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Project Title	**Mobile Phone based Awareness of Surroundings for the Visually Impaired**
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Mobile Phone based Awareness of Surroundings for the Visually Impaired

A dissertation submitted for the Degree of Master of Computer Science

S.I.G Kalupahana
University of Colombo School of Computing
2019

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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This is to certify that this thesis is based on the work of

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under my supervision. The thesis has been prepared according to the format stipulated and is of acceptable standard.

Certified by:

Supervisor Name:

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Signature: Date:

ABSTRACT

Assistive technology helps improve the day to day activities for people with disabilities. One of the methods utilized by assistive technologists employs the use of mobiles. Mobile computing has evolved from being used as communication devices to multi-purpose mobile computing devices. Modern day smart phones are equipped with a set of assistive features that can be used by the handicapped for exploring the applications. This thesis explores the idea of a mobile application for the visually impaired to improve the surrounding awareness. It is inspired by the existing assistive technology such as scene describing mobile applications and mobile technology such as mobile sensors. One method explored in this thesis is to facilitate sensors to monitor the direction the visually impaired person is facing and automate the process of screen capture. Additional method is to provide manual screen capture by introducing hard tap on the 'Device' as an alternative to tap on 'Buttons' in the touch screen. This thesis utilizes a machine learning model that is a trained model for scene describing [1]. A proof of concept which runs on an IPhone containing MobileNet as the trained model is presented. The evaluation on the success of improving the awareness of a visually impaired person is carried out with a group of visually impaired undergraduate students.

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S.I.G Kalupahana

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AI- Artificial Intelligence

MCQ-Multiple Choice Question

1. Introduction

The senses of human beings help to obtain inputs from the environment to learn the surrounding. Vision is a primary sense of the human and is used by humans to identify objects from childhood days. This is what enables one human to describe to another human places encountered previously; giving others the opportunity to visualize it. Blind and visually impaired people do not have the ability to gather visible contextual information about the surroundings. Braille readers are amongst the oldest of visual aids that were employed for reading. Devices like braille readers help the person to visualize the words that are being read using touch. Until the era of mobile phones there has been little hope about a visual aid to keep the visually impaired aware about the surroundings.

With the advancement of mobile technology compact devices such as mobile phones and tablets capable of handling sophisticated user-oriented applications have been released. These devices provide the basic features like the touch screen, camera, microphone and speaker that the visually impaired users find useful. Therefore these devices can act as visual aids to narrate the surroundings to the visually impaired. Using these devices the person can communicate through the sense of sound and touch while gathering contextual information about the surroundings. This research will be using mobile phones which are portable and used by many people around the world today.

The economy today cannot ignore the visually impaired as there are an estimated 253 million people with vision impairment: Of them 36 million are blind and 217 million having moderate to severe vision impairment [2]. Solutions need to be seek so that this community can also work amongst the rest of the world. This research is based on the methods that a blind or visually impaired person's awareness about the surroundings can be made more efficient specifically with the use of mobile phones. Mobile devices built today contain interesting features that can be applied as the base for improving user friendliness. Sensors such as accelerometer come inbuilt within the device hardware. This can be used to monitor the device movement and interact more closely with the user.

1.1 Statement of Problem

The user experience required for a visually impaired person is different from that desired by a sighted person [3]. In this case, applications or devices are specifically built to support this community. Scene describing applications are an increasing trend nowadays along with the advancement of mobile features. Most existing scene describing applications that are built for this community can take a picture of a scene and speak out the picture in words [4], [5]. However the user has to initiate the task of taking the picture using the mobile application. This causes a delay from the time the user takes to find the application to the time the user initiates the task of taking a picture. This is noticeable as unlike a sighted user, a visually impaired user will be slower in pace [6].

1.2 Scope

This solution is a smart awareness mobile application that is for the visually impaired users. This solution is an IPhone based application that will work using the sensors in the mobile phone. In addition to that the application will be built using the latest frameworks and technologies currently available. The solution will work as a guided app, for helping this community of users to be aware of the scene around them at any given time.

2. Literature Review

2.1 Awareness of the Visually Impaired People

The modern technology is delivering assistance to the lives of the people. Mainly the technology is used for the development of the human abilities. Machines are making human life easier and it can be seen today that technology has made impact on every aspect of the human lives [7]. Every person has various technological devices and they improve their communication capabilities through the use of such devices. Mainly the smart phones and smart technological assistive devices are playing a major role in the development of the human capabilities in the day to day lives [8].

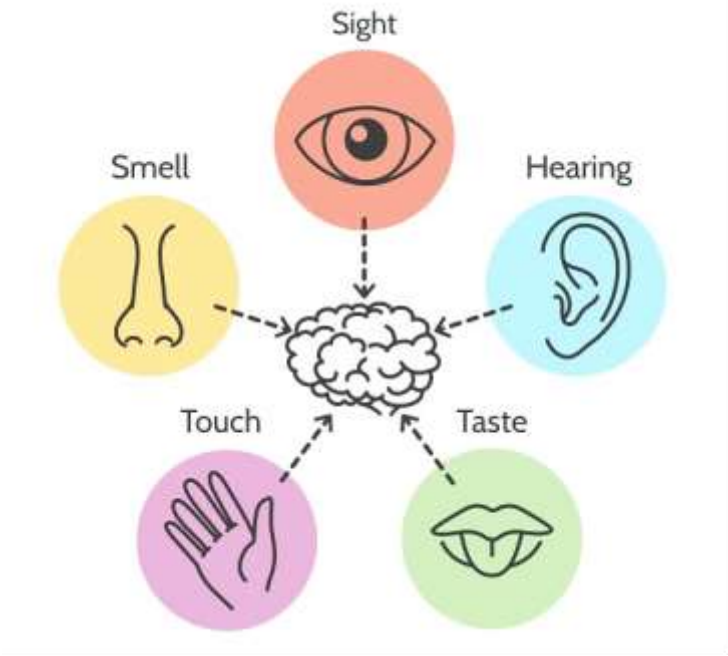

Figure 1 : The Five Senses of Human Beings

Most of the technological devices are aligned to the needs of the people who have all their senses functioning properly. However not all the people have the same level of capabilities [7]. Some people have various disabilities and those disabilities are challenging to the people when conducting their day to day functions effectively. The eyesight can be named as one of the most important senses of the human body and with the eyesight people are improving their awareness of the surroundings. When the eyesight is lost, it would challenge the daily routine of the person [9]. Many technologies are trying to address such disabilities of the people and the technology has succeeded up to a certain standard, to ensure positive benefits for the disabled people.

Hearing, motor skills, visual improvement, and various other challenging areas for the disabled people have effectively been addressed through the new technological developments. However when it comes to the visually impaired people, this challenge opens up more challenges in their daily life, since they partially or do not see their surroundings properly. Higher level of information is transferred to the brain through eyesight [10]. With the eyesight or seeing the world the people learn and experience many things in their lives. From the entertainment to new things that can be done, people see and learn with the eyesight. However it is a known fact that several people do not have the luxury of eyesight. But the technologies are constantly trying new methods to deliver the assistance to the people who have various visual problems regularly [11]. .

When a person is navigating in the environment, the brain needs a higher level of information to be addressed to identify a proper level of awareness in the surroundings. Based on the information received through the sensory organs, the person would take various decisions to ensure the positive level of navigation in the environment [12]. Hearing and eyesight play a major role in this regard and it can be seen those sensory information creates balance of the person. However when a person loses the eyesight that person would be more oriented to use other sensory organs to take various decisions during the navigating in the space.

The visually impaired person would make decisions through various brain strategies. Since the eyesight of the person is damaged, that would allow the person to improve the other sensors, including hearing, touch, feelings of vibrations and temperature to make their decisions regarding movement [13]. The visually impaired person would remember a lot of information about the surroundings when compared to a normal person.

Many studies have showed that the visually impaired are more talented at defining objects and names of the objects through touch compared to the normal people who have better eyesight. Mainly the visually impaired focus on the unique information or characteristics identification of the objects and also remember these well to identify the objects when it is required [14]. Not limited to that the visually impaired remember sounds and smells in much improved manner when comparing to a normal person [12]. The ears and other sensory inputs help these people gather a clear idea about the surroundings and define their mobility methods or movement strategies accordingly.

When addressing the needs of the visually impaired it is essential to identify the strengths and weaknesses of the person effectively. The visually impaired have limited level of strengths when it comes to the visual identification and therefore they should be guided with tactile methods to identify the surroundings effectively [13]. The visually impaired should be given the opportunity to assess the information through other sensors of the body. The modern technology can deliver better solutions to the visually impaired to address these considerations effectively and efficiently [11].

2.2 Emergence of Assistive Technology to facilitate 'Surrounding Awareness'

Many studies found that a visually impaired person would identify the different behaviors of a person through hearing the sound of breath of a person. When people are communicating with each other various gestures show the thinking pattern of the person, breathing patterns can be named as one of them. Blind people use their own experience with the breathing patterns of the people and identify the mood of the person in front of him [14]. The brain of a blind person is using its abilities to cope with the needs of hearing improvements to ensure the delivery of better awareness of the surroundings to the person.

The assistance through hearing can be named as the natural way of guiding a visually impaired person to achieve the expectations of movement [7]. It can be seen that the assistive technologies are supporting the visually impaired people by delivering proper level of guidance through the hearing. However when it comes to the delivery of assistive technologies to the people who need aid, it is essential that the technology has the abilities of decision making effectively. When considering the earlier ages of the technological development, the decision making abilities of the computers were in lower standards and the computers can only make the decisions based on the given commands [16].

However with the development and improvement of the new technology, it can be seen that the computers are advanced with the abilities of decision making [10]. Artificial Intelligence is an improving technology in the world and it can be seen that many parties are using the AI methods to improve the functionalities and capabilities of the particular subject area. With the big data applications, cloud computing technologies and advanced algorithm implementations the AI has improved immensely during the last few years. The decisions can be taken effectively and

efficiently with the AI methods and it can be seen that the people favour the various outcomes of the AI technologies [15].

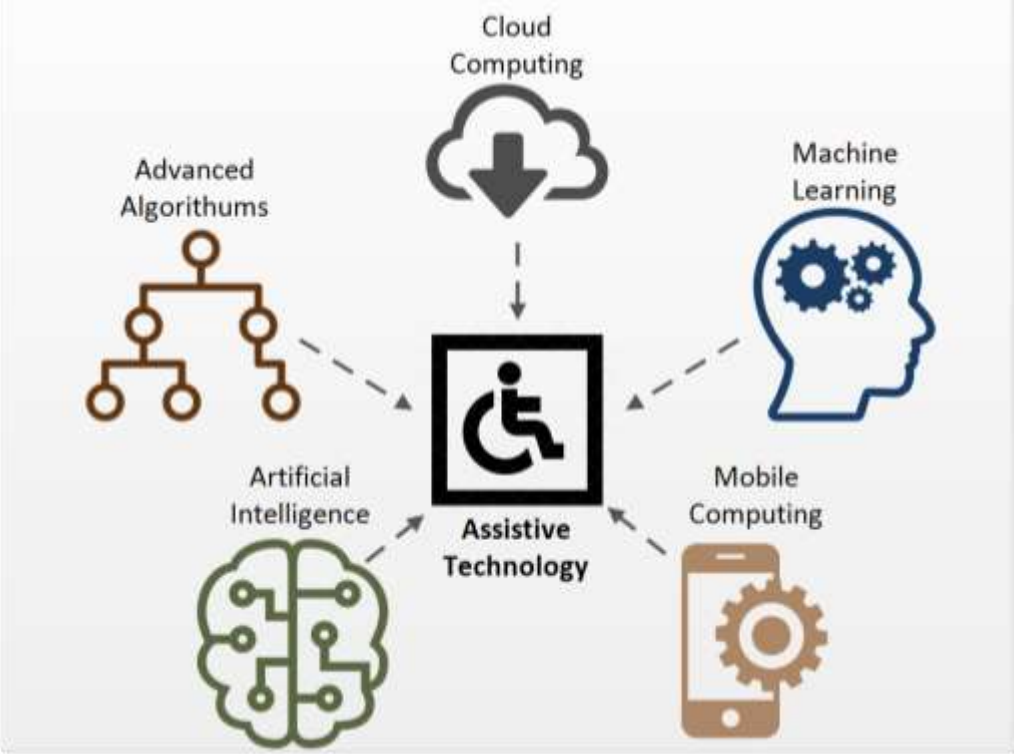

Figure 2 : Assistive Technologies

The discussed computer science technology areas have mainly delivered the positive level of support to the study of assistive technology. However it can be seen there are various other methods and technologies in the environment which are supportive to helping the visually impaired people. Mainly these methods came to the market under the categories of vision enhancement, vision substitution, and vision replacement. However when considering these categories it can be seen that the technologies are mainly focusing on the development of devices for the vision enhancement and vision substitution. The vision replacement category is strongly coupled with the medical and biological considerations of the subject scope [16]. The digital devices and machines would deliver the replacement of the vision and mainly it is focused on the delivery of vision to the visually impaired person. However the categories of vision enhancement and vision substitution would allow better flexibility to the assistive technologies of the visually impaired people. It can be seen there are several assistive devices which are developed under these considered categories. These devices have specific features and capabilities for which such methods are utilized.

Electronic travel aids or commonly known as ETAs are the devices that gather information of the surrounding environments and transfer the gathered information to the user in understandable manner focusing on the other sensors [17]. Such devices are using the sensors, sonar, cameras or laser scanner to identify the objects of the surroundings. Such methods would try to create a better picture to the visually impaired person and that is supportive to the visually impaired person when doing the regular tasks. However these devices should consider more on the improvement of transforming more information to the person effectively to ensure the positive assistance. These devices determine the surrounding obstacles of the person and also deliver a clear description of the surroundings. The instructions given by the devices would deliver the information to conduct the movements of the person and define time gaps to ensure the safety of the visually impaired person. Speaking out the distance to the visually impaired person is very supportive and it allows the user to take necessary decisions during the movement. These descriptive outcomes of the devices help create a better mental picture to the user and using the mental map the person can make decisions similar to a normal person [17].

Electronic orientation aids or EOAs delivers the similar level of assistance to the visually impaired people as well [13]. Mainly the EOA focuses on the delivery of routing descriptions to the user. The user would be able to get a clear idea of the unfamiliar places with the use of such devices. The device is delivering the necessary information to the user to trace the path to ensure the calculation of the location of the user. The user would be able to get the clear level of idea of the place with the route descriptions with the devices. Position locator devices or PLDs deliver the support to the blind people. Mainly these devices would use the GPS technologies and that is supportive to the visually impaired person [11]. With the GPS location identification, the technology allows the digital smart solutions providers to deliver the better guidance or assistance to the visually impaired people.

Smart Cane is one of the modern assistive tool for the visually impaired people. The Smart Cane is designed using various sensory technologies [11]. Mainly the tool uses, vibrators, buzzers, ultrasonic sensors, water detectors and microcontrollers to identify the surroundings of the visually impaired person. The servo motors of the device identify the obstacles ahead of the tool and deliver better picture about the surroundings to the person thus improving the awareness [8]. The voice and hand vibrators deliver the better alerts to the visually impaired person to guide his

actions effectively. The Smart Cane is a portable and easy carry device and the durability of the device is high as well [16]. This product delivers better support to the visually impaired people when compared to the traditional canes of the visually impaired people [11].

Haptic shoe is another invention in the assistive technologies for the visually impaired people and the shoe is transmitting the GPS signals to identify the various obstacles in the surroundings of the person. [18] The visually impaired person can wear the haptic shoe and walk freely with the proper level of identification of the surrounding objects. However it can be seen that some blind people use the cane with the haptic shoe because the other people would not be able to recognize the person as visually impaired since the haptic shoe looks similar to a general shoe. [18]

Similarly the navigation bracelet allows the blind people to wear the bracelet and get a proper level of idea about the surroundings of the person. There is a proximity sensor in the bracelet and it allows the person to identify the surroundings and deliver necessary alerts to the person when getting closer to the objects.

As discussed there are many assistive technologies for the blind people which are developed using the modern technology effectively. And most of the inventions are using sensors, cameras and tactile media to inform the blind person about the surroundings and various obstacles in the pathway. This enables the person to conduct his day to day life effectively and efficiently without seeking the help from the people [10]. The assistive technologies deliver a better level of support to the person to improve the independence on the day to day activities. Not limited to that the methods are using improved technologies, this delivers a clear identification of the current place and surroundings to the blind person.

Mainly the surrounding awareness is improved through the methods and it can be seen that there are many potential development as well. People are using mobile devices most of the time and these mobile devices can be used for the improvement of the assistive technologies to the visually impaired people. The improving processing power of the mobile devices would allow the modern devices to improve the performance when processing information. Mainly the AI technologies can be effectively used for the execution of algorithms and various decision making activities of the devices.

2.3 The Era of Mobile Computing

The mobile computing has gained a higher level of popularity in the world. The computers have improved their functionalities and capabilities during the last century. Mainly the Third and Fourth generations of the computer technologies had created considerable changes in the human lives. [17] The fifth generation is focusing on the improvement of the AI methods and creative abilities of the computer. The fifth generation of the computer development is mainly improved after the year of 2010. After 2010 it could be seen a higher level of demand for the mobility improvement of the computers.

The users expect to have the devices which are portable and can be used in anywhere when it is required. As the devices get a higher level of portability that has improved the interaction with the computers. Laptops have improved the portability of the computers. Currently tablets and PCs have further improved the portability and flexibility of the computers.

The mobile phone is identified as a popular handheld device which delivered effective support to the people to improve their communication. Mainly people used the mobile phone for SMS and voice calls, in other words for their communication needs and since the mobile phones are handheld and portable; the popularity of the devices has grown with the time. Companies have identified the effectiveness of the mobile phone as a communication device and various value additions were added to the phones to achieve better market acceptances and competitive advantages to the phones. Nokia, Motorola, Sony and Ericson had played major role in the improvement of the features of the mobile phones and later their efforts had allowed the mobile phones to grow as a smart device. [14]

Later on Samsung and Apple approached to the mobile phone industry and allow the phones to develop with highly improved modern technologies. Various abilities and features are improved in the value of the mobile devices. Mainly the camera features, operating system features and other quality improvements are happened to the mobile industry. Mainly the competition between Apple and Samsung allow the organisations to identify and find various new technologies for the improvement of the mobile devices [19].

The era of mobile computing has improved its features mainly due to the competition of the mobile phone brands. The customers have a higher level of demand for the new features and also the customer switch for better products in the market easily. The market development has ensured with the feature improvement of the mobile devices.

The new era of mobile computing has developed as it was specified during the time. However with the development of the mobile computing it can be seen there are major changes are happening in the society. The living standards and the technology usage of the people have gone high in much considerable manner. The paradigm shifting is happened due to the development of the technology.

Each and every day the mobile computing is making a new step in the technological development [11]. Not limited to that smart mobile devices allow the computer engineers to develop new software applications to ease the lives of the people. Not limited to that the standards for mobile application development is improving to ensure the quality product delivery to the customers as well [11].

Since the mobile computing is improving its popularity and the demand of mobile devices is increasing. Mainly it can be seen many visually impaired people are using smart mobile devices to achieve better level of flexibility. The mobile computing allows the visually impaired people to use location based assistive technologies. In addition to that the mobile assistive technologies are improving the capabilities of the visually impaired and older people.

Apple Inc. introduced Siri application to deliver better voice assistance to the people. It can be seen that most of the users get the idea or benefit of talking with the phones and organise the day to day functions effectively. With the voice commands the smart phone users have the ability to improve the flexibility of using the phones. The users did not need to type the commands and it can be named as time taking effort to the people. However with the talking assistance of the smart mobile phone has become much handier to the people. The user gets the ability of using the phone whenever required, even when driving, having a meal or in a shower without having the need of using the person’s own hands for the phone.

This is supportive to the blind people as well. Today most of the smart mobile phones can be setup to use for the people who have various disabilities. Mainly the voice assistant applications are supportive to the blind people and they can use the phone without having any challenges. It can be seen there is a higher level of orientation to use the mobile computing to improve the abilities of the disable people. Since the mobile computing has higher level of portability and mobility the people can achieve a higher level of use out of the smart mobile phones.

2.4 Existing Mobile Applications that facilitate 'Surrounding Awareness' for the Visually Impaired

As it was mentioned the smart phone devices have higher level of abilities of running various applications. Mainly the smart phones have a higher level of processing capacity and run the real time assistive applications. This supports the blind or visually impaired people to identify various surroundings effectively. Most of the mobile applications are using voice assistance to assist the visually impaired or blind people about the surroundings.

As it can be seen mobile phones have their inbuilt hardware and software that provide assistance. Out of these the camera, GPS and various other sensors are used to identify the objects of the surroundings and allow the user to identify surroundings accordingly as well. It can be seen that some applications are proprietary applications. Other applications are not platform oriented and allow its features to effectively use in any mobile device. Latest smart phone devices also have a special set of accessibility features that are built into the mobile software making it easier to support visually handicapped people. Text to speech is one such feature where by using touch the device monitors whether any text has been tapped and speaks it out for the user to understand. These features differ in its technicality based on the mobile operating system e.g.: VoiceOver is built into IPhones while Talkback is built into Android phones. Google Now is also a useful tool, (somewhat similar to Siri in IPhones) that will use voice command to make calls, start timers, set reminders, etc. Also when sending a text message unlike for a normal person who can use the keypad to type the text, the microphone can be used to speak out the message which will be converted to text by the device.

However it can be seen that there is a massive level of development of the mobile applications for the blind and visually impaired people. The improving hardware features allow the developers to add and improve the features of the mobile applications. Mainly the camera quality of the mobile phones allows the clear identification of the surroundings and the related shapes [20].

Be My Eyes [21] can be named as one of the most creative application of the mobile application. This application allows the blind people to get help from other people real-time. However this application would not use much of advance devices to achieve the expectations and assistance to the blind people. The good will of the people would be used by the application and allow people to help the blind people real time. This is more like a video conferencing and the camera is supportive to deliver the video feeds to the helper. The helper will define the surroundings to the blind person and that is supportive to conduct the actions of the blind person.

However it can be seen many mobile applications are allowing the blind people to describe the surroundings. The efficiency of the surrounding scanning and identification of the user's needs, the quality and usability of the application can be improved. However the current applications have some challenges and usability gaps. The software developers are improving the features of these applications continuously and each iteration of the development would deliver much better and user friendly product to the users. The blind people would have a much better future with the development of these applications.

Envision enables people with visual impairment to live more independently. With Envision, visually impaired users can shop in supermarkets, use public transport, read menu cards in restaurants, recognise their friends, find their belongings and so much more, all on their own.

Envision Technologies has developed Envision AI application to help the blind or visually impaired people [5]. This application has the ability of reading text from any selected or focused surface effectively and efficiently. Not limited to that the application is very intelligent and it can identify the language of the text and read it correctly as well. Not limited to that Envision can describe the scenes as well. The Envision can be programmed to identify and recognise the faces of the people. Mainly the family members can be identified through the application and it is supportive to the development of the person. Also the application allows the blind person to integrate with the social media and other instant messaging communication applications as well. It improves the ability of the interacting with the social media of the blind people.

Lookout application can be downloaded from the Google Play app store and this application allows the blind people to interact with the surroundings as well [22]. It uses the camera of the smart phone or the Pixel device to recognise the surroundings effectively. The user should wear the device and the camera of the device should be away from the body. It allows the blind people to improve the surrounding awareness effectively. Mainly the application is improving its features during the time and it will effectively address the needs of the blind people during the time without having many challenges [7].

Another application that delivers a positive level of support to the blind and visually impaired people is Seeing AI that is developed by Microsoft [10]. Seeing AI uses the camera of the smart mobile phone to identify the surroundings. Mainly all the needs of the blind people are almost addressed by the application. The application is greatly comply with the Microsoft devices as well. Identification of currencies, various text on the various surfaces, and description of the surroundings would be explained by the application to deliver better surrounding awareness to the blind people [10].

Simplicity and ease of use are features that are need to be specifically addressed when designing for the visually impaired. TapTapSee is an application that can identify the surroundings in a photograph [23]. Considering its simplicity and ease of use, TapTapSee is an essential awareness application for any individual with vision loss. This application can quickly identify objects within an inside or outside environment and it can be installed without charge. Compared to Seeing AI it cannot read documents however this reduces the complexity providing a faster environment for the individual to interact with.

According to the assessment of the current technologies, it can be identified that the mobile phones are using the simplest ways to most complicated methods to deliver surrounding awareness to the blind or visually impaired people. Mainly the mobile computing technologies are using the scanning methods to identify the surroundings. The camera is playing a major role in the surrounding awareness improvement of the blind people. With the development of the camera technology, the smart mobile devices can deliver a better service to the blind people. Not limited to that the improvement of the processing powers of the mobile devices and upgrades to the operating systems would ensure the feature development of the application for the surrounding awareness improvement.

3. Problem Analysis

The proper tools and techniques need to be available to utilize the maximum brain power. Otherwise it will only hinder the momentum of any person. Applications built to improve awareness of the blind and visually impaired need to have a sophisticated software engineering technique. The main purpose would be providing maximum information to the senses that the person can use. In other words the application should use sound and touch senses. Smart devices that can detect touch are beneficial for the blind. But the fact is that a mobile device is just a flat device unlike braille readers that use touch to convey words to the person. Therefore the user cannot get information the device conveys unless it is communicated in a manner of sound or speech. However there are mobile applications that can articulate any text that is touched to speech thereby the person is aware of what is being done.

When moving deeper into the problem it would not be only text, there can be the surroundings around the person at any given moment. Preferably the user can take a photograph and the application should be intelligent to convert it to text such that a normal person understands. Machine learning models can facilitate this purpose. There are many trained models with the recognition ability of over 1000s items [1]. However there are several factors that need to be considered when improving a person's awareness of the surroundings. For example: specifically the time that the application takes to refresh the alertness of the person. Any user would need to find the button on the screen that can execute this action using voice-assistant. And this user has none other than the sense of sound to confirm it. In addition to that some applications communicate with a web based service to retrieve the description of the surrounding. This may include a minimum of two service calls. One service request to send the buffered image data and another service to retrieve the description derived by the machine learning model, this can cause a delay in the response based on network signals.

Finally the person will tap the button initiating the application to process the photograph and articulate it to the user. This would be the satisfaction point for the user. However when considering something like an item within the reach of the user it would be acceptable to tap on the device or a button. In a situation where the person is travelling, the person would need to regularly access the application to know what the surrounding looks like.

4. Methodology

Taking the above information into consideration this model is designed to supply the user with constant data of the surrounding scenery with the usage of mobile devices. Advanced technology has created mobile phones with the ability to identify movements using sensors [24]. Out of the many such sensors available the magnetometer and accelerometer are of application to this research.

1. Magnetometer: The magnetometer is a sensor that is used to give the right direction with respect to the north-south pole of earth by use of magnetism. Mobile devices have magnetometers that can identify device's orientation relative to Earth's magnetic field. [25]
2. Accelerometer: The accelerometer measures force in each of its axis. As mobile devices have 3 axis, the acceleration of the devices in the entire three axes are captured by the accelerometer. [25]

4.1 System Overview

Most existing mobile scene describing applications need to be controlled by the user. Therefore to reduce the complexity of usage from a blind or visually handicapped person's perspective the device inbuilt accessibility features of the mobile are being used. Out of these features one is that it makes the process easier by articulating a description of what is being tapped to the person. Hearing and touch are a set of important senses that a visually impaired person is more oriented to depend on. Moving beyond accessibility features this application can automatically monitor changes using sensors. Thereby reducing the user interaction with the mobile device and keeping the user aware of the surroundings.

The image below shows the different positions of the user relative to the Earth's magnetic field. Similarly the mobile device's orientation will change relative to Earth's magnetic field and these transformations will need to be monitored. As the user will be carrying the device in a fully oriented position that exposes the camera e.g.: In the pocket of a shirt. There is hardly any chance that the device orientation will change. Therefore sensors like gyroscope that retrieve any orientation changes of the device relative to the devices coordinate frame cannot fulfil this purpose.

However when using the magnetometer any changes in the device's position relative the Earth's magnetic field can be monitored. The new coordinates will serve as new positioning data. This event can be made use of to take a new surrounding update. A surrounding update is the procedure of capturing the scene using the camera and using image classification to process it to understandable text. As such the machine learning model used is a simple, lightweight model [26] that can operate on a smart phone, consequently avoiding communication with the internet. This lightweight and offline methodology provides access for the user to use the features in situations with less access to internet e.g.: when travelling to remote areas where unlike the urbanized areas there are poor network connections.

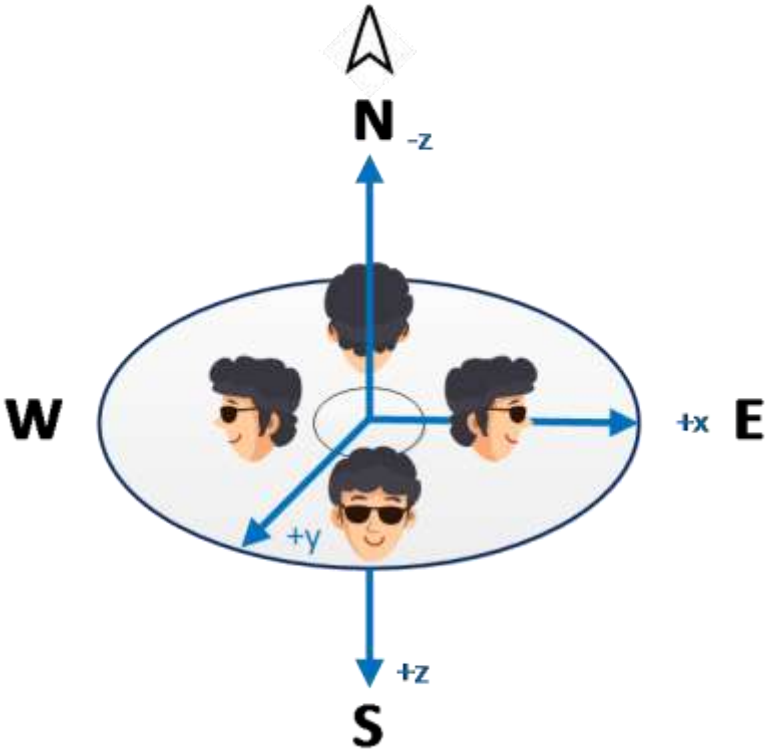

Figure 3 : Global positioning relative to the Earth's magnetic field

The accelerometer gives the linear acceleration of the mobile device on the three axes. In a case where the user is moving along with the device in the pocket the device can supply the acceleration of the user by means of the accelerometer. The usage of this method is to avoid indistinct photographs that will be taken when the user is in motion. This is accomplished by setting an upper limit of acceleration. In addition to that when requesting for an update manually the accelerometer readings are needed to detect hard-taps on the device.

4.1 Automatic Instructive Component

In the instance that the application is running, both the accelerometer and magnetometer will operate cooperatively. The change in magnetometer data denotes that this person changed the direction relative to the Earth's magnetic field. And the change in accelerometer data indicates movement in any axis of the device. Although it might seem like that accelerometer is sufficient to detect any movement that the blind or visually impaired person makes, acceleration can happen on any axis without changing the orientation of the device e.g.: the person can move front on a flat surface facing front. It does not change the orientation of the device therefore the surrounding may or may not change unless like a distinctive distance is moved or e.g.: door opens.

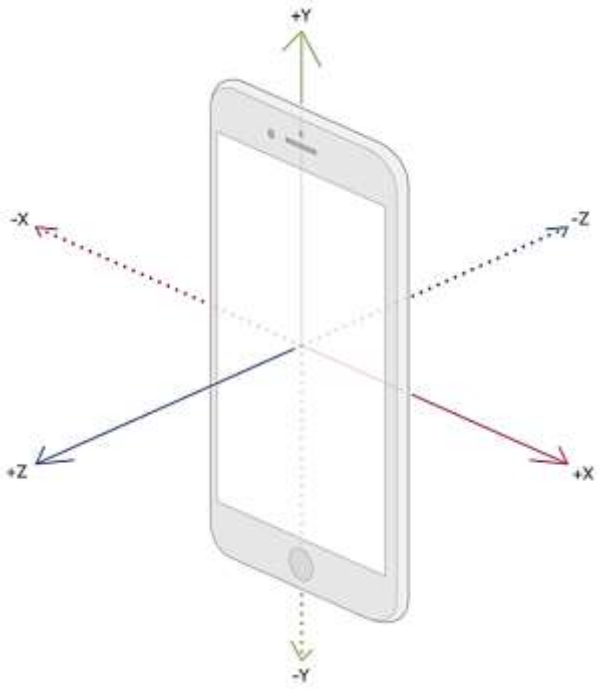

Figure 4 : Accelerometers measure changes in velocity along the x, y, and z axes[27]

Therefore the change in direction relative to the magnetic north will prompt to keep the user aware about the surrounding specifically in instances where the person strolls through a neighbourhood, crosses roads and turns at junctions. A forty-five degree change from the previous magnetic heading of the device and the current heading will prompt a new surrounding update. The values mentioned above will be the default values that are set. The user has the privilege to customize these figures to fit his/her pace of motion and awareness. Therefore a separate window with customizations will be available.

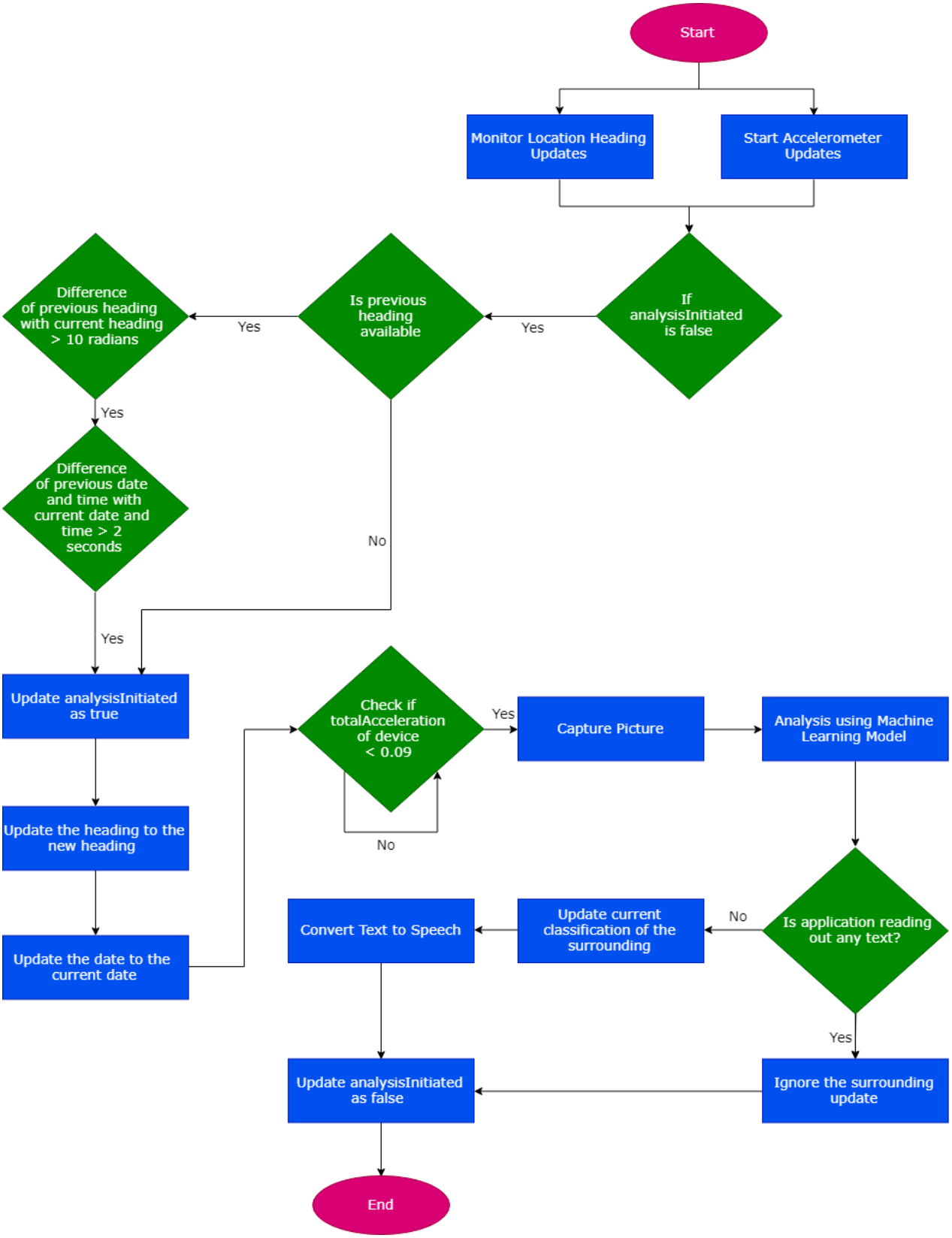

Figure 5 : Flowchart of the automatic mode

4.2 Manual Instructive Component

In a case where there is no “turning” taking place another option has to be pursued. As this would suggest the user is not moving, moving in one direction or has moved less than ten degrees. Therefore the user is given the privilege of requesting for an update when needed.

As the user would need to request an update, a separate manual instructive component that can be handled by a visually impaired is incorporated. In a case where only manual updates are needed when asked for one, the user can switch off the automatic instructive component. This manual instructive component can be handled by the use of detecting hard-taps on the device. The calculation for monitoring a hard tap is done by the means of a high pass filter for the accelerometer data retrieved via the sensor. The combined acceleration on the x, y and z axes are calculated and fluctuations from the previous recordings of acceleration on either axes are recorded. If any change in acceleration exceeds a sensitivity level it will be detected as a hard tap. The detection of a hard-tap triggers a timer of 54 seconds. The total number of hard-taps detected within a time of 54 seconds will be assessed. One hard-tap will trigger a new surrounding update. Any number of taps more than 1 will be utilized as a method to close the application. The number of taps is limited to a time interval of 54 seconds, which is started with the detection of the first hard-tap. In addition to that this component gives the user the benefit of exiting the application without interacting with the user interface. When more than one hard-tap are sensed the application exits. As the application will require to be running on foreground to access the camera, the application has the ability of avoiding the screen lock and thereby running in foreground. The user is given the freedom of controlling the application.

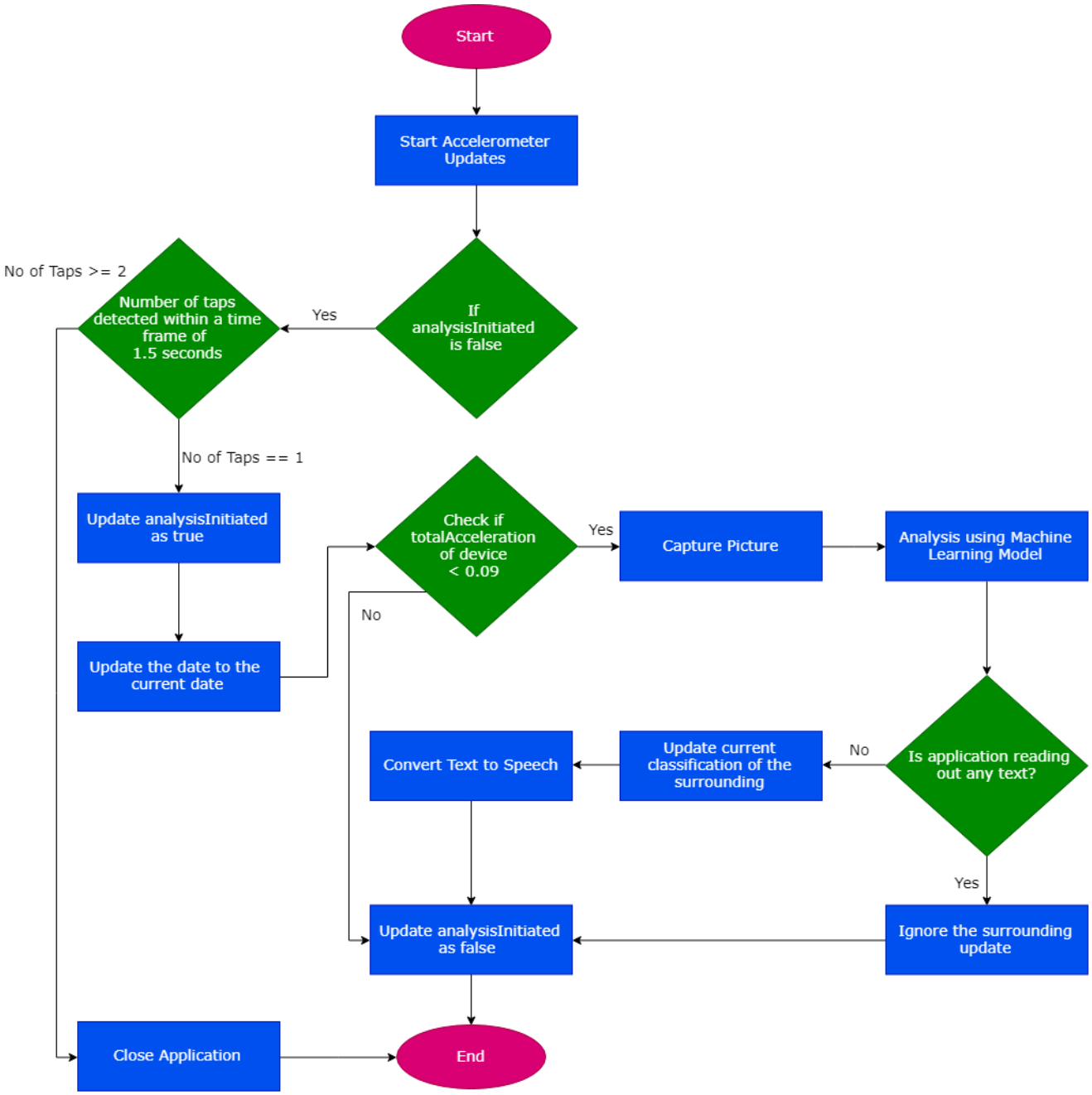

Figure 6 : Flowchart of the manual mode

4.3 Observational Study

However as the application speaks out the update, a new update may trigger based on the changes in the magnetometer readings of the device. Therefore a flag is maintained at the start of each update. This is to avoid the start of another surrounding update while one is on progress. However incidents may occur where an update is over and the flag is updated, but it has not been finished been spoken out by the device speaker. This can cause the update of a previous surrounding to be spoken out while the photo of the current surrounding is taken.

In a case such an incident occurs there are two options. Either the application can stop speaking the previous update and read the new update or modestly ignore the new update while continuing speaking out the previous update. However when considering the first option where the speaker is prompted to stop speaking, the user will find it confusing as to what the scene was concerning. As improving the awareness of the visually impaired hearing is the main factor that needs to be prioritized, therefore the second option is taken to consideration for this research.

5. Evaluation

6.1 Questionnaire Evaluation

This evaluation was based on the hypothesis that an application can be used to keep a person aware about the surrounding, it may not be the 100% accurate about the surrounding but it will notify the user that the surrounding has altered. This is achieved based on the user's actions such as when moving and turning at corners or bending down therefore the user needs to carry it with the front camera facing the person's front view.

This evaluation study followed an opinion and interview based approach. It was conducted by approaching a group of 10 visually impaired undergraduates who have experience of using smartphone applications for at least the last 2 years. An IPhone running the application was given to each user to carry in their front pocket with the back camera facing front. The users were required to use the applications for minimum 30 minutes and fill an online questionnaire. It contained 15 questions, out of which few were open-ended questions and remaining questions were relating to the ease of usability, user experience, satisfaction, efficiency, learning of how application works and to collect feedback of the users. Most questions were based on a Likert Scale. The participants needed to specify the extent to which the product is excelling, helpful etc. using a scale. In addition to that there were questions based on evaluating their overall experience and to get the participants overall idea of the application. Participants were also given the opportunity to suggest any improvements for the future development of the application. The questions that were included in the evaluation are given below.

Each user in the group was unique in their own way. Amongst the users existed several who were born partially blind, first sighted but had become partially blind at around the age of 12-15. Some had become completely blind around the age of 12-15. The difference in how managing with the general lifestyle of human nature is for each individual was evident.

No	Question
1	Any previous experience with background awareness mobile applications for the visually impaired? (MCQ)
2	Name some applications if you have used any (Text)
3	How would you compare this application to those applications? (MCQ)
4	Was it too complex to understand the way it works at first? (MCQ)
5	Is it disturbing when the application speaks out? (MCQ)
6	Would you prefer if the application responded when stationary or when moving or both? (MCQ)
7	Does the application respond as and when you want it to? (MCQ)
8	What is your opinion on the idea of the application reading the surrounding to you? (MCQ)
9	Are you satisfied the control you have over the application? (MCQ)
10	Are you satisfied the freedom you have over the application? (MCQ)
11	Are you satisfied with the feedback the application gives? (MCQ)
12	Are you satisfied with the response time of the application? (MCQ)
13	Do you have any recommendations for improvements of this application? (Text)
14	What is your impression of having an introduction of the application? (MCQ)
15	What is your overall Impression of the application? (MCQ)
16	What is your overall rating of the application? (MCQ)

Table 1 : Questions of the Evaluation Form

6.2 User Feedbacks

Almost all the visually impaired users acclaimed the idea of the application. A majority of them were aware of the concept behind it. Another acclaimed point that it is easy to use and hands-free. As it describes what it there in front of the person, no additional commands are needed like persistent tapping for a surrounding update.

Most importantly they valued getting to know what is in front before taking another step. Therefore they considered it equivalent to a navigation application including enhanced awareness. One question that all of them agreed on were that when the phone speaks out is not disturbing and every time a variation is made from the direction the phone is facing it needs to speak out, be it even a small variation.

The accuracy of the response was brought of the attention by several as it was not as accurate as expected when in an outside environment particularly, and that would mislead the user. Amongst some of the ideas proposed one was that if the response of the application was very accurate they might even consider moving without the white cane. As it seemed they thought that even their navigation can be assisted with a smart phone.

6.3 Results and Discussions

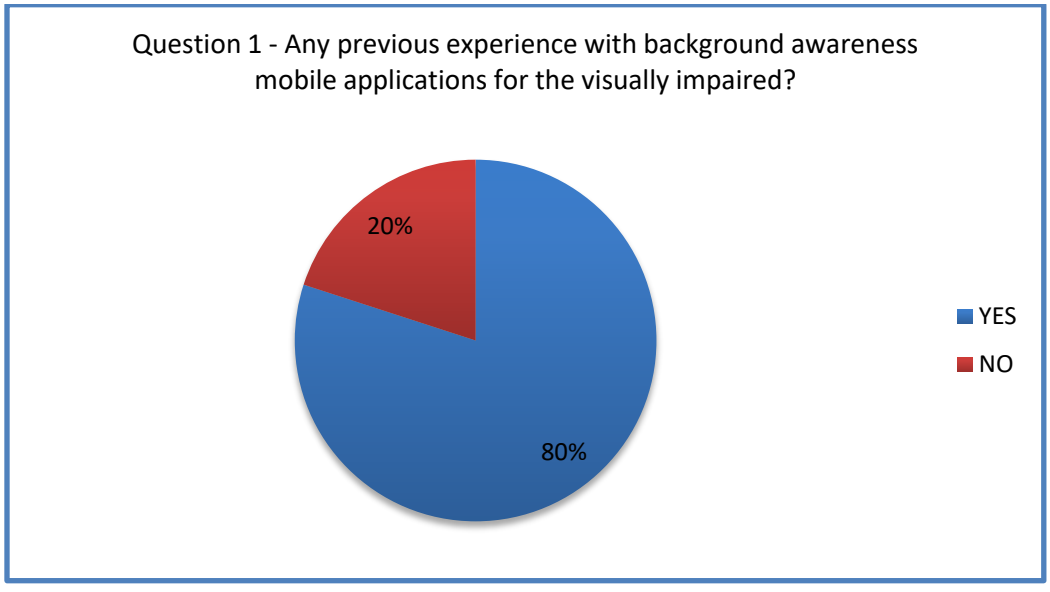

Figure 7 : Distribution on previous experience

Question 2 - Name some applications if you have used any?

Awareness applications TapTapSee [23] and Be My Eyes [21] were some of the applications the users were familiar with. Several mentioned that some applications needed the user to initiate the task of to taking a screen capture for a surrounding update and in addition to that it saves the photo taken. Therefore it takes up a lot of space when using the application. And when used continuously involuntarily it tends to stop working as it runs out of storage space.

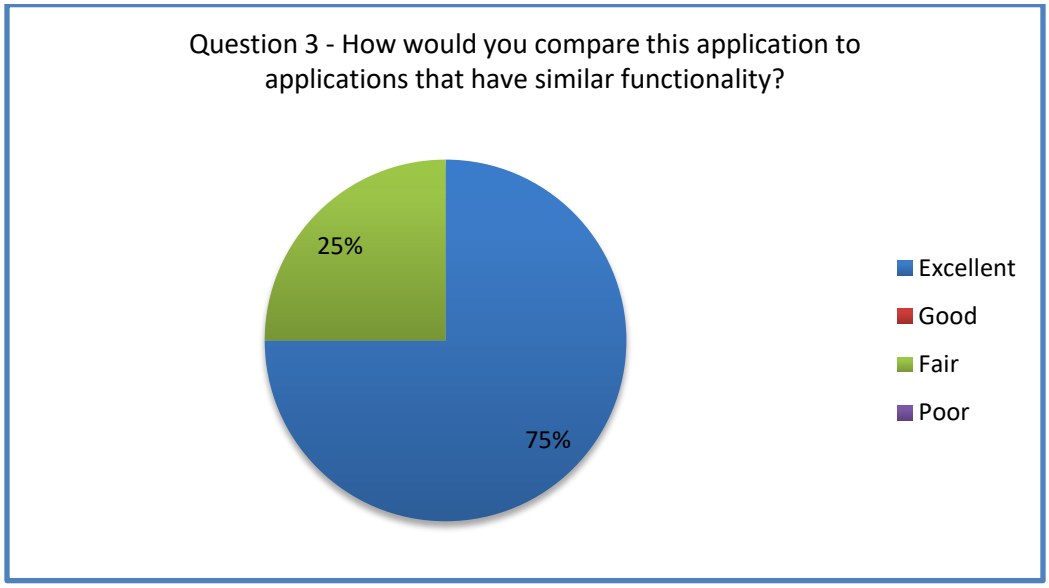

Figure 8 : Comparison with previously interacted similar applications

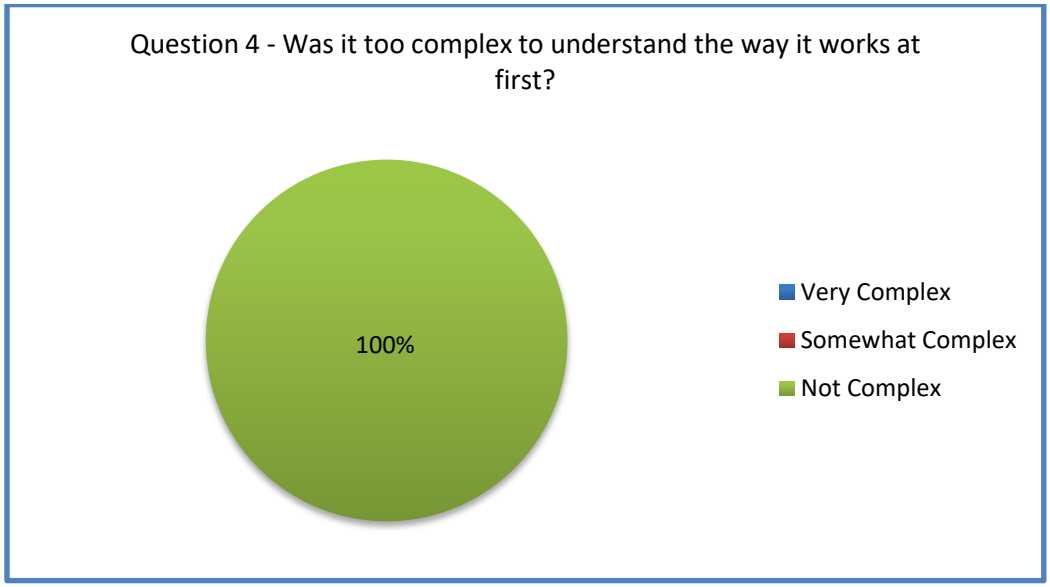

Figure 9 : Distribution on complexity with usage

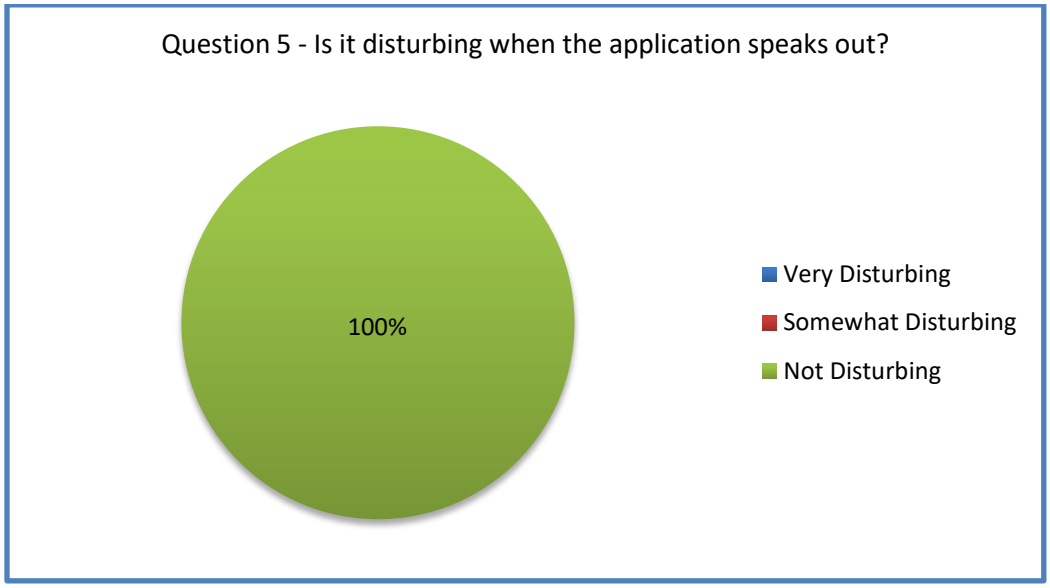

Figure 10 : Distribution on disturbance with usage

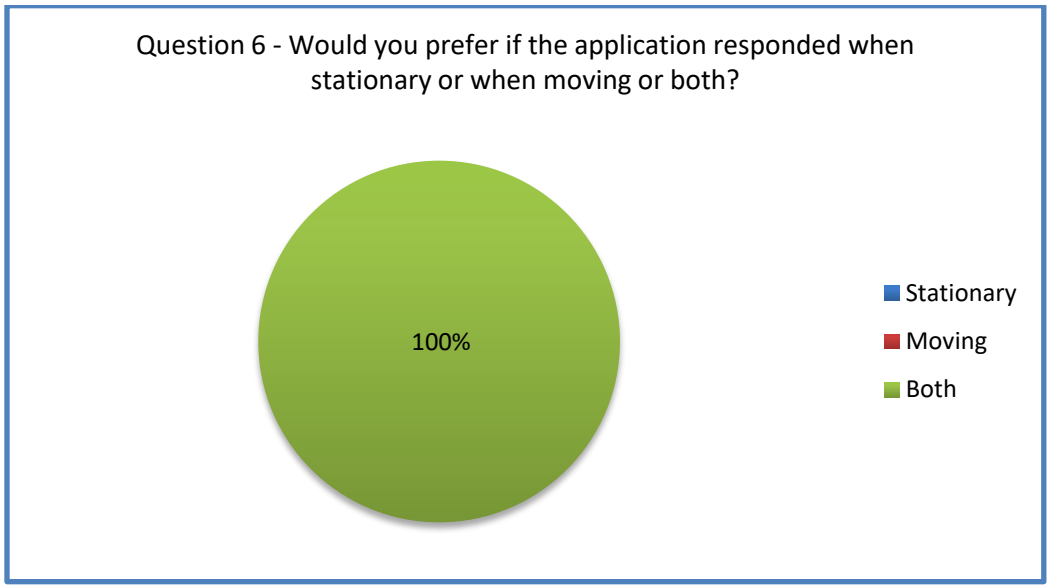

Figure 11 : Distribution on the preference for usage

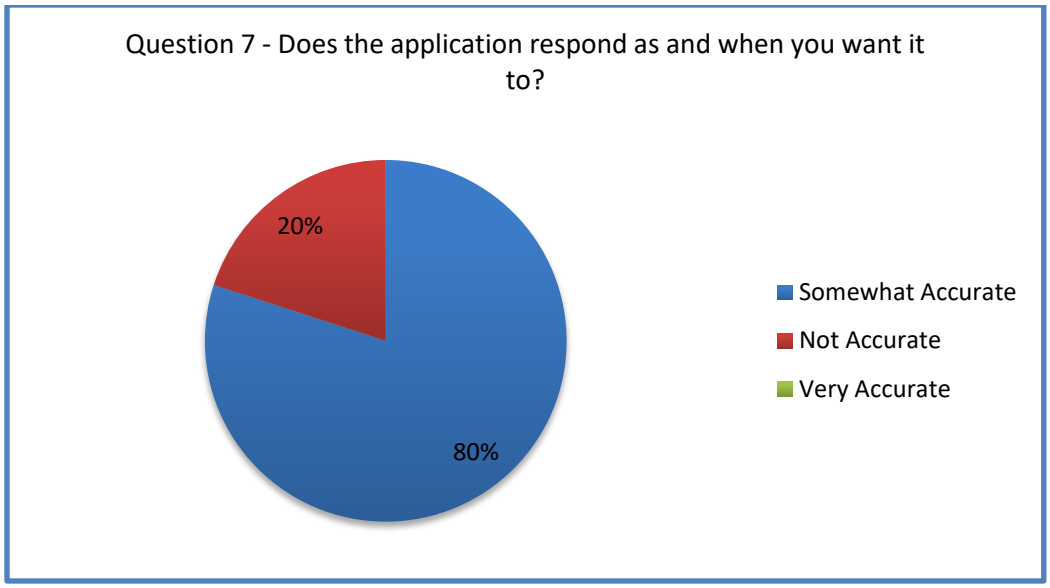

Figure 12 : Distribution on the accuracy of responsiveness

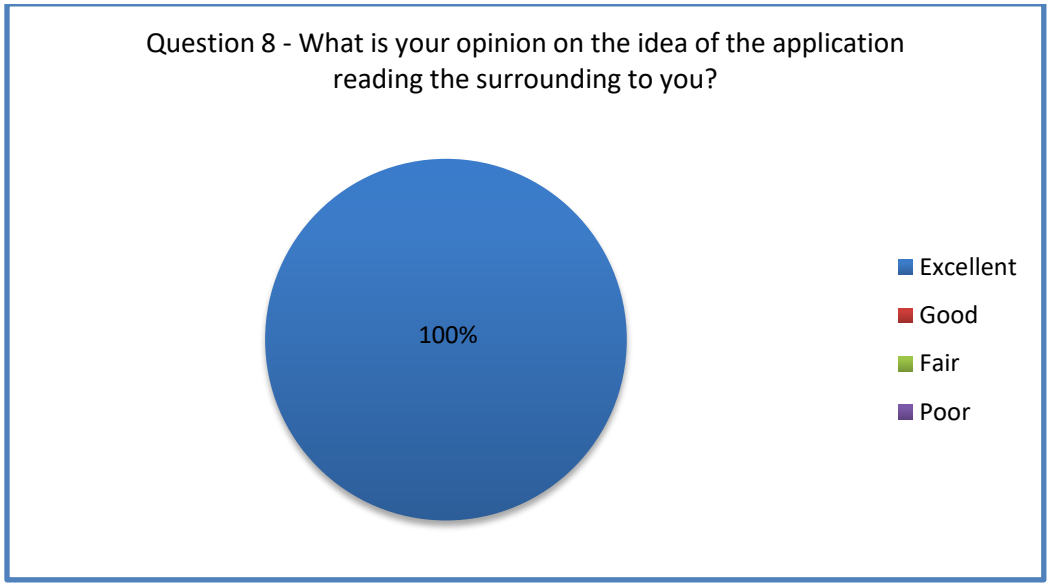

Figure 13 : Distribution on the idea of the application reading the surrounding

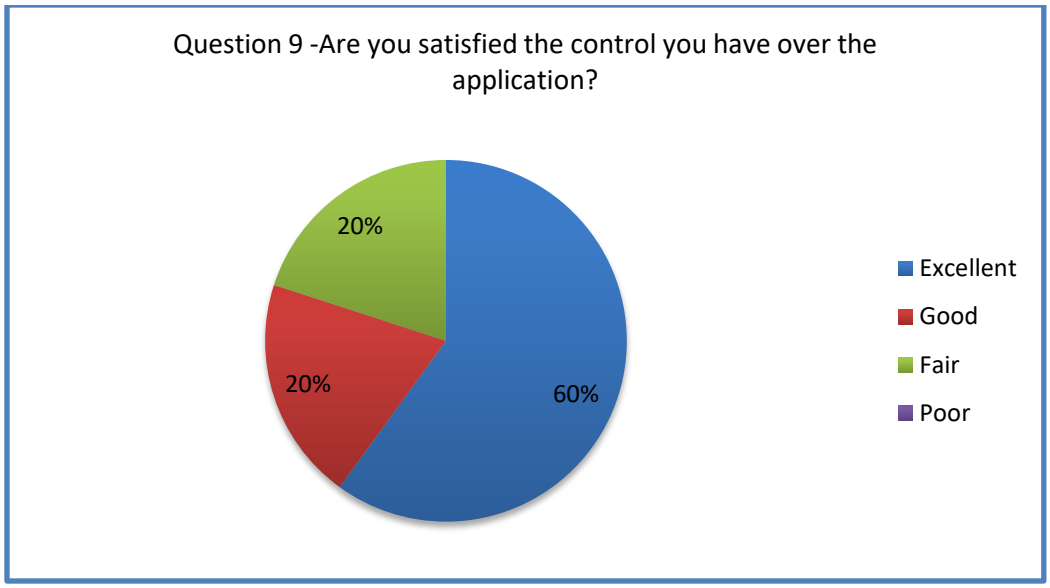

Figure 14 : Distribution on the satisfaction with the control available

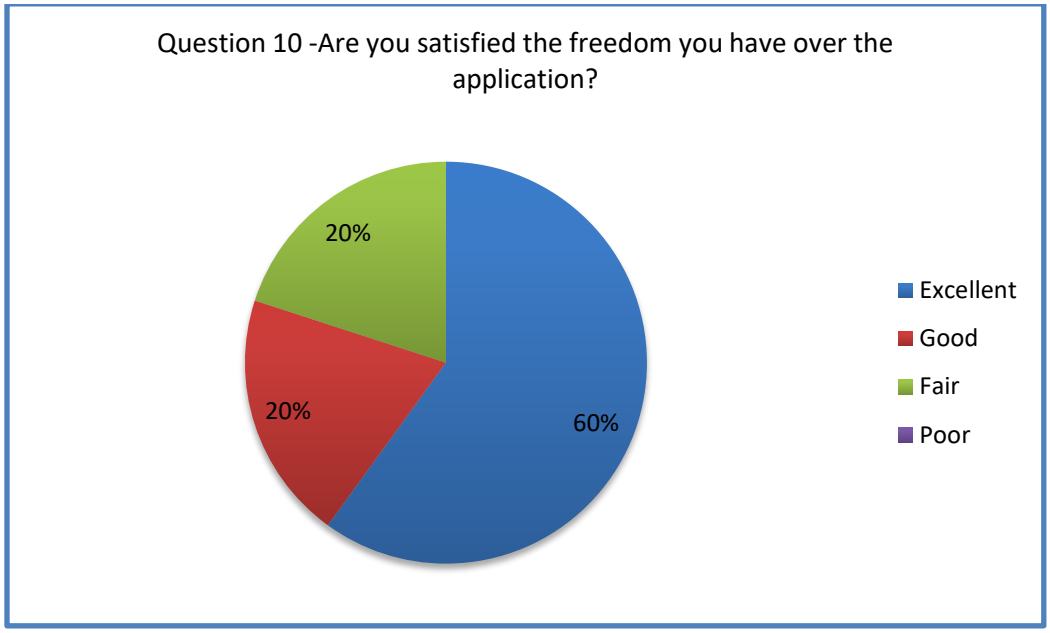

Figure 15 : Distribution on the satisfaction with the freedom available

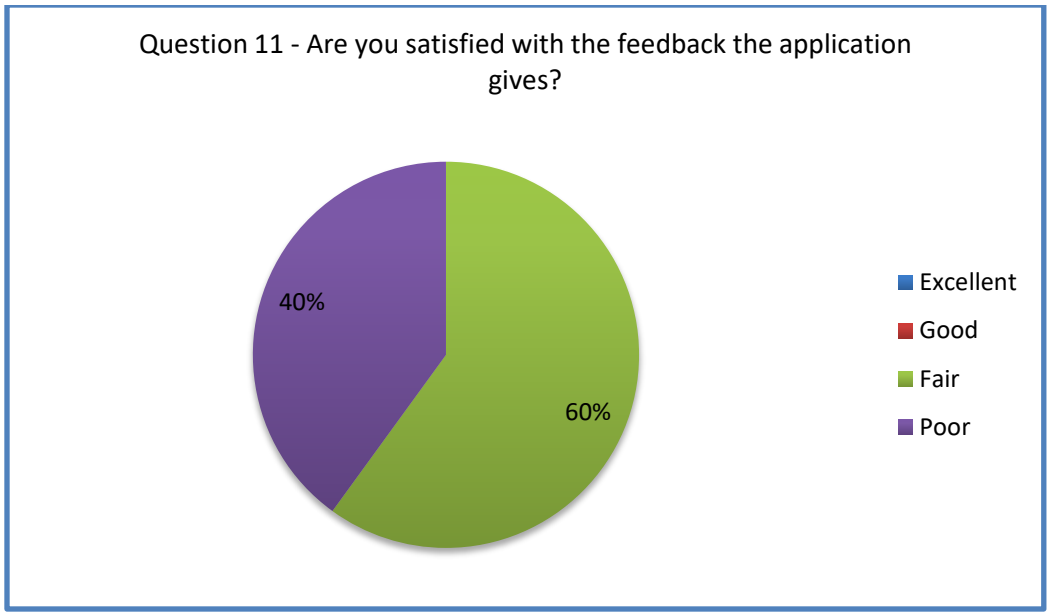

Figure 16 : Distribution on the satisfaction with the feedback given

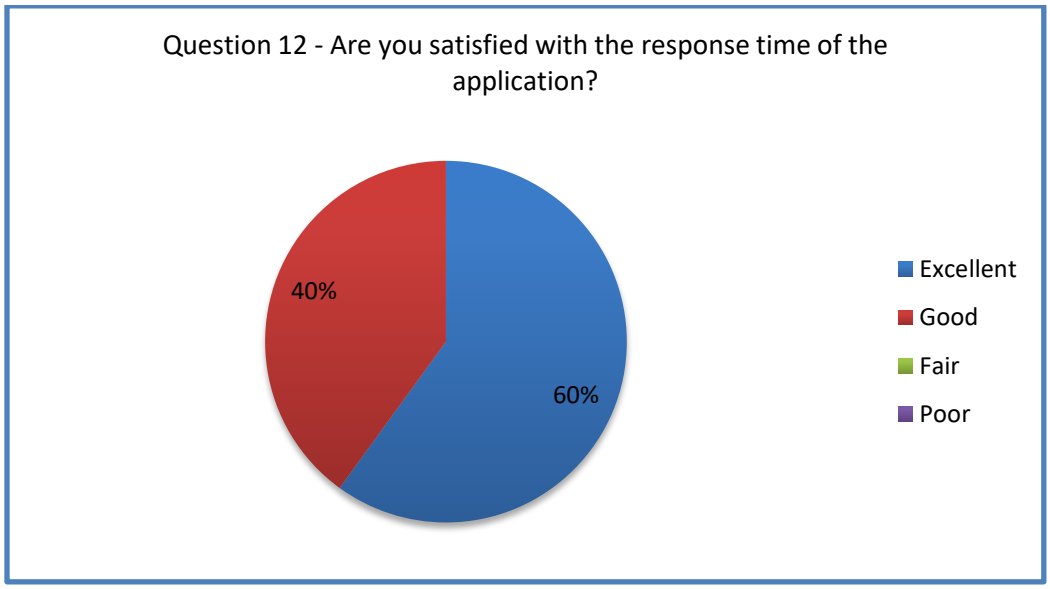

Figure 17 : Distribution on the satisfaction with the response time

Question 13 – Do you have any recommendations for improvements of this application?

One idea proposed as an enhancement to keeping the person aware was to give coordinates to how far/close the identified object is. And in addition to that for the person to drift away from it without colliding give a specific measurement to move e.g.: number of steps to the left etc. It would be similar to an obstacle avoidance behavior [15] that is implemented in robots, but for visually impaired humans.

With expanding communities of people from variety of backgrounds, each community has its own culture and ethnicities. Therefore the ability of the application to support any visually impaired regardless of the society that person may be familiar with would be an achievement. Supporting multiple languages such as e.g.: Sinhala, Tamil and supporting multiple mobile platforms were several such suggestions.

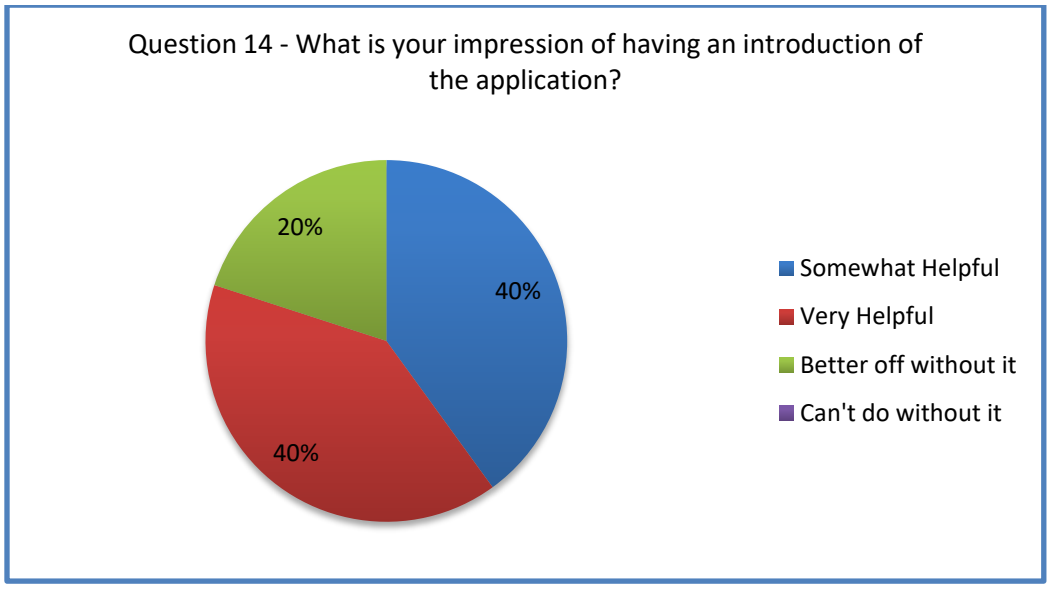

Figure 18 : Distribution on the impression of the introduction

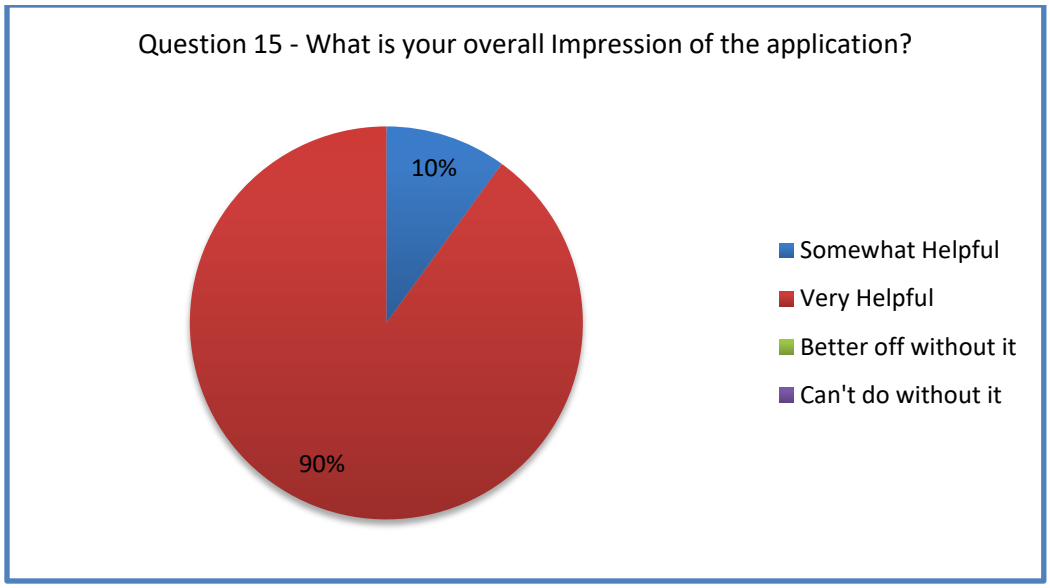

Figure 19 : Distribution on the overall Impression

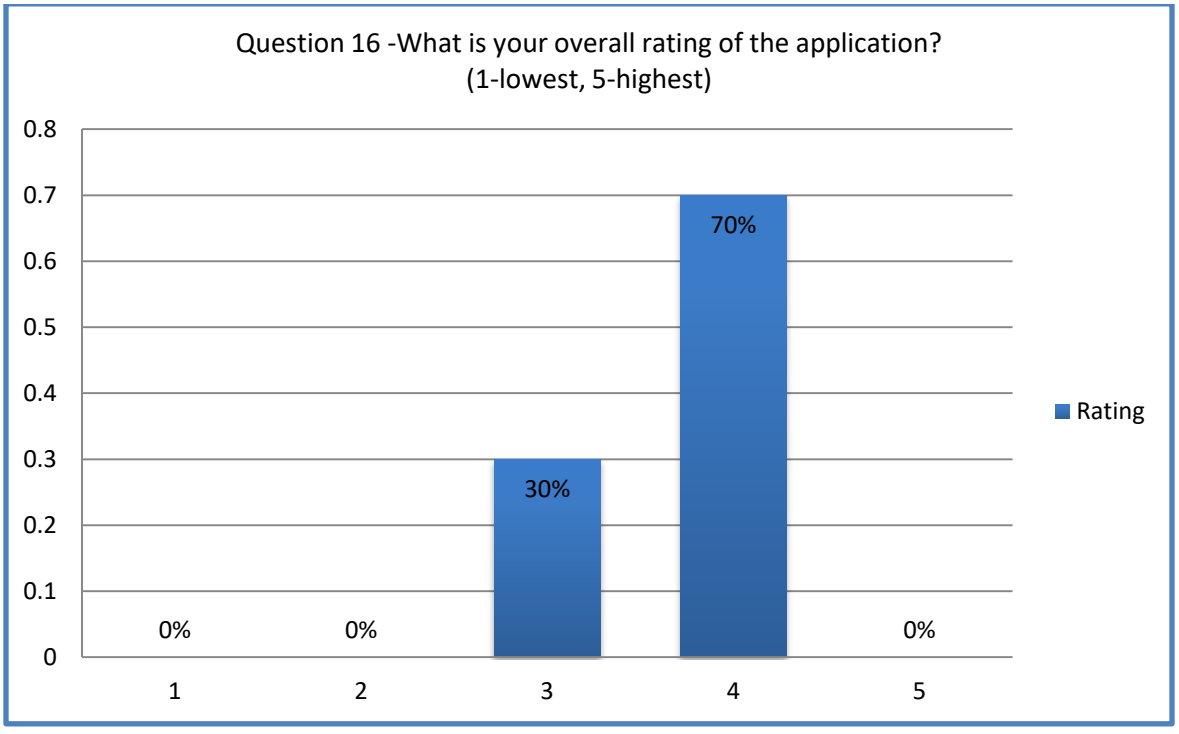

Figure 20 : Distribution on the overall rating

6.4 Conclusion and Recommendations

The main objective was to evaluate the success of improving a visually impaired person's awareness of the surrounding using the mobile phone. The mobile operating system provides accessibility features to minimize user interaction with the mobile phone. Also the mobile phone sensors track different movements of the user. These features provide can help minimize user interaction with the device while keeping the user aware of the surrounding.

Analysis of the survey data obtained show that 100% support the concept of reading text, 0% find it disturbing or complex. It is recommended to improve the efficiency of the machine learning model. In addition to that currently a difference of 10 degrees (which can be customized) should be exceeded for an automatic awareness update to trigger. However if the user is constantly on the move, multiple updates will occur. But the system will avoid queuing the updates as it will become expired after sometime. This causes the user to miss valuable information. This behavior is explained in detail in the Observational Study of the Methodology. Hence it is recommended to test into several techniques that can be applied to prove an enhanced behavior.

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