

Institutionen för datavetenskap  
Department of Computer and Information Science

Final thesis

**Development of a smartphone interface to support the  
visually impaired**

by

**Swetha Baburao**

LIU-IDA/LITH-EX-A--13/010--SE

2014-04-20



**Linköpings universitet**

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Supervisor: Magnus Ingmarsson

Examiner: Magnus Bång

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## Abstract

The World Health Organization (WHO) estimates that 2 billion people in the world will be aged 60 and over by the year 2050. Along with the aging process, there will be declination of sensory, physical and cognitive factors. Vision impairment is a worldwide problem faced by people of all ages. The usage of smartphones has escalated exponentially. Smartphones are now equipped with features like text to speech converters, speech interpreters, voice guided navigation, and intelligent assistants. Appropriately designed, these can be valuable tools for the visually impaired. However, despite the advanced accessibility implemented in the smartphones, the elderly still seems to prefer ordinary phones which have physical buttons. The aim of this thesis was twofold; (1) to identify factors hindering the elderly and their use of smartphones, and (2) to develop smartphone interfaces to improve accessibility.

Two Android applications were developed in this thesis. The Magnifier is a magnification tool for physical objects and text. EyesFree is a text to speech service that reads out the screen content to the user. The requirements for the apps were elicited by studying existing applications and also by interviewing potential users. EyesFree and Magnifier were evaluated using the think aloud protocol method and the results show that they are useful applications for the visually impaired.

The Android operating system provides a number of accessibility features and services to help the users with different abilities to navigate the device easily. Paradoxically, these features are quite difficult to use, for example, they are not easily launched and closed. The meta application and user interface of EyesFree exemplifies how users can access the internal features of the OS such as the speech services more effectively.

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## **Preface**

This report is the result of the master thesis project carried out in Human-Centered Systems (HCS) division of the Department of Computer and Information Science (IDA) at Linköping University, Linköping, Sweden.

HCS division's research aim is to make the interaction between individuals, computer systems and information resources easier. This master thesis aims the same – to design smartphone interfaces which are easier to interact for the old people with vision impairment.

Linköping, Sweden, April 2014

Swetha Baburao

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My beloved parents Baburao Shanubhog and Anuradha Shankar Narayan Shastry, my brother Raghavendra Baburao for giving me strength and moral support to complete my thesis work. Every milestone I have accomplished wouldn't be so special without them.

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Linköping, April 2014

Swetha Baburao

# 1. Introduction

The World Health Organization (WHO) estimates that 2 billion people in the world will be above 60 by the year 2050 [17]. Along with the aging process, there is often a decline of sensory, physical and cognitive abilities. The elderly often have difficulties using personal computers, smartphones and electronic gadgets. In most cases are these difficulties due to visual, hearing, mental and mobility impairment that arise in the old age. Moreover, common disabilities among the old people are blurred vision, hearing loss, and declining memory power. Older people are less exploratory of technology when compared to the younger generation. This demands some kind of assistive interface or assistive technology which will make the device usable for people with special needs [1].

The digital divide refers to the situation when some people have access and knowledge to IT and some people don't have access. The gap which is caused by the digital divide can partly be bridged by designing interfaces that are easier to use for people with different disabilities. A special class of interfaces are called *accessibility tools* and these interfaces don't change the software of the PC or mobile, instead they provide a scaled down and easy to use interface to the already existing software.

## 1.1 Goals of the thesis

The purpose of this thesis is to improve the usability of the Android smartphone interface for people with mild to moderate vision impairment. Moreover, the goal is to develop a smartphone interface to improve the usability of existing interfaces to meet the requirements of the visually impaired.

## 1.2 Scope and delimitation

The scope of this thesis is limited to designing and implementing a smartphone interface to support vision impairment. The intended user group is people aged 55 to 64 with a slight to moderate vision impairment and with partial temporary or partial permanent vision loss.

All smartphone platform operating systems cannot be catered for in this work. Therefore, the effort has focused on the Android platform solely. Moreover, the work will be restricted to people with mild and moderate visual impairment and, hence, the requirements of blind people or people with severe visual impairments are not considered in this thesis.

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## 2. Background

Aging is a natural process and so is the development of impairment as a result of aging. According to the Finnish Centre for Interdisciplinary Gerontology, is disability in the elderly a dynamic social phenomenon that relates to individual physiological, psychological and medical conditions as well as socio-economic position, cultural norms and environmental factors [13]. Impairment in medical terms means diminishing strength of a body organ or functionality. There are stages of impairments: slight, moderate, severe, profound and complete loss. The U.S Census Bureau has categorized the elderly population as young old (65-74), the old (74-84) and the oldest old (85+) [21]. According to Eurostat, the median age in Europe is considered to be 41 years. 15 – 64 years is considered to be the working population and 65 years and over are considered old. But there has been no categorization done on the older people. Something that goes unnoticed from the Eurostat is that in the 2010 statistics, the working population (15-64) accounted for 67% of the population and the older (65 and over) accounted for 17.4% of the population.

It is more likely for elderly people to develop slight or mild impairments between ages 55 to 65. By the age of 80 and above, the impairment can have increased significantly.. According to Statistics Sweden is many people between 55-64 are suffering from different disabilities as can be seen in Table 2-1 [24]:

Type	Percent of the population
<b>Motor disabilities</b>	
55-64 years	7.0
65-74 years	11.0
<b>Serious motor disabilities</b>	
55-64 years	3.2
65-74 years	5.5
<b>Impaired hearing</b>	
55-64 years	23.2
65-74 years	26.9
<b>Impaired vision</b>	
55-64 years	3.1
65-74 years	3.8

**Table 2-1** Disabilities, proportion of persons in percent by indicator, age in Sweden, 2010-2011 [24]

## 2.1 Vision Impairment

From the definition of vision impairment, we can understand that vision impairment is the reduction of vision that can range from anything from initial to profound vision loss. This type of vision impairment cannot be corrected with glasses or contact lenses. “Visual impairment represents a continuum, from very poor vision, to people who can see light but no shapes, to people who have no perception of light at all”. Various kinds of retinal degeneration lead to different kinds of vision problems which are summarized in Table 2.2:

Light or Glare sensitivity	Various eye diseases like macular degeneration, uveitis, ocular albinism (congenital disease in which eye lacks some pigment), conjunctivitis, meningitis, cataract can cause glare. People suffering from this are extremely sensitive to light as their eyes tend to cause glare.
Loss of Central vision	People suffering from this have a progressively degenerating nerve cells right at the center of retina. There will be a blind spot in the center of the vision. The peripheral vision is still retained even though not very clear, the peripheral region is still recognizable.
Loss of Peripheral vision /tunnel vision	People suffering from this retain clear central vision only. In some cases little patches of retinal activity on the periphery are preserved, making it possible to detect movement and objects that assist with one's orientation. This can be compared in trying to perceive what takes place in a room behind our back.
Night Blindness	People suffering from this see poorly at night. It takes time for their eyes to adjust when they move from a bright area to a dim one. They may also suffer from the loss of contrast.
Blurred vision	Blurred vision can affect one eye or both the eyes. People with this problem have a blurred vision where there are unable to perceive fine details. The causes for blurred vision are many like myopia, cataracts and so on.
Loss of Contrast	People suffering from this have an inability to differentiate shades and hues which are close in color.

**Table 2-2** Various vision impairment problems

Low vision could include light sensitivity, blurred vision, distorted vision, loss of contrast, peripheral vision loss, and loss of central vision, generalized gaze, and night blindness. Naturally, vision problems can also be caused by accidents or have hereditary factors. The scope of this thesis is to consider initial stages of vision impairment caused by aging processes.

Old-age impairments change the life of the people experiencing it. It can result in social isolation, reduced interests and hobbies. These problems also tend to affect the person psychologically. The life quality of the impaired old can be improved if they had easier means to communicate, travel, and carrying out regular activities. Professor Julienne Hanson, University College London, conducted a study on the housing support and needs for older visually impaired people. The study was conducted for 18 months on 400 older visually impaired people living in different parts of UK like Plymouth, Birmingham and London. The results showed that, half of the subjects could not reach their local amenities such as banks, hotels, public transport, and grocery stores easily. There was a need for some kind of personal guide. Most of them also had troubles accessing public transportation [9]. Many of the subjects needed some kind of additional arrangements in their apartments to make their daily life easier. These arrangements could be changes in the home lighting and moving furniture to the corners for the visually impaired. The visually impaired are capable of making cognitive maps of their physical environments [9]. Frequent and unnecessary furniture moves have to be avoided to help them carry out tasks easily through their cognitive maps.

---

## **2.2 Tools for the impaired old**

In this section, we quickly review some applications that have been developed to help the visually impaired. Firstly, we look at some general devices and then we look at designs for smart phones and pad-related devices.

### **2.2.1 Eye-Pro GS**

Eyegaze<sup>1</sup> technology was developed by LC Technologies and it helps the user control the cursor with eye movements. This system could be added for any Windows based computer or communication device. The system has a CAMERA that tracks eye ball movements by measuring the speed and focus of eye balls. Eye-Pro is suitable for old people whose mobility skills are impaired and those that find it difficult to operate the mouse. The usage of this system also requires initial calibration setup.

### **2.2.2 PlexTalk**

PlexTalk<sup>2</sup> Pocket book reader was designed and developed by Shinano Kenshi Co.,Ltd. PlexTalk is a phone sized Windows compatible device that uses text to voice conversion to read books. It can also play music, record speech and memos and access online radio through a Wi-Fi feature. This device is not expensive and be used by people who have visual impairment. The text to voice conversion facility will help the visually impaired as they are exempted from reading any text.

### **2.2.3 MAGic**

MAGic<sup>3</sup> Screen Magnification Software is a Windows application that allows the user to magnify the PC's screen 36 times the normal size. This application was developed by Freedom Scientific. MAGic with speech has the facility to even speak aloud the screen contents. MAGic also has large print keyboard which makes it easier for the visually impaired.

### **2.2.4 Proloquo2G**

Proloquo2G<sup>4</sup> an application developed by Assistive Ware and it provides 8000 tapable symbols which eases communication for old people who find it difficult to talk or pronounce words. . This symbol supported communication application provides voice to people who cannot speak. Sentences can be framed by tapping buttons with words or phrases and even symbols. Once the sentence is framed, the device will speak the sentence out. This application has been successful with people diagnosed with autism, Down syndrome, stroke, brain injuries, and cerebral palsy etcetera. This application is developed for iPhone, iPod touch and iPad.

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<sup>1</sup> [http://www.gokeytech.com/eyepro\\_gs.htm](http://www.gokeytech.com/eyepro_gs.htm)

<sup>2</sup> <http://www.plextalk.eu/se/>

<sup>3</sup> <http://www.freedomscientific.com/products/lv/magic-bl-product-page.asp>

<sup>4</sup> <http://www.assistiveware.com/product/proloquo2go>

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## 2.2.5 Internal features of Microsoft Windows

Microsoft Windows provides several internal accessibility tools that are pre-installed in the operating system. Some of its features are mentioned in the following text. Screen content magnifier: The user can hold the windows key and then press the '+' key to magnify any part of the screen. It has a screen narrator which reads out the screen content. It has an on-screen keyboard whose usefulness can be seen when the user types a few characters and the keyboard prompts the word. It has 3 to 4 high contrast schemes which can enable the visually impaired to get a better view. Speech recognition can also be used. The user can set up a microphone and speak into the microphone to give commands to the computer and even to dictate texts. Mouse can be made easier to use by choosing the color and size of the mouse pointer, by using the numerical keypad to move the mouse around the screen (NUMLOCK must be ON) and so on. While using numeric keypad to move the mouse around the screen, the user can activate another setting with which the user can use control key along to move the mouse pointer faster and shift key to move it slower. The user can turn on the toggle keys (NUMLOCK, CAPSLOCK SCROLL LOCK). The user will hear a tone every time the toggle keys are pressed.

## 2.2.6 Non Visual Desktop Access

Non Visual Desktop Access (NVDA<sup>5</sup>) is a free screen reader for Windows OS developed by NV Access. The user has the option to start the NVDA screen reader when Windows is booted (as a Windows start up program). This screen reader starts reading the items on the desktop as soon as Windows starts. The main feature is that the system reads out what is on the screen as the user moves the cursor. For example, if the user opens a document, the screen reader reads out the text as the user moves the cursor over the document. It can also be used to read www browser content. In this application it is possible to alter audio volume and the readout speed. A downside of this screen reader is that it is only compatible with the Windows OS. NVDA can freely be downloaded from the download section of NVDA website.

### 2.2.6.1 Positives of NVDA

NVDA is a screen reader that can read the content of the computer screen, document etc. It has an opening sound and an exit sound which lets the user know that the software has started and is exited respectively. It has several sub-categories under preferences like settings, voice settings, mouse settings, keyboard settings, synthesizer, braille settings, and document formatting and so on. It can be started as soon as Windows OS is loaded, the user will not find it a trouble to start it manually every time the system is started. It has more preferences when compared to Windows 7 inbuilt keyboard and mouse settings. It can be downloaded for free and the setup is very simple. It does not require internet while it is running. It can be carried in portable external memory as it occupies around 60MB of space only (size on disk = 54.8MB) and can be set up on any windows machine.

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<sup>5</sup> <http://www.nvda-project.org/>

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### 2.2.6.2 Negatives of NVDA

NVDA works only on Windows based machine. It takes a while for the user to get used to the synthetic voice from the screen reader. There is only one voice which reads out screen content in US English accent. No others accents are there to select from the voice option. Since NVDA is just a screen reader, there is no option for speech recognition which is available as built in feature in windows 7 OS.

### 2.2.7 SIRI (Speech Interpretation and Recognition Interface)

SIRI<sup>6</sup> is a personal assistant and application built for Apple's iOS. SIRI was an iOS application developed by Siri Inc. which was available on Apple's iStore. After an acquisition, Apple made it available in their operating system. SIRI is available on iPhone 4s and is an integral part of iOS 5 (equipped with A5 chip). With the help of SIRI the user can talk with the OS directly instead of typing. Hence, SIRI lets the user use his/her voice to send messages, e-mail, make phone calls and so on. SIRI can also provide feedback such as telling whether it could understand what the user meant or not. It can also look up information requested by the user. SIRI will get the keywords and search on Internet for relevant answers. Moreover, it can convert users' voice to text just by tapping the microphone icon. The application can understand and speak English, French, German and Japanese.

#### 2.2.7.1 Advantages

The best part of SIRI is that people can talk (giving commands, asking questions) to SIRI and get most of the work done like: finding the temperature of any place at any time, finding the nearest fuel station, add reminders by just telling SIRI to remind the user of anything on any date and time, make phone calls and send text messages, read text messages that are sent to the user, fix appointments, view places on map and ask directions and much more.

#### 2.2.7.2 Disadvantages

SIRI is device dependent. It is available for iPhone 4s and higher versions. User has to connect to internet to use SIRI. SIRI can perform well for people having US, UK, Australian English accents. But for any other accents, commands from users may not be interpreted as required. Overall SIRI has many advantages over disadvantages. Many of its features can be considered while developing prototypes.

### 2.2.8 Talkback/Soundback/Kickback for Android

Talkback<sup>7</sup>/Soundback<sup>8</sup>/Kickback<sup>9</sup> are open source screen readers for Android that can be downloaded from Android market. These applications get activated if the user explicitly turns on Accessibility in the settings menu. The main advantages of Talkback are that it can read out the screen content text as well as graphical controls and alerts of the mobile. A

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<sup>6</sup> <http://www.apple.com/ios/siri/>

<sup>7</sup> <https://play.google.com/store/apps/details?id=com.google.Android.marvin.talkback&hl=en>

<sup>8</sup> <https://play.google.com/store/apps/details?id=com.google.Android.marvin.soundback&hl=en>

<sup>9</sup> <https://play.google.com/store/apps/details?id=com.google.Android.marvin.kickback&hl=en>

disadvantage is that the quite tedious to use. Table 2-3 provides a comparison between Talkback and iPhone's Voiceover system.

<b>Properties of Screen reader</b>	<b>iOS (Voiceover)</b>	<b>Android (talkback)</b>
A click sound is heard as the user moves between menu items. Finger can be dragged anywhere around the screen.	Yes	No
Tap 3 fingers to hear the number of home screens and which one the user is on. Ex page 1 of 3	Yes	No
As new apps are added, additional home screens are created if needed.	Yes	No
Flick 3 fingers left or right to move between home screens	Yes	No
Flick to the right until the name of the app is heard. Next double tap anywhere on the screen to open it.	Yes	No
Will read out the content of app which is opened. Flicking to the right every now and then will read out more information on the app	Yes	No
Clicking on e-mail should tell the user the number of unread messages	Yes	No
After clicking the e-mail, double tapping anywhere on the screen should open the e-mail	Yes	No
Flick right to read to the subject of the messages and flick down to scroll down	Yes	No
Double tap anywhere to open the selected message.	Yes	No
Click on the object of the message and flick down with 2 fingers for the screen reader to read it. Tap 2 fingers to pause.	Yes	No
Across the bottom of screen, if there are additional mail options to reply, compose, forward, delete - flip right to hear these options	Yes	No
Once the option is selected double tap anywhere on the screen to execute the option. Ex - reply	Yes	No
Holding one thumb to select the letter by sliding the thumb across the touch keyboard and taping the other thumb anywhere to type the letter.	Yes	No

**Table 2-3 A comparison - iPhone's voiceover vs. Android's talkback**

---

## 3. Method

This section describes the workflow that constituted the developmental activity of the thesis. It also explains the methods used to carry out each of these processes. Figure 3.1 shows an overview of the stages starting with investigating existing systems and ending with evaluation.

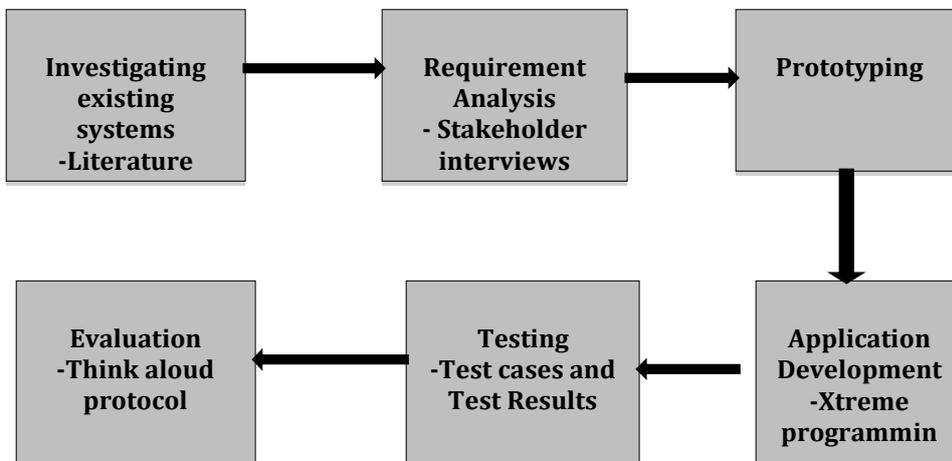


Figure 3-1 Work Flow representing tasks in sequential order.

### 3.1 Investigating existing systems

A literature study [1—9] on age-related disorders was performed with a special focus on vision impairment. Basically, all the devices and software reported in Section 2.2 developed for the visually impaired and blind have been investigated in depth. Subsequently, smart phone applications like SIRI and Talkback etc. were investigated in depth. The positives and negatives of existing system were analyzed.

### 3.2 Requirements analysis

To collect needs and requirements, 30 persons were interviewed [28] in total; 18 people between 55 and 65 years of age and 12 people between 24 and 34 years. From these interviews, a set of needs and expectations of smartphone support was extracted. The Requirement analysis phase was carried out as follows:

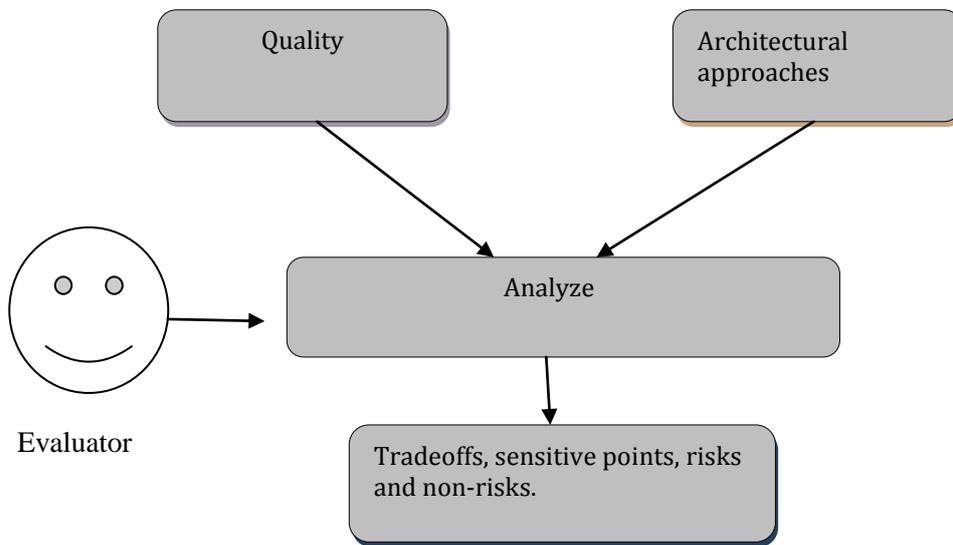
1. Identifying Key Stakeholders: Identifying the key people who will be affected by this project.
2. Capture Stakeholder requirements: By interviewing stakeholders and also by having joint interviews. It can also be done by building prototypes.
3. Categorizing requirements: Categorize the requirements as functional, operational, and technical.

- 
- **Functional:** The main requirements users ask for. These requirements describe how the application or product should function from the end-user perspective.
  - **Operational:** The requirements that are carried out in background to keep the application or product functioning over periods of time.
  - **Technical:** The requirements that define the technicalities like the version of software or the system. These requirements define the specifications of a product.
4. **Interpret or record requirements:** Once the requirements have been gathered, it has to be determined whether they are achievable or not. The requirements have to be prioritized. The impact of the change should be analyzed. Conflict issues have to be resolved.

### 3.3 Prototyping stage

In the initial phase of the prototyping stage, an iterative risk mitigation process called Architectural Tradeoff Analysis Method (ATAM) was employed [25]. ATAM helps making optimal design tradeoffs. ATAM was carried out in the following steps as seen in Figure 3.2:

1. **Collecting requirements and constraints** Since we already had collected our requirements, in this step all the constraints for implementing these requirements were noted down.
2. **Describe architectural views:** From the thesis perspective, the architecture was the OS and the interfaces on which smartphones were partially built. In this step, we were comparing competing architectures like iPhone's iOS version 4 and Google's Android version 4. Analysing distinctive features and reasoning different architectures were also done in this step. At this stage, architectures were just compared and no decision was taken when it comes to choosing among them.
3. **Attribute specific analysis:** Each quality attribute such as ease of navigation, ease at which the accessibility features are utilized and so on, of each architecture was analyzed in isolation in random order. This analysis was also leading to quantitative conclusions regarding each architecture.
4. **Identifying sensitive points:** an analysis was done to check as to how the design changes might affect the existing system and its performance. Sensitive points, in our case, were the smartphone features that may get significantly affected after a new design is taken into consideration.
5. **Identifying tradeoffs:** In this step, we found out the tradeoff points and choose what is feasible to implement. For example, we choose to improve the already existing features in Android OS version 4 rather than developing new ones.

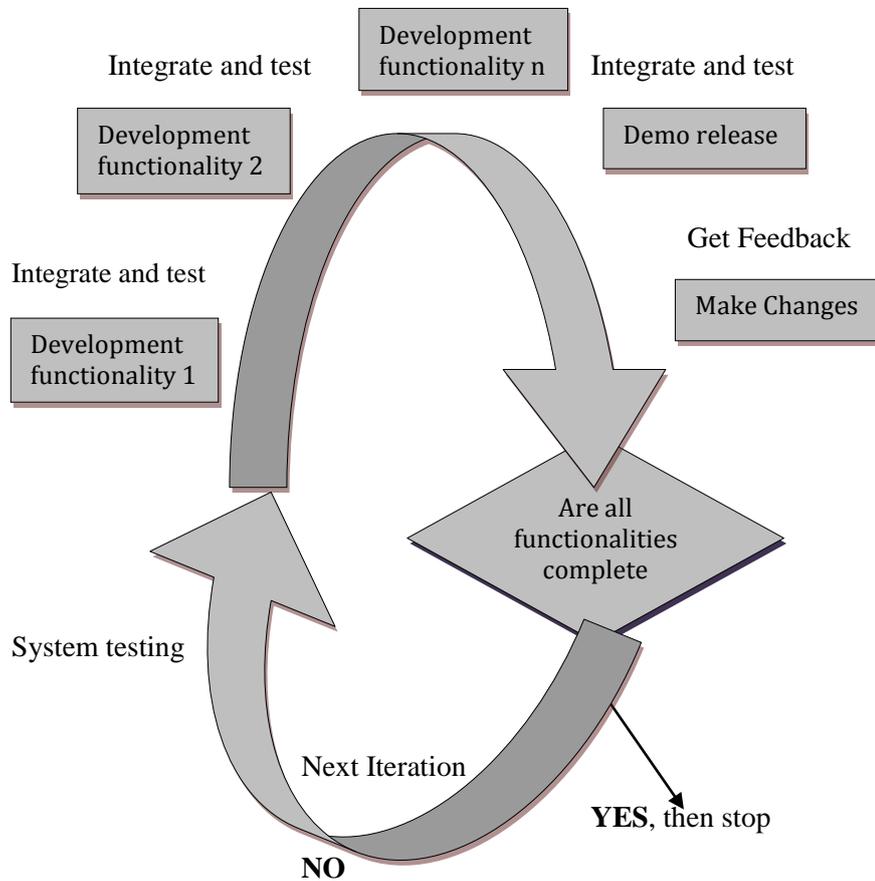


**Figure 3-2 Architectural Trade-Off Analysis method**

The Android OS was selected and, hence, all prototypes were developed for Android devices. The prototypes have been developed using Droid – a draw tool that facilitates designing and building UI for smartphones and tablets which belong to Android platform [28]. Prototyping is the most important stage since the product’s look and feel should be easily usable by the visually impaired. A magnifying glass application and an application to easily turn on the text to speech service were prototyped.

### **3.4 Application development**

EyesFree and the Magnifying Glass were developed in Java for Android using Eclipse Helios Integrated Development Environment(IDE) based on the prototypes developed in the previous stage. The application developed is *installable* which means that it can be installed and uninstalled in the phone whenever desired and downloaded through wired/wireless media as an executable (.apk) files/package. We employed agile development methods because much experimentation and adaption was needed. We also need to incorporate customer and user feedback early to increase customer satisfaction. The applications were developed for Android version 4.0/4.1 and was running on the Android Virtual Machine and on real devices (HTC One X with Android version 4.0 and updated version 4.1). The usability aspects of the applications have been monitored throughout the development stage. Figure 3-3 shows how the iterative development was done.



**Figure 3-3 Agile Development**

### 3.5 Basic technical tests

Both applications were tested on several phones with Android 4.0 and 4.1 like HTC One X, HTC Incredible S, and Samsung Galaxy S2. A number of mobile-specific factors were tested like battery strength and call interruptions. The phone and application behavior was tested under the following conditions:

1. Various battery strengths – very low, low, moderate, high and while mobile are in charge.
2. Tests of battery consumption when the application runs in background and foreground.
3. Memory usage while the application runs in foreground, background and so on.
4. Behaviour of the application when there are interruptions like incoming call, incoming message, device shutdown, while receiving incoming call and messages. These interruptions can occur while the application is being launched, installed, running, exiting, uninstalling.

- 
5. A build released in debug mode should have enabled logs which will help to trace issues backward while the application is running.
  6. Test with single touch inputs, multiple touch inputs.
  7. Testing with both portrait and landscape modes.
  8. Testing on simulators along with testing on real device to test the same build on multiple device screens. A simulator is an imitation of mobile device with respect to UI and some preinstalled features. The testing should not be confined only to simulators.

Testing has been done to test the application functionalities and as well as to test the application in various conditions like battery strength and touch inputs and so on. There are two different test record maintained – one which contains the test cases on the application functionalities with expected and actual results as seen in [Appendix A](#) and another which contains test cases on the applications behavior towards various external(phone) conditions, the expected and the actual results as seen in [Appendix B](#).

### **3.6 Usability evaluation**

A user evaluation of the system was conducted using the Think aloud protocols method [23]. Think aloud protocols encourage the user being interviewed to think-aloud; to say what's on their mind while using the interface on a device. When the user has no issues using the interface, the user will be unable to speak as fast as they can think. Hence, the think-aloud method works at its best when users face some problems because they have enough time to speak what they think. The main advantage of this approach is that we get qualitative user feedback along with quantitative ones. The observer takes notes when the participant achieve different task. Moreover, the observer has to instruct the user on the interface initially and they should facilitate the participant to comment whenever they have an issue or problem. The observer can either take notes or record audio/video.

In this thesis, the observer and the facilitator was the same. Moreover, we did not record any of the tests. Based on the points noted down, qualitative and quantitative analysis has been done and conclusions have been drawn. Moreover, special questionnaires as seen in [Appendix C](#) were developed and the answers to these questions were derived from the notes written down by the observer who was observing and interviewing the participants.

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## 4. Results

This section presents the design requirements on the accessibility applications as well as the actual prototypes that were developed and tested with users.

### 4.1 Design requirements

The requirements for the systems were elicited by conducting informal interviews. Many informants expressed reading problems and wanted functionality that would audibly read out the screen content. This functionality is called Text to Speech and already exists in smartphones. We investigated the usability of the Text to Speech functionality by letting informants test the iPhone and the Android phone. The majority of the users said that the text to speech functionality was better implemented in the iPhone compared to Android. One problem with both smartphones was the *accessibility* of the Text to Speech function; no informant could turn on this feature since it is placed inaccessibly under the Settings and Accessibility menus. Hence, an important design requirement was making the existing smartphone features more accessible by letting users easily locate, turn on and turn off the features. Moreover, a main requirement identified in this phase, was means to magnify objects both on the screen and in the world. Below is a set of general requirements we elicited based on the interviews:

1. Keep everything simple with large text sizes and spaced buttons,
2. Choose simple layouts like linear layouts or relative layouts and avoid scroll layouts as the visually impaired find it difficult to control scroll speed,
3. Keep texts large and fonts simple. Texts and backgrounds should use contrasting colours like black and white respectively,
4. Eliminate toggle buttons and make use of two buttons for options like YES and NO with a minimal spacing of an average index finger between them. Toggle buttons are confusing and difficult to use for people with vision impairments. Keeping the width of the YES and NO buttons and the spacing between them slightly larger will make it easier to use,
5. Having the texts and button descriptions bold will ease the reading process. Moreover, having clear alert dialogs are important whenever necessary especially when toggling on or off features and services.
6. Design two different layouts – one for portrait mode and one for landscape mode to avoid display issues when the user switches orientation from landscape to portrait and vice versa.
7. Use bright notification icons for users with vision impairment.

### 4.2 Eyes Freee

EyesFree is a basic Android application that improves on the existing accessibility features of Android. EyesFree has three central features that are discussed below. These features make access of functions and configuration of the device easier for the visually impaired.

As discussed above, a problem is Androids accessibility Text to Speech feature that is not particularly accessible. For example, it is difficult to enable since the user has to go through several menus. In EyesFree users can turn on Text to Speech from a special accessibility option. The underlying services are turned on and a notification icon is created on the home page status bar. This icon helps users to know that the Text to Speech service is active as long as they see the notification icon on the status bar. The user can pull the notification icon downwards. Once the icon is pulled down, the user can see a screen from where he/she can directly turn off the service.

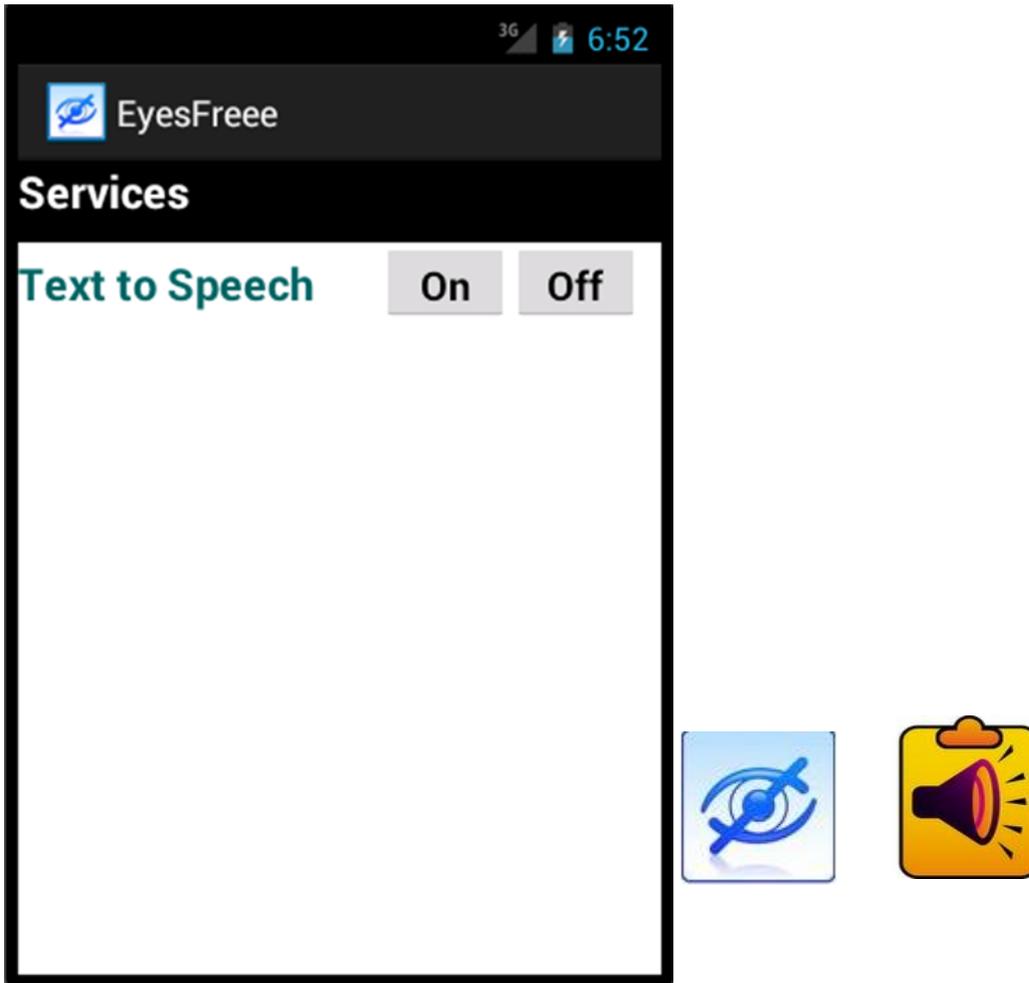
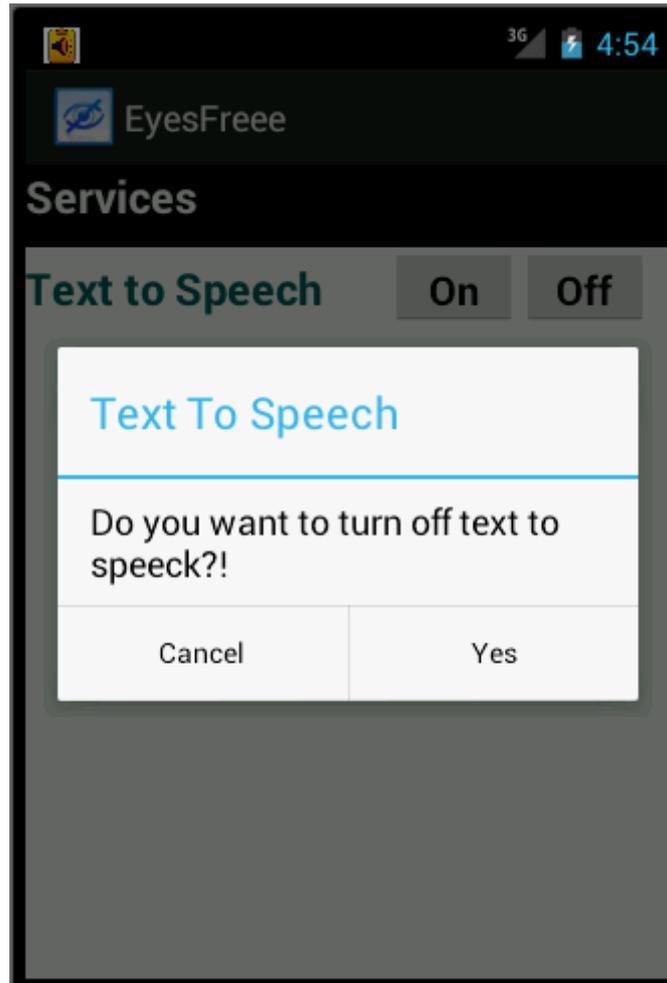


Figure 4-1 EyesFree screenshot, application icon, and notification icon.

Service can also be switched off by entering the EyesFree application. Figure 4-1, shows Eyes Free and the application from which the Text to Speech service can be started. EyesFree has a heading tab with services and option below the heading to turn the service on and off. If the user turns off the Text to Speech service by pressing the off button, the user is alerted with the dialog as shown in Figure 4-2.



**Figure 4-2** EyesFree alert dialog

The alert dialog alerts the user one additional time before completion of an action. Generating notification also tells the user that either a service or an application is up and running. It also acts as a shortcut for entering into the application from home screen directly without having to open the application through application icon.

### **4.3 The Magnifying Glass**

The Magnifying Glass is basic application that let the user magnify any physical object outside the phone using its camera. For better visibility, the user turns on this feature via an icon. The application is suitable to magnify near-field as well as far-field objects. Moreover, the user can capture the image that will be saved in a photo library. Figure 4-5 shows the Magnifying Glass.



Figure 4-3 The Magnifying Glass application icon.

## 4.4 Usability evaluation

The usability of Eye Free and the Magnifying Glass were evaluated with people aged between 55 and 65 with vision impairments. The applications were also tested with young people with vision problems. The Think aloud protocol method was selected for evaluating the applications. The findings from this study are summarized below.

### 4.4.1 EyesFree

The usability analysis identified that it was easy to turn on talkback services from the EyesFree application. Some users said that it would be convenient to turn on the service by just clicking a hardware button. This should be taken into consideration in new designs. Two separated and well-spaced buttons for ON and OFF in the EyesFree application was considered to be better than one toggling button. The navigation was not seen as a problem in this basic application; the users could navigate back to the application screen using the back button and navigate to the home screen by clicking the home button. The notification icon was self-explanatory and indicated the user that a service was running in the background. This icon was considered bright enough to be clearly spotted on the home screen of the phone.

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#### **4.4.2 The Magnifier Glass**

The Magnifier application served the purpose and was considered useful by the test group. The spacing and size of the buttons were big enough. Even if one test person was suffering from tremors, there was no problem clicking the buttons. The zoom functionality is having steps. However, some users preferred zooming continuously on long press. This can be carried out as a part of further development by implementing a long click listener for the zoom buttons. On long press, zooming will happen continually until maximum/zero zoom is reached.

Even though the magnifier icon was self-explanatory, it was not bright enough. Hence it could not be easily spotted in the applications menu. Moreover, it was found that the quality of the preview generated was not as clear as the preview generated by the Android camera application. This issue must be controlled in later releases. Some users expected tactile feedback, especially when they performed actions like turning on and off the service, zooming in and zooming out, clicking on a picture, and cancelling the preview. Tactile feedback is not present in these applications and could be considered in later versions. Similarly, some users expected LED indicator lights glowing when they perform actions in the user interface. These users had problems feeling vibrations.

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## 5. Discussion

An aging society has most of the times been ignored during technological advancement. If we could add another dimension to the design of new IT products, the older generation will benefit a lot. Social networking through smartphones will decrease loneliness and aid them staying in touch with family and friends. Speech support in navigation applications, for example, will assist mobility letting them perform everyday activities such as going to the grocery store or visiting the healthcare facilities. Moreover, media could inform them about local happenings and attractions so that they feel that they are a part of society.

Android is open source and a powerful operating system for smartphones, but the accessibility features are quite difficult to use. Two Android applications was developed in this thesis to improve this situation - The Magnifier and EyesFree – two meta applications that make accessibility features more manageable for the visually impaired. The Magnifier helps the old people with vision impairment to read small letters or objects by using their smartphone as a magnifying glass.

The Magnifier and EyesFree applications can be improved and below are some ideas that could be taken forward to implementation. Implementing pinch zoom to magnify any text in Android mobile phones could be one such idea. A pinch zoom feature should be made an innate feature in Android rather than being a feature of a particular application like Gmail. Gmail (Ver. 4.2.1) supports pinch zoom in the mail texts and images. Regardless of this feature being present in any application, pinch zoom should be possible on any text for better readability. Moreover, implementing high contrast schemes would improve readability for people with vision impairments. A general comment is that the text-to-speech features can be improved in the Android platform as well as the quality of the camera preview.

The accessibility features and services of Android cannot be started easily by the user. Many visually impaired users find it easy to use tactile and physical controls such as d-pads and trackballs to activate functions of devices rather than using touchscreens. To compensate, touchscreens must be easy to use for the visually impaired and there must be an effective screen reader that will help user navigate and activate controls. We believe that Android developers must consider writing applications with various age-related disabilities in mind. Google has published some of the best practices to be followed to improve accessible.

Android phones come in variety of physical configurations as can be seen in Appendix D. As mentioned above, phones with tactile and physical buttons make sense for the visually impaired. Most phones have physical buttons for audio volume, power, as well as camera controls. Also, some phones have tactile buttons to access the main menu. With this understanding, we recommend developers of smartphones to include generic physical buttons on the phones that can be assigned to accessibility functions such as screen readers and so on.

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This research work started with a very broad topic of making smartphone and pads more usable for different categories of elderly and disabled. This phase included background studies on age-related disabilities and supporting tools that have been developed. The next phase was to decide whether to choose Android or iOS as the platform for the prototypes. We employed the architectural trade off analysis method to evaluate the architectures which led us to choose Android. The subsequent development involved a lot of technical experimentation with Android's APIs. Eventually, the user evaluation of the applications was carried out using qualitative think aloud approach.

Interviews were analysed in a less structured way as compared to structured or descriptive way. A structured or a descriptive analysis could have led to a quasi or a whole statistical model for the interview data [25, 26, 27, 28]. Due to time and resource constraints, it was not possible to have a statistical model for the data which was obtained after interview. Hence, the interview analysis may not be as accurate as it would be with a statistical model [26]. Interviews were conducted in English which restricted some old people from taking interviews. Conducting interviews in both English and Swedish would have resulted in better results as it would involve more number of people. With Xtreme programming in the development stage, there is no structure as compared to waterfall model. Also it was not easy to calculate the effort required in terms of hours at the beginning of the development. At times the development work went off the record due to lack of structure. Using think aloud protocol for evaluation had a drawback that people had to tell their opinion during the meetings conducted during evaluation process. Giving time to people to go home and think and evaluate and come back with their opinion in a day's time or two might have yielded much better results.

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## **6. Conclusion**

With advancement of smartphone technology at a rapid phase, the visually impaired are still sceptical when it comes to owning and using a smartphone. As a part of this thesis an analysis has been made to make the smartphone features more accessible for the old with vision impairment. The intention was to improve the existing smartphone accessibility tools by developing two Android applications. The Magnifier is a magnification tool for physical objects and text and EyesFree is a text to speech service that reads out the screen content to the user. A user evaluation showed that these applications were useful for the visually impaired. The meta application and user interface of EyesFree exemplifies how users can access the internal features of the OS such as the speech services more effectively. Future work includes improving the functionalities of the screen reader.

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# Appendix A. Test Cases 1

## Testing applications functionalities

Test Nr	Test application	Test Action	Result Expected	Result Actual	Pass/Fail	Comment
1	EyesFree	Pressing the EyesFree icon once in the application menu screen	The user should enter into the application	The user enters into the application	Pass	
2	EyesFree	ON Button inside the application beside the text to speech	Should turn on text to speech service by telling aloud a welcome note "Hi! I am talkback". Also a notification icon should get created on the home screen of the mobile phone.	Turns on the text to speech service by telling a welcome note "Hi! I am talkback. Also a notification icon is created on the home screen of the mobile phone.	Pass	
3	EyesFree	OFF Button inside the application beside the text to speech	Should first alert the user with an alert dialog which asks the user whether they really want to turn the service off. On clicking Yes, the user should be able to turn off the service and also the notification icon gets deleted from the home screen. On clicking No, the alert dialog should exit and the service should continue to run.	Will first alert the user with an alert dialog which asks the user whether they really want to turn the service off. On clicking Yes, the user will be able to turn off the service and also the notification icon gets deleted from the home screen. On clicking No, the alert dialog exits and the service continue to run.	Pass	
4	EyesFree	Back navigation capacitive or physical button outside the application	Should exit from the application screen and go 1 step back irrespective of whether the test to speech service is ON or OFF. If the text to speech service is ON, it should continue running in the background even after the application exits.	Exits from the application screen and goes 1 step back irrespective of whether the test to speech service is ON or OFF. If the text to speech service is ON, it continues running in the background even after the application exits.	Pass	
5	EyesFree	Home capacitive or physical button outside the application	Should exit from the application screen and go to the home screen irrespective of whether the test to speech service is ON or OFF. If the text to speech service is ON, it	Exits from the application screen and goes to home screen irrespective of whether the test to speech service is ON or OFF. If the text to speech service is ON, it continues running in the background	Pass	

			should continue running in the background even after the application exits.	even after the application exits.		
6	EyesFree	Dragging down the notification bar containing the EyesFree notification icon with a single finger	Should show that the text to speech service is running in the background. Also the user should be able to enter the application by clicking on this shortcut.	Shows that the text to speech service is running in the background. User will be able to enter the application by clicking on this shortcut.	Pass	
7	EyesFree	Rotating the phone from portrait to landscape and vice versa	Should be able to handle rotation changes. There should be appropriate layout changes while rotation.	Handles rotational changes. The layout changes appropriately while rotation.	Pass	There are separate layouts for both landscape and portrait and the rotation changes are handled inside the Android activity class.
7	Magnifier	Pressing the magnifier icon once in the application menu screen	The user should enter into the application and the camera preview should start. Moving the phone around should also result in preview moving accordingly.	The user enters into the application and the camera preview starts. The preview also moves accordingly as the phone is moved.	Pass	
8	Magnifier	The '+' or the 'zoom in' option on the zoom controls widget	Should zoom in on the preview step by step until the maximum zoom is achieved (maximum zoom depends on the camera hardware and varies from device to device).	Will Zoom in on the preview step by step until the maximum zoom has been reached (maximum zoom depends on the camera hardware and varies from device to device).	Pass	
9	Magnifier	The '-' or the 'zoom out' option on the zoom controls widget	Should zoom out on the preview step by step until the preview is back to normal with no zoom or a minimum zoom of zero.	Will zoom out on the preview step by step until the preview is back to normal with no zoom or a minimum zoom of zero.	Pass	
9	Magnifier	Cancel Button	Should stop the preview but not exit from the application.	Stops the preview	Pass	
10	Magnifier	Click Button	Should click the picture and save it into phone memory	Clicks the picture but does not save it into the phone memory	Fail	Will be done as part of further development.
11	Magnifier	Back navigation capacitive or physical button outside the application	Should first alert the user with an alert dialog which asks the user whether they really want to cancel the preview. On clicking Yes, the preview should stop and the application should exit and go 1 step back. On clicking	Alerts the user with an alert dialog which asks the user whether they really want to cancel the preview. On clicking Yes, the preview stops and the application exits and goes 1 step back. On clicking No, the preview continues to run.	Pass	

			No, the preview should continue to run.			
12	Magnifier	Home capacitive or physical button outside the application	Should exit from the application screen and go to the home screen.	Exits from the application screen and goes to home screen.	Pass	Ideally the preview should stop running before it exits to home screen.
13	Magnifier	Rotating the phone from portrait to landscape and vice versa	Should be able to handle rotation changes. There should be appropriate layout changes while rotation.	Handles rotational changes. The layout changes appropriately while rotation.	Pass	There are separate layouts for both landscape and portrait and the rotation changes are handled inside the Android activity class.

## Appendix B. Test Cases 2

### Testing applications behaviour versus the phone conditions

Test Nr	Test application	External Factors	External factor types/values	Expected outcome	Actual outcome	Pass/Fail	Comment
1	EyesFree	Various battery strengths	Very Low	The Service should not start or run in the background if the percentage of battery is below 5%.	The service starts and consumes more batter	Fail	Will be considered in further development
2	EyesFree	Various battery strengths	Low	The service should start running in the background but stop automatically when the battery is getting very low.	The service starts running but does not stop automatically when the battery is getting very low	Fail	The Android OS has more control over starting or stopping a service than the user code. So sometimes the services acts unpredictably
3	EyesFree	Various battery strengths	Moderate	Service should start	Service starts	Pass	
4	EyesFree	Various battery strengths	High	Service should start	Service starts	Pass	
5	EyesFree	Various battery strengths	While mobile is in charge	Service should start	Service starts	Pass	
6	Magnifier	Various battery strengths	Very Low	The camera preview should not start if battery percentage is below 5%	The camera preview starts even if battery percentage is below 5% and user is able to do all functionalities of the application	Fail	The device camera should not start if the battery is too low.
7	Magnifier	Various battery strengths	Low	The camera preview should start and the user should be able to do all the tasks of magnifier application but the preview should stop once the battery percentage is very low	The camera preview will start and the user is able to do all the tasks of magnifier application but the preview stops once the battery percentage is very low	Pass	
8	Magnifier	Various battery strengths	Moderate	A high quality camera preview should start and the user should be able to do all the tasks of magnifier application	The camera preview will start and the user is able to do all the tasks of magnifier application	Pass	The quality of the camera preview is not of very high quality
9	Magnifier	Various battery strengths	High	A very high quality camera preview should start and the user should be able to do all the tasks of magnifier application	The camera preview will start and the user is able to do all the tasks of magnifier application	Pass	The quality of the camera preview is not of very high quality
10	Magnifier	Various battery strengths	While mobile is in charge	A very high quality camera preview should start and the user should be able	The camera preview will start and the user is able to do all the	Pass	The quality of the camera preview is not of very high quality

				to do all the tasks of magnifier application	tasks of magnifier application		
11	EyesFree	Battery consumption	When the application is running in background	Normal battery consumption	Normal	Pass	
12	EyesFree	Battery consumption	When the application is running in foreground	Normal battery consumption	Normal	Pass	
13	Magnifier	Battery consumption	When the application is running in background	Normal battery consumption	Normal	Pass	
14	Magnifier	Battery consumption	When the application is running in foreground	Normal battery consumption	Normal	Pass	
15	EyesFree	Interruptions	Incoming call	The service should continue running in the background	The service continues running in the background	Pass	
16	EyesFree	Interruptions	Incoming message	The service should continue running in the background	The service continues running in the background	Pass	
17	EyesFree	Interruptions	Device shutdown	The service should stop and the user should turn the service on again once the phone is on	The service stops and the user has to turn the service on again once the phone is on	Pass	
18	EyesFree	Interruptions	While on call	The service should continue running in the background	The service continues running in the background	Pass	
19	Magnifier	Interruptions	Incoming call	The preview should continue running in the background	The preview continues running in the background	Pass	
20	Magnifier	Interruptions	Incoming message	The preview should continue running in the background	The preview continues running in the background	Pass	
21	Magnifier	Interruptions	Device shutdown	The preview should stop and the user should turn the application on again to start the preview once the phone is on	The preview stops and the user has to turn the application on again to start the preview once the phone is on	Pass	
22	Magnifier	Interruptions	While on call	The preview should continue running in the background	The preview continues running in the background	Pass	
23	EyesFree	Touch Input	Single touch	The functionalities should work as expected	The functionalities work as expected	Pass	
24	EyesFree	Touch input	Multiple touch	The functionalities should not work as expected	The functionalities works in an unexpected way	Pass	Multiple touch could sometimes lead to exiting application or some other weird outcome
25	Magnifier	Touch Input	Single touch	The functionalities should work as expected	The functionalities work as expected	Pass	
26	Magnifier	Touch input	Multiple touch	The functionalities should not work as expected	The functionalities works in an unexpected way	Pass	Multiple touch could sometimes lead to exiting application or some other weird

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							outcome
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## Appendix C. Questionnaire

### For EyesFree

1. Is it easier to turn on talkback (text to speech) service from EyesFree application as compared to turning on the service by going to settings->accessibility->talkback.
2. Is it better to have two separate ON and OFF buttons with better spacing in-between them as compared to toggle button?
3. Is the EyesFree application icon self-explanatory? Icons should be able to represent the concept graphically.
4. Is the EyesFree application interface simple and easily readable?
5. Is the EyesFree application easily usable and navigable?
6. Is the notification icon which gets created on the phone home screen helpful? Does it indicate the user that this service is running in the background?
7. Is the notification icon self-explanatory? Does it give an idea to the user that text to speech service is running in the background?
8. Does the notification icon act as a shortcut to enter into the EyesFree application? Is this helpful?
10. Is the alert dialog which appears while turning off the service useful?

### For Magnifier

1. Is the Magnifier icon self-explanatory? Does the icon graphically represent the application concept?
2. Is the magnifier interface simple and easy to use? Is it possible to locate and use the zoom in, zoom out, cancel and the click buttons easily?
3. Are the zoom in, zoom out, cancel and click buttons big enough and well-spaced? People aged between 55 and 65 may have shivering and if buttons are very closely placed, it may lead to clicking a wrong button.
4. Does the magnifier solve the purpose?
5. Is the clarity of the preview generated by the magnifier clear enough?
6. Does the zoom in and zoom out work properly? Does zoom in and zoom out do stepwise zoom?
7. Does the click button save the photo in the phone memory?
8. Does the cancel button stop the preview?
9. Can the user navigating back with the help of back button? In Magnifier application's case, the user has to exit the application on pressing the back button.
10. Can the user get back to the home screen from the application by clicking the home button?

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## Appendix D. Android OS versions

Version history by API level (versions available until Dec – 2013)

Android 1.0 (API level 1)

Android 1.1 (API level 2)

Android 1.5 Cupcake (API level 3)

Android 1.6 Donut (API level 4)

Android 2.0 Eclair (API level 5)

Android 2.0.1 Eclair (API level 6)

Android 2.1 Eclair (API level 7)

Android 2.2–2.2.3 Froyo (API level 8)

Android 2.3–2.3.2 Gingerbread (API level 9)

Android 2.3.3–2.3.7 Gingerbread (API level 10)

Android 3.0 Honeycomb (API level 11)

Android 3.1 Honeycomb (API level 12)

Android 3.2 Honeycomb (API level 13)

Android 4.0–4.0.2 Ice Cream Sandwich (API level 14)

Android 4.0.3–4.0.4 Ice Cream Sandwich (API level 15)

Android 4.1 Jelly Bean (API level 16)

Android 4.2 Jelly Bean (API level 17)

Android 4.3 Jelly Bean (API level 18)

Android 4.4 KitKat (API level 19)

## Appendix E. Comparison Talkback versus Voiceover

Properties of Screen reader	iOS version 4(Voiceover)	Android version 4(talkback)
A click sound is heard as the user moves between menu items. Finger can be dragged anywhere around the screen.	Yes	No
Tap 3 fingers to hear the number of home screens and which one the user is on. Ex page 1 of 3	Yes	No
As new apps are added, additional home screens are created if needed.	Yes	No
Flick 3 fingers left or right to move between home screens	Yes	No
Flick to the right until the name of the app is heard. Next double tap anywhere on the screen to open it.	Yes	No
Will read out the content of app which is opened. Flicking to the right every now and then will read out more information on the app	Yes	No
To get out of the application back to the current home screen flick left with 2 fingers.	No	No
To get out of the application back to main home screen flick left with 2 fingers twice. Once to get back to the current screen and another time to get back to main home screen	No	No
To get out from current home screen back to main home screen flick left with 2 fingers.	No	No
Clicking on e-mail should tell the user the number of unread messages	Yes	No
After clicking the e-mail, double tapping anywhere on the screen should open the e-mail	Yes	No
Flick right to read to the subject of the messages and flick down to scroll down	Yes	No
Double tap anywhere to open the selected message.	Yes	No
Click on the object of the message and flick down with 2 fingers for the screen reader to read it. Tap 2 fingers to pause.	Yes	No

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Across the bottom of screen, if there are additional mail options to reply, compose, forward, delete - flip right to hear these options	Yes	No
Once the option is selected double tap anywhere on the screen to execute the option. Ex - reply	Yes	No
Holding one thumb to select the letter by sliding the thumb across the touch keyboard and taping the other thumb anywhere to type the letter.	Yes	No

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På svenska

Detta dokument hålls tillgängligt på Internet – eller dess framtida ersättare – under en längre tid från publiceringsdatum under förutsättning att inga extra-ordinära omständigheter uppstår.

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