Despite of the burden they felt, a guide dog is actually a very helpful mobility aid that enable visually impaired to travel safely. A guide dog can be useful in detecting obstacles and guiding visually impaired in the crowds, curb and sometimes in finding an object within the sight.

However, some people have misunderstood the concept of using a guide dog. They mistakenly thought a guide dog can shows the visually impaired the direction where to go. Another misunderstanding had occur when they thought a guide dog can indicate whether it is safe or not to cross the street. This is not true; an example a guide dog would not able to detect the meaning behind the changes of traffic signal colours. Instead, the visually impaired are the one responsible and have to examine by themselves whether it is safe or not to cross the street.

2.3.3 Skills of independent mobility are obscure and complicated for some VIPs.
Most of the time, we can see that visually impaired used to move around independently along the pedestrian crosswalk in the public places. This is because visually impaired are unable to drive a motor vehicle, therefore their mobility depends primarily on walking. To adjust their negotiation of the road system, they need to be able to find their way through open spaces and across roads. They will either move around alone accompanied by white cane or with the aid of a sighted person who will act as a guide. They independently navigating through the places using the most of their residual sight and mobility aids.

2.3.4 Strategies to overcome the navigation issues.

Nowadays, most of the public facilities have been equipped with disability-friendly accessibility equipment for these special people like VIPs. One of the facilities that have been applied and installed globally is tactile ground surface indicators which also called as tactile paving (“Tactile Paving”, n.d.). It can be found on many pedestrian crosswalk, train station platform and stairs to assist the blind and visually impaired pedestrian. It provide textured surface features built into the ground surfaces and gives of sensory information underfoot for the visually impaired. Visually impaired pedestrian can feel the textural changes on the ground using their feet or white cane.

![Figure 3: Tactile ground surface indicator. (Independent Living Center NSW, n.d.)](image)

The role of white cane in identifying the tactile surface indicator is very important for the blind. Since the earlier time white cane have been
helpful by providing information in detecting ground level changes, obstacles and hazards and stairs in the path of travel. For example, changes in surface textures between concrete and grass as well as tactile ground surface can be detected by white cane. Visually impaired had always uses white cane as their accompaniment in their daily activities. However, the uses of white cane are limited to detecting the surface at the ground level but not for the things that are not attached to the ground (Chew, n.d.). This gives disadvantage to the blind because hazard will not always be on the ground and the visually impaired surely could not see it.

Taking from the concept of white cane and a guide dog, latest innovations in technology considered the needs of navigation aid for the visually impaired. Some of the available devices that are useful for visually impaired includes smart cane (Assistech IIT Delhi, 2013) , iGlasses (Rempel, 2012) , and digital sign system (Legge et al., 2013). All of this devices was developed mainly to help the visually impaired in independent navigation. According to Assistech IIT-Delhi (2003), SmartCane is an electronic device which serves as a travel aid that was made to overcome the limitations of the traditional white cane. It allows the cane to detect knee above and hanging obstacles in the surrounding.

As compared to the white cane, this electronic travel aid able to tells the visually impaired the presents of obstacle before touching the it with the cane and this helps in counteracting undesirable contact as well as collision with people or other obstacles. The development of this device helps the visually impaired to get a safer independent navigation experience in the city. Rempel (2012) mention in his article, Royal National Institute of the Blind (RNIB) and Ambutech have developed a head mounted device that enables a secure independent travel as it can detects the object around the visually impaired using ultrasonic sensors and respond is send back using vibration. It primarily intended to protect head and upper body and works effectively with the accompaniment of the guide dog.

Besides that, Legge et al. (2013) have developed a Digital Sign System which consist of three components; a handheld sign-reader, image processing software and a talking digital map running on a mobile device.
This device highlighted the features of independent navigation that allows visually impaired to retrieve information from the digital sign, finding nearby places and giving direction or routes for the selected places from starting location to destination. One of this device features have the same objective as Text Signage Recognition which is to allow visually impaired to read and retrieve information from signage. This demonstrates the feasibility of enabling independent navigation for visually impaired.

2.4 Text Signage Recognition

From the study of the previous work on this topic, a text signage recognition model was developed using Tesseract OCR engine together with OpenCV. The developed application was deployed to achieve the purpose which to develop a text signage recognition application that can helps the visually impaired to get a better navigation experience and reduces the chances of facing dangers when navigating alone.

According to Foong (2013), the developed TSR model was tested by normal sighted users by using selected sample images from International Conference on Document Analysis and Recognition (ICDAR) 2003 dataset. To gives off a valid testing process and a real testing environment, all of the users were blind-folded. The test result shows that the recognition rate has achieved a satisfactory results even though the result recorded is slightly lower than the results recorded from the training phase.

From the testing results recorded, Foong concluded that the developed TSR model had encountered some problems in recognition process. The problems mentioned includes:

- Images with white coloured text cannot be recognized correctly.
- TSR incorrectly recognized character ‘O’ as ‘Q’ and vice versa.
- Illuminating texture images cannot be recognized at all.
- TSR cannot recognized image that had incomplete character
- Sometimes speech synthesizer failed to speak the word accurately.
By analysing the recognition rate founded from the testing, Foong stated that the challenges still persist in the recognition performance of the developed TSR model. Therefore, there exist plenty of rooms for improvement on the developed TSR model such as by reducing the noise from the captured images in order to give accurate text signage recognition performance to visually impaired users.

However, the text signage recognition prototype able to recognize well on the image that had simple or plain background. Not just that, the Text to speech translation also able to read out the characters correctly if TSR manage to extract the text in the image.

![Figure 4: The existing TSR model](image)

Figure 4 above shows the system architecture of the existing TSR prototype application. The image pre-processing steps involved in this model covers six main operation which are convert to grayscale, morphology transformation, Thresholding, find edges of characters, copy the masked image and pasted onto new white background and lastly binarization. From this we can see that the existing TSR model does not include any specific noise removal operation or technique.

2.5 Noise in image processing

Noise is a random variation of image intensity which visible as grain in film and variations of pixel level in digital images (R. Verma & J. Ali). The quality of the
image captured can be degraded due to the presence of noise in image. Image noise often appear as image having degradations such as uneven contrast, uneven background and unwanted background of the image or scenery in the image captured. The primary sources of image noise are:

i. The image sensor are affected by the environmental conditions at the time of capturing.

ii. Insufficient sensor temperature and levels of light.

iii. Interference in the transmission channel.

iv. The presence of dust particles on the scanner screen.

Noise can appear in the background and foreground of image captured and disrupt the recognition process and the accuracy of tasks of Optical Character Recognition (OCR) system (Farahmand, Sarrafzadeh, & Shanbehzadeh, 2013). Therefore, in order to allow better recognition performance of the OCR, we need to perform noise removal techniques in the image captured. Noise removal is another steps in pre-processing process.

According to Kamboj and Rani (2013), noise removal techniques can be divided into three main categories which are:

i. Linear filtering

Linear filtering can be used to remove certain type of noise. Smoothing by averaging and smoothing by Gaussian filter are the most commonly used filtering methods under linear filtering.

ii. Median filtering

Median filtering is a non-linear filtering technique used to remove noise from image. It is widely used to remove noise while preserving the edges of image.

iii. Adaptive filtering

Adaptive filtering is one of the most commonly used techniques to remove additive noise in most devices such as mobile phone and other communication devices. However this filtering technique requires more computation time than other filtering techniques.
In this project, image captured by VIP are highly exposed to image noise especially referring to the unwanted background of the image or scenery captured in the image. To give a better recognition performance, as well as giving the best TSR usage experience for VIP, image noise needs to be filtered. Gaussian filter under linear filtering technique is used to remove noise from image in this project.
CHAPTER 3

METHODOLOGY

3.1 – Development Methodology

Throughout the development process, Agile Development Methodology has been adopted. Agile development methodology is a software development methodology that adopted iterative and incremental process models which focus on process adaptability and rapid delivery of working software product. In agile methodology, tasks are divided into small boxes illustrate the time frames to deliver the specific features of the software build. Each of the builds then will consists of activities such as design, coding and testing the implemented coding.

This methodology focuses on keeping code simple, testing on the coding often in order to remove errors and delivering the working product within the schedule.

![Agile Development Methodology](image)

Figure 5: Agile Methodology

From the figure above, it can be seen that the project cycles is repeated until an adequate working product of the project is finally attained. This project comprises of four main phases which are requirements planning, user design, construction and cutover.

3.1.1 – Project Activities
3.1.1.1 – Requirement Planning

A high level view of the project is established to give a better understanding of the project and technologies involved.

**Table 1: Requirement Planning**

<table>
<thead>
<tr>
<th>No</th>
<th>Activities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Define problem statement and the proposed solution.</td>
<td>In this project, the inaccuracy of the image recognition by the existing signage recognition application is viewed as an obstacle to the visually impaired people from having a comprehensive experience in detecting text signage. Thus, this project aims to propose a noise filtering technique for TSR which filter noise from image captured by VIP.</td>
</tr>
<tr>
<td>2</td>
<td>Theoretical understanding of the project</td>
<td>A qualitative research is conducted from the related research works to understand the literature of the project. Several theories and concepts are derived from the research to understand the signage’s image recognition process and how the implementation of the image recognition concept (OCR) can help the visually impaired.</td>
</tr>
<tr>
<td>3</td>
<td>Data collection and information gathering</td>
<td>Data collection and information gathering on user requirements is carried out through several methods such as interviews, observation and focus groups. The findings from the data gathering activities is clearly represented and examine for system requirements.</td>
</tr>
</tbody>
</table>

3.1.1.2 – User Design

During this phase, the activity associated with the system requirement is clearly defined. The skeleton of the system is designed after evaluating the problems of the developed TSR prototype and the system architecture on solving one of the problems of TSR prototype is proposed.

3.1.1.3 – Construction
In this phase, the detailed design of the proposed system is implemented and constructed using the proposed software and development tools. It includes programming, system integration and testing of the prototype product.

3.1.1.4 – Cutover

This phase comprises of the post development activities which includes testing the technique implemented, user training and maintenance. The development cycle will be considered as completed when all of the objectives and system requirements are met.

3.1.2 – Proposed System Architecture

System architecture is needed to describe the model and design system of the proposed project in a diverse way and helps in improving decision making. The proposed system architecture will show how the system will work in processing and recognizing the image captured by VIP. The main focus of this project is to propose a noise filtering technique for TSR prototype. The images captured by VIP are prone to variety types of noise. Noise is a random variation of image density, brightness and colour, which make the text in the image difficult to be read. In this project, the author will be focusing on filtering the noise of unwanted background images or scenery. Figure 6 shows the enhanced Text Signage Recognition (TSR) model of the existing prototype application.
The proposed text signage recognition model above for this project is composed of four main processes which are:

1- Image acquisition
   
   In this phase, the input images are taken from camera by VIP. The input image may contain more than one background colours and noise. Noise must be first eliminated and background colours must be converted to binary image. Therefore, image pre-processing is needed before OCR is used to extract the text from the image.
2- Image Pre-processing

i. Applying **Gaussian filter** to reduce details and smooth out the image.

![Gaussian Applied](image)

**Figure 8: Gaussian filtered image**

Noise is defined as an undesirable by-product of image captured that adds extraneous information which can be in the form of different colour intensity of background image and more. In this project, Gaussian filter under linear filtering technique is used to remove noise from the signage image captured by VIP. Gaussian filter also called as Gaussian smoothing is the result of blurring an image mainly to reduce noise from image and reducing image detail (“Gaussian Blur”, n.d.). Generally, this filter is used to reduce details and smooth out the image captured byVIP. The input image will be filtered by an isotropic Gaussian filter by specifying a scalar value for sigma. Generally the formula for applying 2D Gaussian filter is:

\[
g(z) = \frac{1}{\sqrt{(2\pi)^2|\Sigma|}} e^{-\frac{1}{2}(z-\mu)^t \Sigma^{-1} (z-\mu)}
\]

Where \( z \) = vector containing coordinate of image \((x, y)\)
\( \mu \) = mean of Gaussian function

Function `imgaussfilt(Image, sigma)` is used to perform noise removal operation where it is a 2D Gaussian smoothing kernel with standard deviation is specified by the value of sigma. In image processing, kernel is a small matrix that is useful for blurring which can provides a variety of effects depending on the element values. (“Kernel”, n.d.). The sigma value is the result of standard deviation calculated from the Gaussian distribution.
ii. Adjust image intensity

Intensity adjustment is used to map an image’s intensity values to a new range. The new range value was determined through the intensity value limits vector.

![Image Intensity Adjusted](image)

**Figure 9: Adjust the intensity of the image**

Intensity adjustment is used to map an image’s intensity values to a new range. The new range value was determined through the intensity value limits vector.

Image = `imadjust(I, [low_in high_in], [low_out high_out])`

Where [low_in high_in] specifies the low and high intensity values that we want to map and [low_out high_out] specifies the scale over which we want to map them.

iii. Convert image to grayscale

After noise has been filter, image is converted to grayscale image. Image is converted to grayscale by eliminating the hue and saturation information while keeping the image intensity information.

![Grayscale Image](image)

**Figure 10: Grayscale Image**

Then image is converted to grayscale by using `rgb2gray()` function.
iv. Thresholding

Thresholding include partitioning the converted grayscale image into multiple set of pixels or segments. The selected pixels must lies between the threshold value and its limit. If not, the pixel values will be rejected.

![Thresholding applied](image)

**Figure 11: Thresholding applied**

Then graythresh( ) function is used to compute the global threshold value before convert to black and white image. It follows by im2bw( ) function for conversion to binary image.

v. Detect and find edges of characters

Then find the contours of characters in the image, in order to find the edges of characters. The background objects in the image will need to be eliminated and darken for the characters on the image to be visible as it supposed to be. This is done by creating a mask on the edges of characters of the image.

![Detect edge of characters](image)

**Figure 12: Edge of characters detected**

For detecting the edges of the characters, edge(I) function is used to find edges in specified intensity image. By default, edge(I) function used Sobel operator where it operates by creating a black and white image which emphasizes edges and transition.
vi. Convert to grayscale then to binary image

![FLATS FLATS](image)

**Figure 13: The pre-processed Image**

Then, a mask was created by applying imdilate(I,se) function. The mask will darken and eliminate all background in the image and leave only the characters to be visible in the image. Finally image is converted to binary image before proceed with the text recognition of OCR.

3- Text Recognition

This step involves converting the processed binary image to character streams representing letters before proceed with the speech synthesizing process.

4- Speech synthesizing process

Text to speech synthesizer is a system that converts text that has been extracted from Optical Character Recognition (OCR) to speech. It will automatically read out the text if it is recognized correctly, otherwise it will read out the letters one by one or error message will be displayed.

3.1.3 Gantt Chart

Refer APPENDIX A.

3.2 – Research Methodology

3.2.1 – Qualitative Research
Qualitative research is a method of inquiry data by revealing target audiences range of behaviour and insights in reference to specific issues or topics. In this project, qualitative research includes in-depth interview with focus group or targeted users which is the visually impaired people at MAB Ipoh, observation and analysis of documents and materials.

3.2.1.1 – Interview with low visually impaired

Interview with the students of Malaysian Association for the Blind at Ipoh to obtain the views and understanding from the perspective of low visually impaired users regarding the text signage recognition application. The findings from this interview are recorded and analysed to be used in the designing the system architecture. This is important to design a system that suites the needs and ability of low visually impaired.

3.2.1.2 – Observation

Observation is made while the low visually impaired students of MAB experience to use the TSR prototype application during the demonstration session. The problems encountered by the user during the session are observed and recorded for analysis.

3.2.1.3 – Analysis of documents and materials.

A detailed research regarding text recognition techniques and tools was conducted for data collection.

3.3 – Development tools

In order to successfully implement this project, the following designing tools and software will be used.

3.3.1 – Software
    i. Matlab
    Matlab is a high level language computing environment and programming language that is used to explore ideas across areas such numeric computational, algorithm development, data analysis and visualization, programming and many more. In this
project, the author is using the Matlab as the platform to improve the TSR noise filtering technique for VIP by following the proposed system architecture.

ii. Microsoft SAPI SDK 5.1
Microsoft Speech Software Development Kit (SDK) 5.1 is a set of software codes that allow you to build speech applications for Windows. It is the combination of the Speech Application Programming Interface (SAPI) that can recognize human voice and works as Text-To-Speech (TTS) engine that convert text to audio.
CHAPTER 4

FINDINGS AND DISCUSSION

4.1 – Preliminary testing and interview with the students from Malaysian Association for the Blind (MAB) Ipoh.

Preliminary testing had been conducted with students from Malaysian Association for the Blind (MAB) Kinta Valley Rehabilitation Centre, Ipoh Perak. The main purpose of preliminary testing conducted was to study the problem that has not been clearly defined from the prototype application. This preliminary testing is also done to test the functionalities and designs of the developed prototype application for improvement and adjustment that will be perform in the development phase during FYP2.

4.1.1 – Objective

In this preliminary stage, exploratory study was used to address the feasibility of the TSR prototype application in the real environment with VIP. The main objective of conducting this exploratory study is:

i) To explore how well the TSR prototype application can support the targeted user which is low visually impaired people.

4.1.2 – Method

Four selected students between 19 – 25 years old from MAB were selected to participate in this study. The study is divided into 3 main parts in which the selected respondents actively participate in it. The study first started with analysing the respondents’ background information. The session continued by recording respondent’s interaction with the TSR prototype and the testing results obtain is recorded for further analysis. The interview session was conducted right after the testing session ended in which the respondents was interviewed by asking several questions relating to their experiences and feedbacks after the interaction with the TSR prototype application. Throughout the study, Sony Xperia C was used in the testing and a total of 6 images was used comprises of 3 sample ICDAR 2003 images and another 3 are handwritten image.

4.1.3 – Study Result
The results and findings from the exploratory study conducted are divided into 3 parts which are:

4.1.3.1 – Pre – Testing

The session first started by gathering respondent’s background information. The following is the summary of background information acquired from the respondents.

i) Demographic information

Three of the respondents selected are male and one respondent are female. All of them are in their early 20’s which ranges from 19 to 25 years old.

ii) Low vision

All four of the respondent stated that they are under the categories of low vision. As mention in the previous chapter, World Health Organization, WHO (n.d.) sites describe low vision as a loss of visual acuities but with very little functional use of vision.

Respondent 1 said that “I can see things but it is not that clear and sometimes I will need to use magnifier if the text or image is small and contains more than one colour.” Respondent 2 and 3 also mention the same thing and added that they can see things when it is up close but became blurring when it is in distance. While respondent 4 said that he unable to see things clearly when the light is too bright, “… when the lighting is too bright, my sight became blurry and I cannot see things clearly.”

From this we can conclude that all of the respondents can still see things which referring to object and text but with very little acuities. They admitted that they can still see things such as visual of an object but when their vision became blurry, most of the time they cannot identify what it is. Reading a text from the image is slightly difficult for them especially when the font of the text is small and the image
consist of variety of background colours. Sometimes they have to use magnifier in order to read text from the image.

iii) Usage of smartphone

Since the respondents are in their early 20’s, all of them owned a smartphone which three of them are using Samsung phone (Android) and one respondent is using iPhone (iOS). They frequently use their smartphone in their daily life mostly to communicate with other people. They also mention that their phone are equipped with an accessibility features for visually impaired user which is Talkback in Android and VoiceOver in iOS. This proves that low visually impaired can interact with their mobile devices just like normal people do.

iv) Current usage of mobile application for independent navigation.

All four of the respondent admitted that they have never used any mobile application to support them during independent navigation. Respondent 1 said that finding places is quite difficult for him and he had never used any mobile application to support his navigation. Respondent 2 and 3 added that they rarely going out alone and most of the time they will be accompanied by someone. While respondent 4 said that “most of the time I will be accompanied by my white cane and finding the right places is the main difficulties I faced when navigation but I never used mobile application to support me”.

They mention the most common limitation that they faced during independent navigation is finding a room, place, and differentiate male and female toilet. From this we can see that although they use smartphone in their daily life, but they never use mobile application for navigation. This shows the importance of using a tool to support VIP in navigation.
Mobile application is the best tool to support them since it is easy for them to just install the application in their mobile phone and it is portable which they can bring anywhere and for TSR itself can help them in identifying the right places by recognizing the text from the signage image that they have captured.

After recording the respondent’s background information, the session continued with testing the TSR prototype application by the same respondents. Prior to the testing conducted, the author had observed the respondents behaviour and interaction with the application. The following is the summary of author observation pertaining to user behaviour and application design.

i) User behaviour

Based on the author observation, the behaviour of respondents in capturing the image is different with each other. This behaviour can be further divided into two categories which are focus and angle.

<table>
<thead>
<tr>
<th>Respondent 1</th>
<th>Focus</th>
<th>The author observed that upon capturing the image, Respondent 1 capture the image after the camera focus on the image.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Angle</td>
<td>The author observed that upon capturing the image, Respondent 1 holds the camera in landscape mode and slightly tilted the camera. As a result, instead of just capturing the dataset image; camera also captured the background of the dataset image which is the table where the dataset is placed on.</td>
</tr>
<tr>
<td>Respondent</td>
<td>Focus</td>
<td>Angle</td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>2</td>
<td>The author observed that Respondent 2 will capture the image right after he placed the camera on the image.</td>
<td>The author observed that upon capturing the images, Respondent 2 holds the camera in landscape mode and slightly tilted the camera. As a result, respondent does not capture the whole image and one of the images contains missing letter.</td>
</tr>
<tr>
<td>3</td>
<td>The author observed that, respondent 3 will wait until the camera focussing on the image before capture it.</td>
<td>The author observed that respondent 3 holds the camera right above the image and captured it.</td>
</tr>
<tr>
<td>4</td>
<td>The author observed that Respondent 4 will capture the image right after he placed the camera on the image.</td>
<td>The author observed that upon capturing the images, Respondent 4 holds the camera in landscape mode and slightly tilted the camera. Nevertheless, respondent 4 manage to capture the images without missing any letter but the background of the image which is the table was also being captured.</td>
</tr>
</tbody>
</table>

ii) User Interface

From the author observation, all of the respondents require some help in using the TSR prototype application. For them, the font size for “Select Image” option is quite small and the brightness of the mobile phone screen itself is quite dim. Because of this, the respondents cannot see the user interface
clearly and needs guidance from the author in order to use it. As display below is the user interface of the TSR prototype application. For normal sighted people they would not have any problem with this interface, but for VIP as they cannot see things clearly, this will be quite difficult for them to use.

![TSR Prototype Interface](image)

**Figure 14: Screenshot of existing TSR prototype**

Based on the observation recorded from the testing, the problems that affect the recognition performance of the TSR prototype application are:

i) Unwanted background image or scenery of the image captured by VIP become noise and causes TSR failed to recognize the text in the image.

ii) Certain angle that the user use to capture the image whether the camera is tilted or not will decide on what kind of image will come out as the result. TSR failed to recognize images that is slanted from this testing.

### 4.1.3.2 Testing Results

Each of the images used in the testing are different with each other. This is to evaluate the usability of the TSR application on different type of images. The results from the testing were recorded for each respondent in the table below.
### Table 3: Respondent 1

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Image captured by respondent</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="FLATS" /></td>
<td><img src="image2" alt="FLATS" /></td>
<td>TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding.</td>
<td>The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td><img src="image3" alt="KNOW" /></td>
<td><img src="image4" alt="KNOW" /></td>
<td>TSR failed to detect and recognized image. After user capturing the image, apps hang for few seconds then it goes back to “select image” page.</td>
<td>The presence of white background colour of the paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td><img src="image5" alt="Library" /></td>
<td><img src="image6" alt="Library" /></td>
<td>TSR failed to recognize image correctly. It shows nonsense letter eg: “NP11…”</td>
<td>The presence of unwanted background image of the table on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured that is a bit slanted.</td>
</tr>
<tr>
<td><img src="image7" alt="Flight" /></td>
<td><img src="image8" alt="Flight" /></td>
<td>TSR incorrectly recognize image as “flldg…”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image9" alt="School" /></td>
<td><img src="image10" alt="School" /></td>
<td>TSR failed to output any result. Image is extracted and is display but text and voice output is not displayed.</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image11" alt="So" /></td>
<td><img src="image12" alt="So" /></td>
<td>TSR correctly recognized image as “So”</td>
<td>TSR able to recognize because it only contains S and O which is quite easy to be identified.</td>
</tr>
</tbody>
</table>

### Table 4: Respondent 2

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Image captured by respondent</th>
<th>Results</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="FLATS" /></td>
<td><img src="image2" alt="FLATS" /></td>
<td>TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding.</td>
<td>The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td><img src="image3" alt="KNOW" /></td>
<td><img src="image4" alt="KNOW" /></td>
<td>TSR failed to detect and recognized image. After user capturing the image, apps hang for few seconds then it goes back to “select image” page.</td>
<td>The presence of white background colour of the paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td><img src="image5" alt="Library" /></td>
<td><img src="image6" alt="Library" /></td>
<td>TSR failed to recognize image correctly. It shows nonsense letter eg: “NP11…”</td>
<td>The presence of unwanted background image of the table on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured that is a bit slanted.</td>
</tr>
<tr>
<td><img src="image7" alt="Flight" /></td>
<td><img src="image8" alt="Flight" /></td>
<td>TSR incorrectly recognize image as “flldg…”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image9" alt="School" /></td>
<td><img src="image10" alt="School" /></td>
<td>TSR failed to output any result. Image is extracted and is display but text and voice output is not displayed.</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image11" alt="So" /></td>
<td><img src="image12" alt="So" /></td>
<td>TSR correctly recognized image as “So”</td>
<td>TSR able to recognize because it only contains S and O which is quite easy to be identified.</td>
</tr>
<tr>
<td>Original Image</td>
<td>Image captured by respondent</td>
<td>Results</td>
<td>Remarks</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Flats</td>
<td>Flats</td>
<td>TSR failed to detect and recognized image. After user capturing the image, apps hang for few seconds then it goes back to “select image” page.</td>
<td>The presence of white background colour of the paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td>Know</td>
<td>Know</td>
<td>TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding.</td>
<td>The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image.</td>
</tr>
<tr>
<td>Library</td>
<td>Library</td>
<td>TSR incorrectly recognize image as “N up N1 M1..”</td>
<td>The presence of unwanted background image of the table on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured that is a bit slanted.</td>
</tr>
<tr>
<td>Flight</td>
<td>Flight</td>
<td>TSR incorrectly recognize image as “fMgh..”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td>School</td>
<td>School</td>
<td>TSR incorrectly recognize image as “5Cfh O Q”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td>So</td>
<td>So</td>
<td>TSR correctly recognized image as “So”</td>
<td>TSR able to recognize because it only contains S and O which is quite easy to be identified.</td>
</tr>
</tbody>
</table>

**Table 5: Respondent 3**
TSR incorrectly recognized image as “fvfvfl”  
The presence of white background colour of the paper on the captured image causes TSR failed to recognize the image.

TSR almost can recognize the image. However, letter “O” is missing from the extracted text. Result shows “KN W”.  
Because the image is captured right above the image and there are noise in the image captured in between N and O.

TSR can almost recognize the image. However the letter Y is replaced with 1. The extracted image shows “Librar1”  
Because the image is captured right above the image and TSR mistaken Y as 1.

TSR incorrectly recognize image as “Fligwr..”  
Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.

TSR failed to output any result. Image is extracted and is display but text and voice output is not displayed.  
Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.

TSR correctly recognized image as “So”  
TSR able to recognize because it only contains S and O which is quite easy to be identified.

Table 6: Respondent 4

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Image captured by user</th>
<th>Results</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLATS</td>
<td>FLATS</td>
<td>TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding.</td>
<td>The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured is slightly slanted.</td>
</tr>
<tr>
<td>Image 1</td>
<td>Image 2</td>
<td>Description 1</td>
<td>Description 2</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td><img src="image1" alt="TSR incorrectly recognize image as “illlnfkl…”" /></td>
<td><img src="image2" alt="TSR incorrectly recognize image because the image is a bit blur which may happen because user does not focus the camera on the image upon testing." /></td>
<td>TSR incorrectly recognize image as “illlnfkl…”</td>
<td>TSR incorrectly recognize image because the image is a bit blur which may happen because user does not focus the camera on the image upon testing.</td>
</tr>
<tr>
<td><img src="image3" alt="TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding." /></td>
<td><img src="image4" alt="The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured is slightly slanted." /></td>
<td>TSR failed to detect and recognized image. It hangs for few seconds then error message is shown stated that TSR is not responding.</td>
<td>The presence of unwanted background image of the table and the white paper on the captured image causes TSR failed to recognize the image. Besides, the angle of the image captured is slightly slanted.</td>
</tr>
<tr>
<td><img src="image5" alt="TSR incorrectly recognize image as “HHH..”" /></td>
<td><img src="image6" alt="Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library." /></td>
<td>TSR incorrectly recognize image as “HHH..”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image7" alt="TSR incorrectly recognize image as “r1SCJ….”" /></td>
<td><img src="image8" alt="Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library." /></td>
<td>TSR incorrectly recognize image as “r1SCJ….”</td>
<td>Because the text is handwritten, the font of the letters written is slightly different than those that had been stored in the data library.</td>
</tr>
<tr>
<td><img src="image9" alt="TSR correctly recognized image as “So”" /></td>
<td><img src="image10" alt="TSR able to recognize because it only contains S and O which is quite easy to be identified." /></td>
<td>TSR correctly recognized image as “So”</td>
<td>TSR able to recognize because it only contains S and O which is quite easy to be identified.</td>
</tr>
</tbody>
</table>

From the testing results illustrated above for each user, we can summarize the testing result as below. Even though the TSR prototype application cannot recognize most of the images captured by the VIP accurately in this testing. But, this is because of the presence of unwanted background image which became noise to the image captured. The TSR prototype application can recognize image better when the image had simple background and contains less words.
Table 7: Summary of Preliminary Testing Results

<table>
<thead>
<tr>
<th>No</th>
<th>Image</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLATS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>KNOW</td>
<td>X</td>
<td>X</td>
<td>○</td>
<td>X</td>
</tr>
<tr>
<td>3</td>
<td>LIBRARY</td>
<td>X</td>
<td>X</td>
<td>○</td>
<td>X</td>
</tr>
<tr>
<td>4</td>
<td>FLIGHT</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>5</td>
<td>SCHOOL</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6</td>
<td>SO</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

○ Almost can be recognize
√ Recognize
X Failed to recognize

4.1.3.3 Post – testing

In the third part of this exploratory study, the respondents were interviewed by asking two questions relating to their experience and feedbacks on after experience using the TSR prototype application.

i) The implementation of TSR for VIP

The respondents agree that text signage recognition can improve and will provide a better experience for their independent navigation. Respondent 1 said that “this application is useful for people like us because it will make it easier for us to find places by recognizing the signage and read out the text out loud”. Respondent 2 added that the application will be very useful and handy for them since they can just bring their mobile phone and use the application anytime.

Respondent 3 and 4 also admitted that TSR will be very useful to the VIP because it helps them translate the text that appeared in the signage image which cannot be read by them. From this, we can conclude that the implementation of text detection and recognition for VIP would be a useful
support in improving independent navigation experience among the visually impaired community.

ii) Recommendation and other relevant information

They suggested one thing to be improved on this application is the user interface; they suggest the author to enlarge the font for application menu like “Select Image”. Not just that, since the earlier version of TSR not working that well during the testing. They are hoping for a better recognition performance by TSR application from this project so that they can use it later on. The respondents also commented that there are many assistive devices available but it is too expensive and they could not afford it. Prior to that, they are really supportive on the development and improvement of the TSR and looking forward for the implementation of this project.

4.2 – Prototype Design

Unlike the previous TSR prototype which was developed in the Android mobile devices, this TSR noise filtering technique prototype was created in a standalone system using Matlab as the platform. As the prototype is developed specially to assist the low visually impaired, it is designed based on the system architecture which focused on filtering the noise from the signage images captured by VIP. This program will get the image from the specified folder where the image was stored. The input image will be processed before being extracted for Optical Character Recognition (OCR). Then the extracted characters will be stored in .txt file before being translated to voice using speech synthesizer. Figure 16 below illustrate the screenshots of the prototype:-
In order to evaluate the usability and performance of the TSR noise filtering technique, a series of experiments are conducted. The experiments consist of two type of testing which are:

- Pilot testing with the sighted users
- Usability testing with the low visually impaired (VIP) users.

The performance of the prototype is measured based on the recognition rate of the proposed TSR noise filtering technique. The Recognition Rate (RR) can be calculated using Equation (1):

$$RR = \frac{\text{No. of Recognized Signage}}{\text{Total No. of Signage}} \times 100\%$$

The accuracy of the testing conducted are determined based on the criteria:
- Number of dataset being used for the testing purpose.
  In this project, the dataset were randomly chosen from the ICDAR 2003 datasets and the number of dataset used are standardize to 15 images for both pilot and usability testing.

4.4 – System Testing

A system testing performed by the author was conducted to evaluate the prototype compliance’s with its specified requirement and to evaluate the recognition performance of the TSR noise filtering prototype. This testing was also done to test the design of the noise filtering technique performance, so that it can be improved and adjusted later in the usability testing with the actual population – low visually impaired (VIP) users. A total of 15 different samples of signage images were randomly selected from the ICDAR 2003 dataset (http://algoval.essex.ac.uk/icdar/Datasets.html). Each signage image was captured using Sony Xperia C device and stored in the Matlab destination path. Table 1 shows the system testing results for the ICDAR 2003 dataset.

Table 8: The author’s evaluation on TSR noise filtering prototype

<table>
<thead>
<tr>
<th>Sample Signage Images</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOP</td>
<td>✓</td>
</tr>
<tr>
<td>BEWARE</td>
<td>✓</td>
</tr>
<tr>
<td>YOU</td>
<td>✓</td>
</tr>
<tr>
<td>CAUTION</td>
<td>X</td>
</tr>
<tr>
<td>Bookshop</td>
<td>✓</td>
</tr>
</tbody>
</table>
From the testing results illustrated in the Table 6, it shows that the TSR noise filtering prototype unable to detect and recognize signage image correctly for some image for certain user. “CAUTION”, “KNOW” and “DOOR” are the signage images that could not be recognized by the TSR noise filtering prototype. However, the TSR noise filtering prototype able to recognized signage images with the presence of noise accurately such as “STOP”, “BEWARE” and “SCHOOL”. Hence, in general most signage images with the presence of noise could be detected and recognized by the TSR noise filtering prototype.
The performance of the TSR prototype is further evaluated by calculating the Recognition Rate of the TSR noise filtering prototype.

**Table 9: Summary of System Testing Results**

<table>
<thead>
<tr>
<th></th>
<th>No. of Samples</th>
<th>No. of Recognized Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

\[ RR = \frac{\text{No. of Recognized Signage}}{\text{Total No. of Signage}} \times 100\% \]

A total of 12 out of 15 samples were recognized:

\[ RR = \frac{12}{15} \times 100\% = 80.0\% \]

By referring to the results obtained from the pilot testing conducted, it can be concluded that there are errors occurred during the text recognition process of the signage images tested. For signage images “CAUTION”, “KNOW” and “DOOR”; the TSR noise filtering prototype incorrectly recognized letter ‘o’ as ‘0’ and ‘K’ as ‘x’. Since the letters itself look quite similar, it seems to be that the TSR noise filtering prototype mistook ‘o’ and ‘K’ as ‘0’ and ‘x’ respectively.

**4.5 – Usability Testing with low visually impaired (VIP) users**

At the end of the project implementation, a usability testing was conducted to evaluate the recognition performance of the TSR noise filtering technique prototype by testing it on the targeted users. The testing was conducted with 5 selected low visually impaired people from Malaysian Association for the Blind, Ipoh. The recognition performance of the TSR prototype was recorded throughout the testing for further analysis. The proposed TSR noise filtering technique prototype has been evaluated using 15 signage images which was randomly selected from ICDAR 2003 datasets.

**4.5.1 – Demographic of the users**
The users selected in this testing range in age from 18 to 50, with four of the users are in their early 20’s and only one user in her 50’s. 3 out of 5 users selected are female and the other 2 are male. All of the users selected are low visually impaired users. 3 out of 5 users selected have experiences on using smartphone’s camera and the other 2 does not. Because the other 2 does not have any experience on using smartphone before, the author have to guide both of them on capturing the signage images.

4.5.2 – Results of usability testing

The testing results vary depending on the user’s behaviour upon capturing the signage images. This is because each user’s level of vision is different from each other even they fall under the same category which is low vision. For example, some of the users can capture the signage images properly but others might unable to see the signage images clearly which cause the image captured to be a bit deteriorate. This also affect the recognition performance of the prototype. Table 10 shows each users evaluation on the TSR noise filtering prototype upon the testing conducted.

Table 10: Low VIP user’s evaluation on TSR noise filtering prototype

<table>
<thead>
<tr>
<th>Sample Signage Images</th>
<th>Low Visually Impaired</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>OFFICE</td>
<td>√</td>
</tr>
<tr>
<td>NOTICE</td>
<td>√</td>
</tr>
<tr>
<td>SCHOOL</td>
<td>✓</td>
</tr>
<tr>
<td>BEWARE</td>
<td>✓</td>
</tr>
<tr>
<td>PARKING</td>
<td>✓</td>
</tr>
<tr>
<td>Campus</td>
<td>✓</td>
</tr>
<tr>
<td>Street</td>
<td>✓</td>
</tr>
<tr>
<td>WOMEN</td>
<td>✗</td>
</tr>
<tr>
<td>Way out</td>
<td>✓</td>
</tr>
<tr>
<td>OUT OF SERVICE</td>
<td>✓</td>
</tr>
</tbody>
</table>
From the testing results illustrated in the Table 10, it shows that the TSR noise filtering prototype unable to detect and recognize signage image correctly for some image for certain user. “TOILET”, and “WOMEN” are the signage images that could not be recognized by all users. However, the TSR noise filtering prototype able to recognized signage images with the presence of noise accurately such as “BUS”, “LADIES” and “STREET”. Hence, in general most signage images with the presence of noise could be detected and recognized by the TSR noise filtering prototype.

The performance of the TSR prototype is further evaluated by calculating the Recognition Rate of the TSR noise filtering prototype.

Table 11: Summary of Usability Testing Results
<table>
<thead>
<tr>
<th>User</th>
<th>No. of Samples</th>
<th>No. of Recognized Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>75</strong></td>
<td><strong>58</strong></td>
</tr>
</tbody>
</table>

\[ RR = \frac{\text{No. of Recognized Signage}}{\text{Total No. of Signage}} \times 100\% \]

A total of 58 out of 75 samples were recognized:

\[ RR = \frac{58}{75} \times 100\% \]
\[ = 77.33\% \]

By referring to the results obtained from the usability testing conducted, it can be concluded that errors still occur during the text recognition process of the signage images tested. For signage images “TOILET” and “WOMEN”; the TSR noise filtering prototype incorrectly recognized letter ‘o’ as ‘0’. Comparing with the previous pilot testing conducted, the TSR incorrectly recognized letter ‘o’ and ‘K’. Some debugging has been applied and the TSR able to recognize letter ‘k’ correctly. However, problem still persist when the TSR unable to recognized letter ‘o’ correctly. Since the letters itself look quite similar, it seems to be that the TSR noise filtering prototype mistook ‘o’ as ‘0’. Some of the images captured by users were a bit slanted, skewed and deteriorated which affects the recognition of the TSR noise filtering prototype.

For example, TSR noise filtering prototype unable to recognize image ‘Notice’ from user 3. This is because the end of the letter ‘N’ are missing from the image captured. Therefore, instead of extracting ‘Notice’ from the image; TSR noise filtering prototype only manage to recognize the last part of the word correctly (‘tice’).
To conclude and summarize the findings obtained from both of the testing conducted, it shows that the results vary depending on the user’s behaviour upon capturing the signage images because each user’s level of vision is different from each other. Other than that, the recognition rate obtained from the usability testing is lower that the recognition rate obtained from the system testing which is 77.3% while 80.0% are obtained from the system testing. This is because the usability testing was evaluated by the low vision VIP and the signage images captured by them may be deteriorated due to their behaviour upon capturing the images which results in lower recognition rate.
CHAPTER 5

CONCLUSION

5.1 Relevancy to objectives

Based on the previous discussion, the objectives of the project are:

- To assess the usability of the existing Text Signage Recognition (TSR) prototype application with the visually impaired.
- To propose a noise filtering technique for TSR which filter noise from image captured by VIP.
- To evaluate the performance of the TSR noise filtering technique by estimating the recognition rate.

The project serves the earlier mention objectives. Preliminary testing has been conducted with low visually impaired from MAB to assess the usability of the existing TSR model. Throughout the testing conducted, author has evaluated and analyse the problems with the TSR prototype model and propose a solution for improvement in this project. From the testing conducted, it can be concluded that the development of text signage recognition is feasible for the visually impaired. This is because the text signage recognition application can be a very helpful support for the VIP in their daily use. The users which is low vision VIP mentioned this in the preliminary interview conducted, stating that if the TSR application work as it supposed to be; it will be really helpful to them in their daily navigation.

The new TSR noise filtering technique which was deployed with Matlab r2015a could successfully recognize the signage images from the International Conference on Document Analysis and Recognition (ICDAR) 2003 datasets with satisfactory recognition performance based on the usability testing conducted. The author hopes that this project had successfully met the objective being acknowledge early and could help to support the VIP on their independent navigation.

5.2 Suggested future work for expansion and continuation

There are always a room for expansion and improvement in project development. In the future, author would like to suggest to further improve the
current TSR prototype to detect signage image with cluttered or more complex background, skewed or embossed images, slanted image and poor lighting. This project only covers the scope of filtering the noise from the signage image captured by VIP and it was done in a standalone system which using Matlab platform. In the future, it is possible to apply this technique to a TSR application in Android mobile devices for better portability and VIP ease of use.
REFERENCES


### APPENDICES

**APPENDIX A – GANTT CHART**

<table>
<thead>
<tr>
<th>No</th>
<th>Deliverable/Week</th>
<th>FYP 1</th>
<th>FYP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Planning Phase</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>1.1</td>
<td>Preliminary research for project title</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>1.2</td>
<td>Identify problem and propose solution</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>1.3</td>
<td>Identify objectives, goals, and scope of project</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>1.4</td>
<td>Identify the required tools and software</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>1.5</td>
<td>Submission of project title proposal</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.0</td>
<td>Analysis Phase</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.1</td>
<td>Research on the preceding studies</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.2</td>
<td>Define methodology approach for the project</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.3</td>
<td>Collect data for the system (Preliminary Testing)</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.4</td>
<td>Analyze the collected data (Comparative Study)</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.5</td>
<td>Submission of Interim Report</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>2.6</td>
<td>Proposal Defense</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>3.0</td>
<td>Design Phase</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>3.1</td>
<td>Design system architecture</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>3.2</td>
<td>Design flow of the system</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>4.0</td>
<td>Coding Phase</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>4.1</td>
<td>Deployed the proposed system architecture</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>4.2</td>
<td>Programming</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>5.0</td>
<td>Testing Phase</td>
<td><img src="#" alt="Timeline" /></td>
<td><img src="#" alt="Timeline" /></td>
</tr>
<tr>
<td>5.1</td>
<td>Prototype Testing &amp; Error debugging (Unit Testing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>Pilot Testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.3</td>
<td>Pre-Sedex Presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.4</td>
<td>Submission of Technical Paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>Submission of Dissertation &amp; Project</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finalized Prototype</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process</th>
<th>Activities</th>
<th>Suggested Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B – SNAPSHOT OF IMPORTANT CODES

i) Image acquisition – Get the signage image from the specified folder.

```matlab
warning off
% Clear all
clc, clear all

% Get file from folder
[filename, pathname] = uigetfile('*.jpg', 'LOAD AN IMAGE');
% If full image file name full file (folder, base file name)

% Read image
Image = imread(fullfile(pathname, filename));
```

ii) Image Pre-processing – The input image are meant to be pre-processed to remove the unwanted noise.

```matlab
% NOISE REMOVAL – Pre Processing
% 1 - Gaussian Smoothing
Image2 = imadjust(Image1, Image2);
figure, imshow(Image2)
title('Gaussian Applied'); pause(0.6)

% Adjust image intensity 88
PreFl = imadjust(Image2, [0.3 0.5], []);
figure, imshow(PreFl)
title('IMAGE INTENSITY ADJUSTED'); pause(0.6)

% 2 - Convert to grayscale
if size(PreFl, 3) == 3 % check if its RGB image convert to grayscale
    PreFl = rgb2gray(PreFl);
    figure, imshow(PreFl)
    title('Grayscale Image')
end

% 4 - Convert to Black and White (thresholding)
threshold = graythresh(PreFl);
PreFl = im2bw(PreFl, threshold);
figure, imshow(PreFl)
title('Binary Image')
```

```matlab
% Remove all object containing fewer than 30 pixels
PreF3 = bwareaopen(PreF2, 30);
Im = PreF3;
figure, imshow(Im)
title('Filtered Image'); pause(0.6)

% Detect edges of characters
Image3 = edge(uint8(Im));
figure, imshow(Image3)
title('Detect edge of characters'); pause(0.6)

% Convert image to binary image
se = strel('square', 2);
Image2 = imdilate(Image3, se);
figure, imshow(Image2)
title('Detect edge of characters'); pause(0.6)

Ifill = imfill(labeled, 'holes');
figure, imshow(Ifill)
title('Image filling'); pause(0.6)
```

% Storage matrix word from image
word = Ifill
```

iii) Text Recognition – The binary image will be further processed and converted to text.
iv) Speech synthesizing – text that has been extracted were then fed into speech synthesizer for Text-to-speech translation.
APPENDIX C – INTERVIEW QUESTIONS

Text Signage Recognition

Respondent Name: [Redacted]
Respondent ID: [Redacted]
Gender: [Redacted]

<table>
<thead>
<tr>
<th>Questions</th>
<th>Responds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the level of your vision? Can you read?</td>
<td>- Low vision - Can read</td>
</tr>
<tr>
<td>2. Do you own a smartphone? What do you use it for? And does your phone have any accessibility features?</td>
<td>- Yes, iPhone - Use to call, send text, check messages, access internet</td>
</tr>
<tr>
<td>3. How do you usually navigate outdoor? (limitations/challenges) Have you ever used a mobile application to help you navigate?</td>
<td>- Difficult to find places - No signage, images are unclear, too difficult to see for small images</td>
</tr>
<tr>
<td>4. You have tested the text signage recognition apps earlier, so how do you think of these apps? Do you think it is helpful to use it in your daily life (in navigating especially)?</td>
<td>- Yes, helpful for blind because it will make it easier for the blind to find places and can speak.</td>
</tr>
<tr>
<td>5. Do you have any suggestion or future recommendations for these apps improvement for this project?</td>
<td>- Improve apps so better recognize any image</td>
</tr>
</tbody>
</table>

Text Signage Recognition

Respondent Name: [Redacted]
Respondent ID: [Redacted]
Gender: [Redacted]

<table>
<thead>
<tr>
<th>Questions</th>
<th>Responds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the level of your vision? Can you read?</td>
<td>- Low vision - Can read</td>
</tr>
<tr>
<td>2. Do you own a smartphone? What do you use it for? And does your phone have any accessibility features?</td>
<td>- Yes, iPhone - Use for daily usage, check messages, access internet</td>
</tr>
<tr>
<td>3. How do you usually navigate outdoor? (limitations/challenges) Have you ever used a mobile application to help you navigate?</td>
<td>- Can use signage, images, if it is big enough and near. - Never use mobile apps for navigation</td>
</tr>
<tr>
<td>4. You have tested the text signage recognition apps earlier, so how do you think of these apps? Do you think it is helpful to use it in your daily life (in navigating especially)?</td>
<td>- Yes, helpful for the blind because it will make it easier for the blind to find places and can speak</td>
</tr>
<tr>
<td>5. Do you have any suggestion or future recommendations for these apps improvement for this project?</td>
<td>- Improve apps so better recognize any image</td>
</tr>
</tbody>
</table>
### Text Signage Recognition

**Respondent Name:** Dawn Vicen

**Respondent ID:** 3

**Gender:** Female

<table>
<thead>
<tr>
<th>Questions</th>
<th>Responds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the level of your vision? Can you read?</td>
<td>Low vision - can see image but not clear, especially small images - can read text that is large, sometimes use white background</td>
</tr>
<tr>
<td>2. Do you own a smartphone? What do you use it for? And does your phone have any accessibility features?</td>
<td>Yes, Samsung - For easy use, calling - Text back in Samsung/Android</td>
</tr>
<tr>
<td>3. How do you usually navigate outdoors? (Limitations/challenges) Have you ever used a mobile application to help you navigate?</td>
<td>Navigating not alone - Navigation image can see but not clear (blur) - Difficult to find place, not sure whether right place or not - Never use mobile apps for navigation.</td>
</tr>
<tr>
<td>4. You have tested the text signage recognition apps earlier, so how do you think of this apps? Do you think it is helpful to use it in your daily life (in navigating especially)?</td>
<td>Very helpful because can help blind people know what signage says - Can snap pictures of signage and translate - But needs a lot of improvement.</td>
</tr>
<tr>
<td>5. Do you have any suggestion or future recommendation for this apps improvement for this project?</td>
<td>Improve app to recognize any image - Updated labeling in UI because cannot see clearly.</td>
</tr>
</tbody>
</table>

### Text Signage Recognition

**Respondent Name:** Dawn Vicen

**Respondent ID:** 3

**Gender:** Male

<table>
<thead>
<tr>
<th>Questions</th>
<th>Responds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the level of your vision? Can you read?</td>
<td>Low vision - Low vision - Slightly 1/4 - Little because the light is too bright sometimes can.</td>
</tr>
<tr>
<td>2. Do you own a smartphone? What do you use it for? And does your phone have any accessibility features?</td>
<td>Yes, Samsung early - Being use, communication will better.</td>
</tr>
<tr>
<td>3. How do you usually navigate outdoors? (Limitations/challenges) Have you ever used a mobile application to help you navigate?</td>
<td>Most of the time navigate alone (in white cane) - Difficult to identify the right place, some place dont have label eg: toilet, cannot identify male &amp; female, need help from other to tell - Never use mobile apps.</td>
</tr>
<tr>
<td>4. You have tested the text signage recognition apps earlier, so how do you think of this apps? Do you think it is helpful to use it in your daily life (in navigating especially)?</td>
<td>Very helpful, can make VIP lives easier - Can be used to identify places.</td>
</tr>
<tr>
<td>5. Do you have any suggestion or future recommendation for this apps improvement for this project?</td>
<td>Needing in recognition - Aware of more user friendly.</td>
</tr>
</tbody>
</table>
## APPENDIX D – TESTING RESULTS

### Text Signage Recognition

<table>
<thead>
<tr>
<th>No</th>
<th>Sample Signage Images</th>
<th>User 1</th>
<th>User 2</th>
<th>User 3</th>
<th>User 4</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>plus</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - then enter wrong display not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- app hung/stuck -</td>
<td>- nothing happened</td>
<td>- nothing happened</td>
<td>- nothing happened</td>
<td>- nothing happened</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Han error message</td>
<td>- back to selected image</td>
<td>- back to selected image</td>
<td>- back to selected image</td>
<td>- back to selected image</td>
</tr>
<tr>
<td>2</td>
<td>lunch</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- nothing happen</td>
<td>- only main 2 buttons</td>
<td>- done hanging</td>
<td>- no response</td>
<td>- right above image</td>
</tr>
<tr>
<td>3</td>
<td>Library</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - error exit not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- incorrectly recognized as &quot;book&quot;</td>
<td>- incorrectly recognized as &quot;library&quot;</td>
<td>- incorrectly recognized as &quot;library&quot;</td>
<td>- incorrectly recognized as &quot;library&quot;</td>
<td>- incorrectly recognized as &quot;library&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- app hung/stuck</td>
<td>- done hanging</td>
<td>- only main 2 buttons</td>
<td>- done hanging</td>
<td>- only main 2 buttons</td>
</tr>
<tr>
<td>4</td>
<td>Flight</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - error exit not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- error hanging as &quot;flight&quot;</td>
<td>- error hanging as &quot;flight&quot;</td>
<td>- error hanging as &quot;flight&quot;</td>
<td>- error hanging as &quot;flight&quot;</td>
<td>- error hanging as &quot;flight&quot;</td>
</tr>
<tr>
<td>5</td>
<td>School</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - error exit not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- image extracted but still not correct</td>
<td>- image extracted but still not correct</td>
<td>- image extracted but still not correct</td>
<td>- image extracted but still not correct</td>
<td>- image extracted but still not correct</td>
</tr>
<tr>
<td>6</td>
<td>So</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>App hung/stuck - error exit not responding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- recognized So</td>
<td>- recognized So</td>
<td>- recognized So</td>
<td>- recognized So</td>
<td>- recognized So</td>
</tr>
</tbody>
</table>

During the interview with one of the respondent, Mr. Mohd Hadri B. Johari (Respondent 2).
Photo session with MAB students and staffs after the preliminary testing.

User 1 evaluation on TSR noise filtering prototype
Photo session with MAB staffs and students after the usability testing.