THE REPUBLIC OF TURKEY
BAHÇEŞEHİR UNIVERSITY

REAL TIME INFORMATION ASSISTANT FOR VISUALLY IMPAIRED PEOPLE AND COMPARISON OF SIMILAR ASSISTIVE APPLICATIONS

M.S. Thesis

ERDAL ERDAL

ISTANBUL, 2013

THE REPUBLIC OF TURKEY
BAHÇEŞEHİR UNIVERSITY

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
COMPUTER ENGINEERING

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This is to certify that we have read this thesis and we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Arts.

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ABSTRACT

DEVELOPING A REAL TIME INFORMATION ASSISTANT FOR VISUALLY IMPAIRED PEOPLE AND COMPARISON OF SIMILAR ASSISTIVE APPLICATIONS

Erdal, Erdal

Computer Engineering Master Program

Supervisor: Asst. Prof. Dr. Yücel Batu Salman

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The Internet has become a vital and indispensable means for daily needs. Access to the Internet is essential for various users; and visually disabled or impaired people should also be allowed to access the Internet. Visually impaired people have still trouble in accessing most web sites although web accessibility is institutionalized in several countries. It is difficult for visually impaired users to comprehend, navigate, understand and interact with the most current web sites. Software developers were also encouraged by Web Content Accessibility Guidelines (WCAG) of World Wide Web Consortium (WWWC). Specific needs of visually impaired people do not take enough interest while a number of theoretical models and applications have been developed to provice online facilities more universal and friendly. The purpose of this research is developing and testing new software which provides certain information for visually impaired people to assist them. Current voice recognition and optical character recognition technologies were implemented for the system's infrastructure. All tasks were designed to be performed by the voice commands. The requirements were analyzed with the actual users in a controlled environment empirically. The application allows visually impaired user to access automatically categorized predefined information with the least possible selection from the user menus. The users participating in the experiment decided to revisit a web site or reuse an application based on its accessibility with the parameters of its usefulness and ease of use. The user's performance, error, and satisfaction of the application were compared with an equivalent system. It was proven that our system worked well in encouraging the visually impaired users effectively. The behaviors of

the users can be analyzed and the application can be improved by implementing innovative input ways in the further study.

Keywords: Visually Impaired People, Usability, Voice Recognition, Optical Character Recognition, Accessibility

ÖZET

GÖRME ENGELLİ İNSANLAR İÇİN GERÇEK ZAMANLI BİLGİ YARDIMCISI GELİŞTİRİLMESİ VE BENZER UYGULAMALARLA KARŞILAŞTIRILMASI

Erdal, Erdal

Bilgisayar Mühendisliği Yüksek Lisans Programı

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İnternet günlük ihtiyaçlar için hayati ve vazgeçilmez bir araç haline gelmiştir. İnternet erişimi birçok kullanıcı için büyük önem taşımaktadır ve görme engelli ya da engelli insanların da internete erişimlerine izin verilmelidir. Birçok ülkede internet erişiminin kurumsal hale gelmesine rağmen, görme engelli insanlar halen internet sayfalarına erişimde sıkıntı yaşamaktadır. Görme engelli insanların güncel internet sayfalarını algılamaları, anlamaları ve bu sayfalarda gezinmeleri ya da etkileşim kurmaları çok zordur. Yazılım geliştirici ya da internet geliştiricileri World Wide Web Consortium tarafından yayınlanan Web İçeriği Erişilebilirlik Klavuzu ile teşvik edildi. Çevrimiçi kaynakları daha kullanıcı dostu ve evrensel yapmak için bir dizi teorik model ve uygulama geliştirirken, görme engelli kullanıcıların özel ihtiyaçlarına çok az önem verilmiştir. Bu araştırmanın amacı, görme engelli insanların güncel bilgiye erişmelerini sağlamak için yardımcı olacak bir yazılım geliştirmek ve test etmektir. Güncel ses tanıma ve optik karakter tanıma teknolojileri sistemin altyapısı için uygulanmıştır. Tüm görevlerin ses komutlarıyla yapılması tasarlanmıştır. Gereksinimler deneysel olarak kontrollü bir ortamda gerçek kullanıcılar ile analiz edilmiştir. Uygulama görme engelli kullanıcıya en az seçim yaptırarak, önceden tanımlanmış ve kategorilere ayrılmış olan bilgiye erişmesine olanak sağlar. Deneye katılan kullanıcılar, bir internet sayfasına giriş yaparak ve uygulamayı kullanarak erişilebilirliğe, kullanım kolaylığına ve kullanışlılığına karar vermişlerdir. Kullanıcıların performans, hata ve uygulama memnuniyetleri eşit bir ortamda karşılaştırılmıştır. Geliştirilen sistemin görme engelli kullanıcıları etkin olarak teşvik ettiği kanıtlanmıştır. İlerleyen çalışmalarda, kullanıcıların davranışları analiz edilebilir ve uygulamaya yenilikçi eklentiler yapılabilir.

Anahtar Kelimeler: Görme Engelli Kullanıcılar, Kullanılabilirlik, Ses Tanıma, Optik Karakter Tanıma, Erişilebilirlik

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May 15, 2013 Erdal ERDAL

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CBT	:	Computer-Based Training
ICIDH	:	International Classification of Impairment, Disabilities, and Handicaps
SDLC	:	System Development Life Cycle
SPSS	:	Statistical Package for the Social Sciences
TAM	:	Technology Acceptance Model
WAI	:	Web Accessibility Initiative
WCAG	:	Web Content Accessibility Guidelines
WHO	:	World Health Organization
WWW	:	World Wide Web
WWWC	:	World Wide Web Consortium

1. INTRODUCTION

The popularity and the use of the Internet are increasing each year, this popularity and usage makes computers and other electronic devices vital and indispensable. Popularity of the internet affects the daily life of people. Internet is used to work, play games and socialize with friends as well as for telecommunication. According to Internet World Stats (Internet World Stats 2013), more than 70 percentage of the population in the developed countries uses computers daily. One area of growth is communication industry. More and more people are using web based services to access daily news or magazines instead of traditional formats, such as newspapers or magazines. Internet is rather a visual source of resources and computer interfaces are designed to be accessible by input devices like mouse or keyboard (Molnar and Kletke, 1996). However, all of this mechanism and success of the internet brings a major question about the accessibility of this technology to visually impaired and partially sighted users who are in need of accessing daily news or magazines.

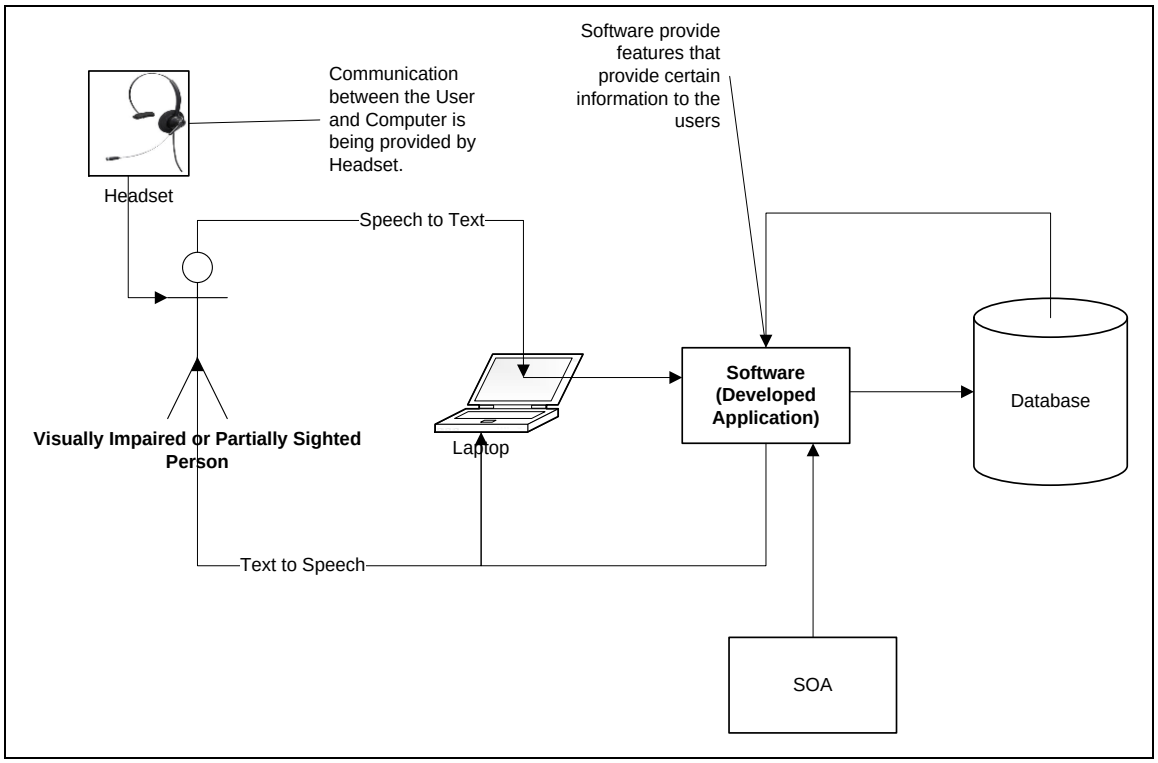
Visually impaired and partially sighted computer users are no exception when it comes to growth of the Internet. Normal sighted users can use the keyboard, mouse or other devices for input and they can use output that they select such as, screens or miscellaneous types of displays. But, visually impaired and low-vision users cannot use these input or output devices. For their necessity of computer, a number of visual assistive technologies have been developed, of these, the Braille keyboard, screen magnifiers or screen readers. The use of Braille keyboard is very difficult and very slow. Screen magnifiers are adopted as default functionality by most of the operating systems. Even though, screen magnifiers help partially sighted users, this functionality cannot be used by visually impaired people. In addition, with the growth of the Internet and the web technologies, web pages are becoming more interactive and graphically rich therefore screen readers are not sufficient.

In addition, to compensate all these disadvantages of disabled people, several governments have passed laws to enforce accessibility of websites for disabled users. In

the United States, laws are being published as Section 508 (Section 508, 1998) of the Rehabilitation Act that prohibits discrimination against disabled people in all of their daily life. After these steps, the WWWC's Web Accessibility Initiative (WAI) developed that known as the WCAG (Web Content Accessibility Guidelines 1.0, 1999). But this methods and solutions cannot succeed exactly; this proven by a research (Hackett et al. 2004); initiated that the accessibility issues seem to have deteriorated in the last few years. They used the Internet Archive's Wayback Machine to investigate the accessibility of random websites from 1997 and 2002 and found that websites became unreachable regularly, and complication of them enlarged over the years. So, what would be the most effective way to make information easily accessible by visually impaired and partially sighted people?

Although, disabled people still cannot access the information they need easily, more software technologies are emerging to improve the voice recognition to enable user independent access to computers. Voice recognition can basically be explained as translating spoken words into the commands that computer can understand. As Bill Gates once proclaimed; "voice recognition technology to be the future of computing itself" (qtd. In Honeycutt, 2003, p. 77). In this paper, we are developing an application to help visually impaired or partially sighted people. A simple diagram that can be shown in Figure 1.1 may help us to understand the approach of newly developed application. With the assist of this application, visually impaired or partially sighted people can access the certain information just with the spoken words instead of hands or eyes. Also, development process of this software is different from other software development processes, all the steps of development is defined. At last, evaluation is done to measure success of software and satisfaction of users.

Figure 1.1: Newly developed application system diagram



There are some researches that define the problems and barriers of visually impaired people (Loiacono et al, 2010) (Leuthold et al, 2007) (Molnar et al, 1995) (Zajicek et al, 2007) (Zhao et al, 2006). Some of them analyzed the current assistive technologies and some of them tried to solve a part of the general problem instead of trying to create a new approach. This research is not only defining the problems but also developing a whole new project for the solution. Developed application can be controlled by the voice input of the users. All the selections listed are read to user, and user is asked for an input to access the desired option.

This paper contains the related issues. Background part of the research tells us the visual disabilities, problems that visually impaired people are faced and assistive technologies for blind and visually impaired people. In the literature review, complete research on the literature has been done. The main issues of this study are defined and these issues' histories are researched. Literature review topics are voice recognition, technology acceptance model and accessibility variables. This session, provides to learn general information about the subject, and it can show the completed studies. The hypothesis of the study is defined in the header of hypothesis. Hypothesis shows the main aim and

expectations from this research. In the methodology part of the research, all parts of the software development stages are defined and the software details are written. The software features, development model, analysis of the requirements, software design, implementation and integration, testing, maintenance, planned future developments, training are the main headlines of main focuses of the software. In the apparatus and materials part, the components that are used in this research are defined. Upon the completion of the application, it needs to be supported with researches and experiments. In addition, participants' details are defined in the participants' part of the methodology. General information about these participants is delivered in details. Experimental procedure is defined that outlines the environment of the experiment that is applied all the participants. The task and the procedure are written that explains the experiment in details. All the participants' tasks are defined. Analyzing part consists of three main sections which are task performance, average number of errors and subjective evaluation of the user satisfaction. In the task performance part, participants' tasks are carefully described, and how the tasks are accomplished. The second section is average number of errors that is measured while the participants are working on tasks. After the completion of the tasks; each participant takes a survey to measure the satisfaction of the users. This survey also compares newly developed application as well as the control application.

Results gathered from the experiments are evaluated and explained in the result and analysis parts of the paper. The paper is continued with the parts on discussion, limitation and future works and these findings are discussed. Sections called limitations and future works includes information about the barriers that are encountered during the research. In addition, future works are also defined in this part. All the information collected and examined in this research is summarized in the conclusion section of the paper.

2. BACKGROUND

The Internet was introduced in 1969 and it since grows rapidly. Thanks to the technologies developed and thanks to the users who understand the importance of the Internet, it is becoming more popular each and every day. There are already over 50 million web pages, and more than 20,000 web sites and more are being added regularly (World Wide Web Size, 2013). The major driver of this growth has been the WWW. There are several possible reasons for the development of the WWW such as ease of distributing and updating, low price of having a website, and the possible to spread a widespread audience (Pawan, 1998).

Information is vital with the globalization of the world. This growth and progress of the internet affects daily lives and arguably one of the most important one of these effects is that users prefer the digital media over traditional. This evolution can easily be observed by the numbers of applications developed for reading news or magazines. Researches also show that, whether a main experience is taking place or not, the Internet is by far the key news source for most of the Americans during the workdays. In a study by the Online Publishers Association, 65 percent of people says "Internet news is the main way I keep in touch with the world events while I'm at work," while 58 percent agrees the same for technology news and 56 percent approves the same for business/financial news. Rapid improvement of the internet provides more and more each day however it still delivers information to user mainly with the support of input and output devices like keyboard, mouse and screens. Therefore visually impaired people have the limited accessibility among all the disabled people (Miyashita et al, 2007). According to the studies, number of the internet users that have visual disabilities increasing swiftly (World Facts and Statistics on Disabilities and Disability Issues, 2013) and presently approximately 10 percent of the world's population, or roughly 650 million people, live with a disability. Of course these numerical values mean all types of disability. Visual disability is one of the most important disability types, for instance, around 360 thousand people are registered blind or partially sighted in the UK and every day 100 people in the UK start losing their sight, so, the number of people in the UK with visual

impairment is set to increase dramatically and affects people of all ages (Sight Loss Statistics, 2013). It is predicted that by 2050 the number of people with visual impairments in the UK will double to nearly four million.

2.1 VISUAL DISABILITIES

Visual impairment is defined as a functional limitation of the eye(s) or visual system (United States Department of Health and Human Services, 1996). The majority of the world population has visual impairments like myopia, hyperopia, low vision, astigmatism, and total blindness. Corrective lenses can significantly improve the life quality of a patient who experience myopia, hyperopia, and astigmatism. These functional limitations can result from congenital (e.g., prenatal or postnatal trauma, genetic or developmental abnormalities), hereditary (e.g., retinitis pigmentosa or Stargardt's macular degeneration), or acquired conditions (e.g., ocular infection or disease, trauma, age-related changes, or systemic disease) (American Optometric Association, 2007). In addition, some of the common causes of Visual Impairment are as follows: Achromatopsia, Histoplasmosis, Central retinal artery occlusion, Cytomegalovirus retinitis, Toxoplasmosis, Microphthalmus. The entire list of common causes of Visual Impairment can be shown in Table 2.1.

Table 2.1: Common causes of visual impairment

Common Causes of Visual Impairment		
Achromatopsia	Congenital cataract	Gyrate atrophy
Albinism	Corneal dystrophies	Harada's disease
Age-related maculopathy: atrophic, exudative	Cortical visual impairment	Leber's congenital amaurosis
Amblyopia	Aniridia	Histoplasmosis
Angioid streaks	Cytomegalovirus retinitis	Keratoconus
Cystoid macular degeneration	Diabetic retinopathy: nonproliferative, proliferative,	Glaucoma: open angle, juvenile, primary angle closure
Anterior cleavage syndromes	Macular hole	Leber's optic atrophy
Cataract	Malignant myopia	Retinal detachment
Central retinal artery occlusion	Microphthalmus	Retinitis pigmentosa
Central retinal vein occlusion	Nystagmus (congenital)	Retinoblastoma
Cerebrovascular accident	Optic atrophy: primary	Toxoplasmosis
Choroideremia	Optic nerve hypoplasia	Retinoschisis (juvenile)
Coloboma	Traumatic brain injury	Solar retinopathy

Visual impairment negatively affects the person's daily life activities, like reading, driving, work-related tasks. The World Health Organization (WHO) International Classification of Impairment, Disabilities, and Handicaps (ICIDH) system is used to categorize disorders (diseases), impairments, disabilities, and handicaps. The definitions are as follows:

A disease is an illness or a medical disorder; regardless the beginning or the source diseases characterize important damage to humans (World Health Organization, 2001).

Impairment is any hurt or irregularity in an anatomical construction or a physical or mental function (World Health Organization, 2001).

A disability is any constraint or absence (causing from an injury) of competency to complete an activity in the method or within the range measured usual for a human being (World Health Organization, 2001).

A handicap shows a person's underprivileged situation in culture, resulting from impairment and/or disabilities (World Health Organization, 2001).

The classification of visual impairment varies worldwide. The WHO categorizes levels of visual impairment based on visual perception and/or visual field limitation, and describes blindness as profound impairment (this can refer to blindness of one eye or blindness of the individual) (World Health Organization, 2001). The WHO definition of blindness specifies visual acuity less than 20/400 and/ or remaining visual field less than 10 degrees in the better Seeing Eye. Visual acuity of 20/70 to 20/400 (inclusive) is considered moderate visual impairment or low vision. Details of visual acuity can be shown in Table 2.2.

Table 2.2 : Levels of visual impairment

<table>
<tr><th colspan="2">Classification</th><th>Levels of Visual Impairment</th><th rowspan="2">Additional Descriptors That May Be Encountered</th></tr>
<tr><th>"Legal"</th><th>WHO</th><th>Visual Acuity (VA) and/or Visual Field (VF) Limitation (Whichever is Worse)</th></tr>
<tr><td rowspan="3"></td><td rowspan="2">(NEAR-) NORMAL VISION</td><td>RANGE OF NORMAL VISION
20/10 20/13 20/16 20/20 20/25
2.0 1.6 1.25 1.0 0.8</td><td></td></tr>
<tr><td>NEAR-NORMAL VISION
20/28 20/30 20/40 20/50 20/60
0.7 0.6 0.5 0.4 0.4</td><td></td></tr>
<tr><td rowspan="3">LOW VISION</td><td>MODERATE VISUAL IMPAIRMENT
20/70 20/80 20/100 20/125 20/160
0.29 0.25 0.20 0.16 0.12</td><td>Moderate low vision</td></tr>
<tr><td rowspan="2"></td><td>SEVERE VISUAL IMPAIRMENT
20/200 20/250 20/320 20/400
0.10 0.08 0.06 0.05
VF 20 degrees or less</td><td>Severe low vision, “Legal” blindness</td></tr>
<tr><td>BLINDNESS (WHO)</td><td>PROFOUND VISUAL IMPAIRMENT
20/500 20/630 20/800 20/1000</td><td>Profound low vision,</td></tr>
</table>

	one or both eyes	0.04 0.03 0.025 0.02 CF at: less than 3m (10 ft.) VF: 10 degrees or less	Moderate blindness
		NEAR-TOTAL VISUAL IMPAIRMENT VA: less than 0.02 (20/1000) CF at: 1m (3 ft) or less HM: 5m (15 ft.) or less Light projection, light perception VF: 5 degrees or less	Severe blindness, Near-total blindness
		TOTAL VISUAL IMPAIRMENT No light perception (NLP)	Total blindness

CF = counts fingers (without designation of distance may be classified to profound impairment)
HM = hand motion (without designation of distance may be classified as near-total impairment)
VA = visual acuity (refers to best achievable acuity with correction)
VF = visual field (measurements refer to the largest field diameter for a 1/100 white test object)

Modified from the International Classification of Diseases, 9th rev. Clinical Modification

Visual impairment is an important problem and detailed studies can show us ways to help and care about the people who have visual disabilities. In the UK, the number of blind and visually impaired people increases along with the increase of the country's population. (Population projections of blind and partially sighted people, 1996) The UK censuses took place on 27 March 2011, according to this census the total population approximately 63.2 million people (Office for National Statistics, 2011) and it is increasing. For people who are completed sixteen years of age and have a visual impairment:

i. 1 .1 million are qualified to be listed blind or partially sighted;
ii. 4% of blind people have no light insight;
iii. 1.7 million people are unable to read normal print;
iv. 36% of blind people can read large print;

v. 2% (approximately 19,000) of blind people are fluent Braille readers;
vi. 30% of blind and partially sighted people use audiotape for their information needs (Guidelines and advice on accessible IT systems and content, 1998).

3.4% of the total population, 8.6 million people, in the USA diagnosed with visual impairments. The numbers of American people who eligible as legally blind are nearly 580,000 and a further 1.8 million people have serious visual impairment (A brief introduction to disabilities, 2013).

The data given above shows that there are many blind or visually impaired people and numbers are high enough to take action to make their life easier. There are significant numbers of people with disabilities and they are potential users of the Internet applications (Laux, 1998). The capability to interconnect and gather data from anyplace in the world from home has extended the chances of disabled people to contribute in humanity more efficiently than ever earlier (Include Telematics Project, 2013). Most of visually impaired or blind people cannot go out easily to buy a newspaper or a magazine. If they can buy, today's technology does not allow them to read, most of visually impaired or blind people have to depend on multimedia tools like radio, television or cassettes.

2.2 ASSISTIVE TECHNOLOGIES FOR BLIND AND VISUALLY IMPAIRED USERS

Computers are still use the devices like monitors as an output device, so people have to use their eye(s) to read, write or basically controlling the computer. Blind or visually impaired peoples cannot completely do all the things that can be done easily by healthy people. Blind people are absolutely not able to cooperate with the computers without the assistive technologies. Plentiful applications are developed to provide and help the computer and Internet practice of people with blind or visually impaired. These technologies can be divided into two groups: those that assist with input and those that assist with output. As mentioned from the groups, assistive technologies that use input

style waits for users' directives, then this command processed, but the other group of applications gives the output and do not wait any commands from users.

The most preferred and developing technology for input is speech recognition. As a standard assistive technology that uses input method, it combines special software and the input devices such as microphone or headset. This provides system commands that expected by the software. Voice recognition technology is being improved regularly with the recent development in computer technologies and computing power. Voice recognition technology converts user's spoken word into meaningful commands that can be recognized by the computers. Flexibility of this technology allows developers to create hands free devices. But there is a distinction between voice recognition and speech recognition. Voice recognition requires machine training, so, speaker has to do a training because voice recognition is speaker-dependent; however, speech recognition is speaker-independent and it does not require a training stage. As Bill Gates once proclaimed; "voice recognition technology to be the future of computing itself". The potency of this technology is defined by Lee, Hauptmann and Rudnicky (1990: p .225) when they state: "The promise of speech-recognition technology is that it will remove the barrier between people and their machines." (Auptmann, Green 1981). Actually voice recognition technology is a new user interface data entry dimension. This technology can be used by not only visually impaired people but it can be used by blind people. In addition, this expertise can also be used to generate new text as a Dictaphone.

Second group of assistive technology is assist with output. This group can be listed; Braille displays, screen readers and screen magnifiers. As mentioned a number of visual assistive technologies have been developed. The screen magnifier is the most available method. Basically a screen magnifier is software that present computer screen content enlarged. Along with the software development, technology also allows factories to build bigger and better output devices. Both the hardware magnifiers and screen magnifiers are present the users but it is the screen magnifier that has become the standard in terms of assistive computer technology for the partially sighted (Fraser, Gutwin 2000). Nowadays most of the operating systems have a default screen magnifier. But there is an exception about screen magnifiers, blind people cannot use

this assistive technology, because screen magnifiers can enlarge the items and can be used by people that partially sighted.

Braille is a system that provides tactile writing and reading used by blind or visually impaired people. This system can be found in books, signs, and elevator buttons. Braille displays are hardware that enables users to read in Braille the text displayed on the computer screen. Thanks to this hardware, users can navigate computers' desktop, create and edit documents, and also use the Internet. Actually, Braille users reading electronic documents using hands instead of eyes. Synonym of Braille display is Braille terminal. The user who wants to use Braille display has to connect it to the computer via a type of connection like USB. After a successful connection, the Braille display will obtain the text on the screen. Then the screen reader will decode the text in Braille and the device will demonstrate it on its built-in Braille cells. A simple Braille display can be shown in Figure 2.1.

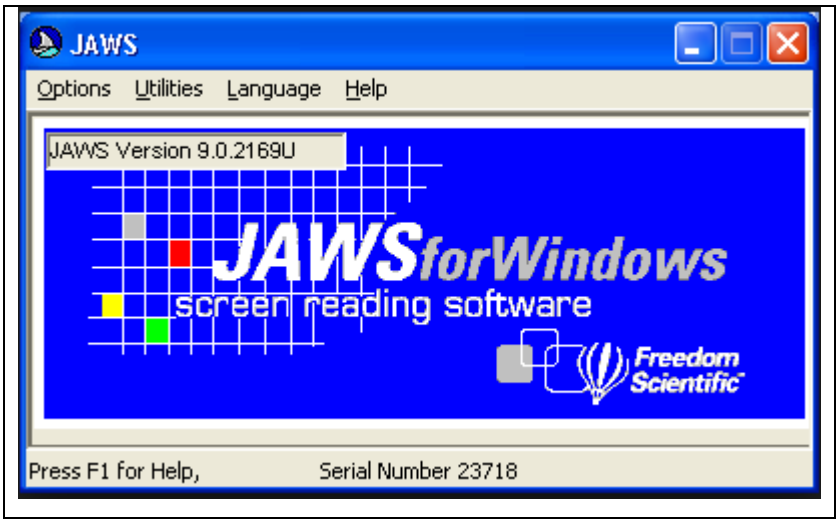
Figure 2.1: Braille display

Braille displays use pins to present Braille symbols which are generally 20 to 80 characters long. Braille display is a good assistive technology for blind or visually impaired people but it has some disadvantages. The user has to learn how this assistive technology can be used, and the truth is if the user is blind from the birth can use Braille display easier. This is because of their tactile skills are developed more. This is

considered as one of the key disadvantages of Braille display assistive technology. Another disadvantage of Braille display is speed of usage. Users, who have lost their sight recently, mostly consider Braille display slow to use. The last and the most important disadvantage of Braille display are accessing the intended information. Braille displays assistive technology uses screen reading technology which runs on the device's background; this is a problem because of the way that web sites are developed since they show unrelated information along with the targeted ones. On top of that, there are new web technologies becoming web standards so fast that a device like Braille display cannot catch up with these improvements due to limited usage of it. In addition to this disadvantages, the users want to access information have to read all the pages from top to bottom which is time consuming.

Screen readers are the last assistive technology that assists with output. It has some similarities with Braille display; Braille display makes the information appear on a Braille line that the users can read with their fingertips. In simple terms, screen reader systems speak out all the information from the screen and the text typed is vocalized. According to Braille display, screen readers are much more complicated. Blind or visually impaired people want to find information they need, and also to navigate easily on the screen. Braille display may be grouped with their simplicities like the simple one can read the active character, the active word or the current line, more complicated Braille displays can read the station of line of the application, the heading bar of the Internet browser and the items that on the menu bar. There is a problem about Braille displays that screen readers only acceptable to read output screen line by line, but today there are solution to this problem like the hotkeys that practically assigned to a piece of information. For instance; one hotkey is defined to announce the misspelled word in the application, another can be defined to read the Internet browser title, etc. Today, so many types of screen readers are available; some of them are licensed and can be bought like JAWS (shown in Figure 2.2), and some of them are open sources.

Figure 2.2: JAWS for windows - capture from application (free version)



Screen readers might be embedded into operating systems, for example, Windows operating systems uses Narrator and Linux also has the screen reader for Gnome Desktop by default. Of course these screen readers are not sufficient for the users but they are helpful for smaller tasks. Screen readers are definitely a helpful assistive technology for the users who are blind or visually impaired. However, also screen readers have some disadvantages. One of the disadvantages of the screen readers is lack of developed applications or web sites. The users can get the updated information they need from the Internet. Developers have to care about disabled people to access information. Another disadvantage is when an application is not working with the keyboard. Some of the web sites do not let users to navigate with keyboards, and force the users to use mouse instead. Unfortunately, people who have visual impairment cannot use mouse, thus they are not capable of communicate with these applications or web sites.

2.3 INTERNET BARRIERS FACED BY DISABLED PEOPLE

As most of us had seen before, poor designed structures might be a real challenge for physically disabled people. This situation is a good example of the barriers that visually impaired people faced on the internet. As mentioned, the Internet has become a powerful tool to improve the quality of life for people with disabilities. Because the Internet is a new way to connect to the outside world, work online, and participate in

web communities, research, or e-commerce for the people with disabilities that range from low vision to quadriplegia.

This new world plays an essential role for disabled people. And as mentioned, there are several kinds of assistive technologies that open a door for disabled people. However, there are some Internet barriers faced by people with disabilities.
The most challenging internet barrier is the poorly designed web sites. Designers may not understand the importance of this issue, of they may have no idea how these basic features can be built into a web page will support somebody who is not capable to read the screen or to control a mouse.

One example of an obstacle would be a photo of a prime minister on a government website with no text detecting it. Screen readers as an assistive technology cannot recognize images unless there is text supplementary with it; a blind person would have no method of meaningful whether the image is an unknown photograph or a logo, or a link to another page. If the designer adds a line of simple unseen computer code to label the photo "Photo of Prime Minister" will let the blind user to know about of the image.

With the improvement of the Internet infrastructure around the globe, web site developers are forced to design media rich content. But screen readers or assistive technologies have no way to render these multimedia objects. It would be a great help to disabled people if these objects would have captions that is not visible on the screen, but can be read by screen readers or assistive technologies.

There are some precautions to solve this issue. One of them is laws; numerous countries have passed laws to apply accessibility of websites for disabled users. As an example the United States, these laws are being published as Section 508 of the Rehabilitation Act (Section 508, 1998), which protects disabled people’s life in all parts of daily life, like education and work. In this Section all the important issues are listed, and these requirements must be traced by Federal agencies when developing government web pages. In addition to laws, The Web Accessibility Initiative is a subcategory of The World Wide Web Consortium (W3C) has published, for the same goal of Section 508,

WCAG that consist checklists. The following barriers are for the blind and visually impaired people (Babinszki, 2013).

i. Understand Disabled People

Instead of following a bunch of rules that can be found on the Internet, try to understand disabled people. Try to think thousands of blind or visually impaired people who try to access the information on the Internet. Learning the assistive technologies that is being used by disabled people is a good starting point. This will allow us to understand the daily challenges of the disabled people while they are trying to use the computers.

ii. Control Human Authentication

Some of the Internet pages that consists like registration forms, confirmation forms which make people enter a text read from an image to submit data. Actually this method helps the system to decrease the amount of spam and that prove the interacting computer is an actual human being. Known name of this method is "captcha". Although the method is useful for the system, it makes interaction with the website impossible for blind people. Screen readers can be used by blind people however; screen readers are not capable to interpret the images. There are alternative ways to differentiate actual human beings from the computers such us simple questions, easy tasks, math questions, e-mail control or sms verification. With these alternative ways blind or visually impaired people should be able to use web sites effectively.

iii. Link Text

All the web pages consist of links. When there are hyperlinks on the web page this brings two problems along with it. One of them is page links to and the second one is text links on page.

Some of the links have no definitions and the visual name can be useless and meaningless as “click here”. To simplify access to disabled people, links should have explanatory names.

iv. Headings

Web page headings should be used properly throughout the entire web site to allow assistive software to distinguish the priority and the hierarchy of the content.

v. Uncategorized Information

As it should be; all the developers or content providers try to provide as much information as possible. However, putting unrelated information into a single page is a serious problem, not just for the visually impaired users but also for sighted users. Trying to find certain information on a single page with multiple irrelevant data requires user to go through the page line by line. Visually impaired people should wait for the full page to be read earlier than they can access the information. This is time consuming.

vi. Label Images

Visually disabled users cannot take the advantages of the media rich content. However, developers can insert “alternative text” or “image caption” to make image understood. Even though, user cannot see the image itself, brief description can be helpful to give the sense of the image. These tag information can be read by the screen readers and might be able to provide information to users and make the page even more accessible.

vii. Podcasts and Videos

Web pages contain videos or podcasts also creates accessibility issues for the visually impaired users. Captioning and Audio Transcription are few of the methods for describing multimedia contents. Both of them provide a transcription of all spoken text on the multimedia content. Both of them are expensive but the easiest way is to type out multimedia content to a text file and put it down on the web page as a text alternative.

viii. Using Colors

Colors are important for everybody regardless visually impaired or sighted. Selection of the right colors can enhance web site and help people to find information that they need. Selection of the colors can improve the usability of the websites in general, and the contrasts color can provide accessibility to visually impaired users.

ix. Provide Information for Forms

Web sites often require users to fill out forms online. If these forms and fields cannot be explained clearly to the users, information provided by the users might unusable. Screen readers should be able to explain to blind people what they have supposed to do while filling out a certain form. For the screen readers to explain, developers should give proper instructions which can be read by assistive software.

x. Contact Information

Users should be able to contact the web administrator with any question they might have. Visually impaired people are not exceptions. Links to contact forms and forms themselves should be easily access by users.

If developers and designers consider these steps, they would make a difference for disabled people. Also there is much more accessibility rules than listed above. Section 508 standards in the United States or WCAG can help.

3. LITERATURE REVIEW

Visual disabilities, assistive technologies and the Internet barriers faced by people with disabilities are discussed in the previous parts of the study. The Internet barriers are the main problem of visually impaired or disabled people. To overcome the Internet barriers, technology can help disabled people. Voice recognition is one of the hot topics to help the visually impaired people.

The Internet barriers prevent visually impaired people from the online resources and benefits of the Internet. In addition, there are kinds of Information System theories that consider visually impaired people. As mentioned, kinds of theories are available but best of them must be selected for the proper result. Technology Acceptance Model (TAM) can be a fine selection for the research. TAM is the theory that generally used for the users' behavior (Lee et al, 2003). TAM claims that, while people use new technologies, there are parameters that the users looking for, to use and make it useful. Actually TAM cannot suitable to analyze behavior of the users with visual impairments, but TAM can help to determine suitable needs for specific community (Li, 2009). There are already some researches made in TAM, in addition to demonstrate that includes suitable community-certain factors, can provide clear description of acceptance behavior (Chen et al, 2011).

TAM is not enough for the visually impaired people since reliability of access to information is another essential issue. As discussed in the previous sections, web sites are not designed properly to be easily accessed by visually impaired people. For example, when visually impaired people try to search information on the Internet online, the users are unable to access other pages since buttons or links cannot be recognized by screen readers.

There are several researches on assistive technologies for the visually impaired people. A study is done that describes a user study to examine the simultaneous spatial sound for visually impaired people (Sodnik et al, 2010). Also some of the researches exist that

searches the commercial status of audio and music websites, such as "Factors that affect visually impaired users' acceptance". Making the web site accessible by the visually impaired people can increase their reach and revenue (Babinszki, 2013). Screen magnifiers are common assistive technology which is developed also called "Visual search-based design and evaluation of screen magnifiers for older and visually impaired users." (Zhao, 2006). In this research, some of the parameters, like color of the application, have been changed and tested by participants, and then results are evaluated. Research evaluation revealed users' access time and number of help requests are significantly decreased. Unfortunately this research cannot help the problems of the blind people, because screen magnifiers can be used by partially sighted people. Also there are some researches to document the general accessibility guidelines (Leuthold, 2007). Creating a new accessibility rules and compares these rules with the current ones. There are some studies on developing an internet browser (Zajicek, 2007) or creating an add-on for internet browsers (Internet Accessibility, 2008). These researches provide an advantage to partially sighted people, but it is impossible to have these assistive technologies used by blind people. In addition, by the dynamism of the internet pages, it is being harder and harder to read a web page via browsers.

3.1 VOICE RECOGNITION

According to developing technologies and the needs of visually impaired people, voice recognition technologies can deliver a path. Especially, with the automatic voice recognition technology, users can speak naturally and results can be satisfying.

The user-system performance of the continuous speech technology is an important sub-topic. One of the metric tests is the identification rate. Recognition rate generally restrained as percent of words that correctly recognized. Complexity of the system can influence the recognition rate. Advanced systems that have several thousand words reported detection rates of 94% - 98% (Karl et al., 1993; Dalton et al., 1997).

Another metric of the test is user productivity. Each system has different properties like size of the task. Despite the development, from point of performance, voice recognition systems can be or cannot be better than standard methods like keyboard or mouse. And

literature consists of many papers that compare the voice recognition with traditional methods that some of them are resulted in favor of voice recognition, and some of them are resulted in favor of traditional methods. However these results are influenced by the type and the size of the task.

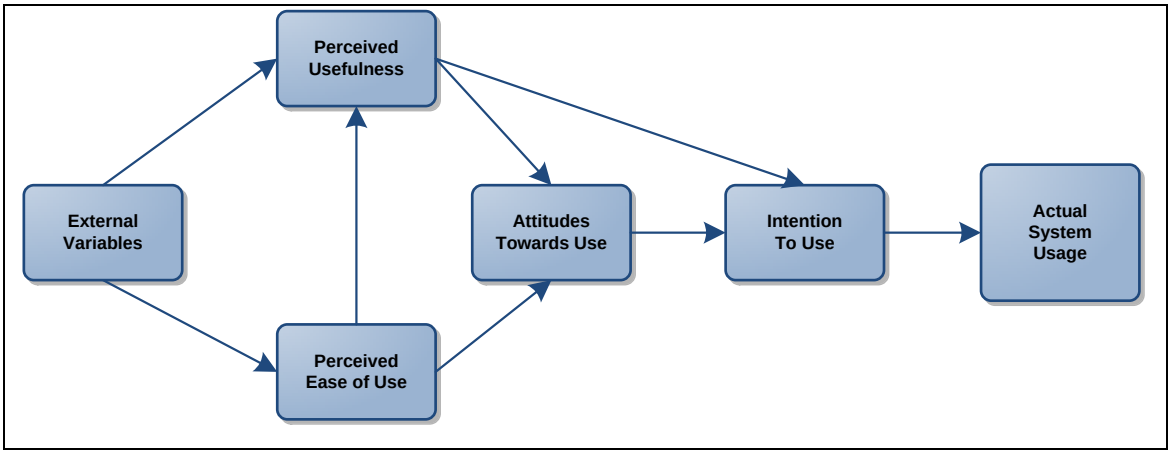
In addition, performance of the voice recognition systems has enhanced the passing years. For instance, one of the early systems has the ability of text entry rates of 8 words per minute (Dabbagh and Damper, 1985). However, by 1997, ability of the text entry improved to 25-30 words per minute (Mello, 1997).

As usual, human factors influence the voice recognition systems performance. The user must know or learn how to speak with the system for the best performance. Voice tone and pause time are some of the parameters that influence the system performance.

3.2 TECHNOLOGY ACCEPTANCE MODEL

TAM was created from the Theory of Reasoned Action (1979), can be shown Figure 3.1, to test the adoption of a new technology by people. According to TAM, there are two significant factors that change or affect the user acceptance. One of the significant factor is perceived usefulness and the second is perceived ease of use of the technology.

Figure 3.1: Technology acceptance model



Perceived usefulness is defined by Fred Davis as "the degree to which a person believes that using a particular system would enhance his or her job performance".
Perceived ease-of-use is defined by Fred Davis as "the degree to which a person believes that using a particular system would be free from effort" (Davis's, 1989).

Actually both these factors have relation between each other with actual system or technology usage. As guessed, perceived ease of use affects the purpose to use a new technology not only directly but also indirectly via perceived usefulness. This is the relation between the important factors. This refers the increasing perceived ease of use emotion can increase the users' technology acceptance. The secondary relationship may be introduced that the easy use of a technology can provide it more useful.

TAM has shown that the perceived ease of use and behavioral aim has a direct relation between which is more relevant. However, perceived usefulness that has secondary relationship is fewer significant to technology users.

TAM has been approved and generally accepted. Also TAM has been used to test users' acceptance of Web-based systems under some situation; web usage (Agarwal&Karahanna, 2000; Riemenschneider, Harrison, &Mykytn, 2003), online shopping (Devaraj, Fan, &Kohli, 2002; Lin & Lu, 2000), online learning (Cheung, Lee, & Chan, 2002) and others (King, He, 2006). All these studies and fields have proven TAM to be a "powerful and robust predictive model of a person's willingness to accept and use a technology" (King, He, 2006, p. 751).

In addition, TAM provides to advance more and more useful ways for developing Information System usage as a guide for developers or researchers. In this paper, TAM has been chosen to create a better model, especially for the acceptance performance of visually impaired people.

3.3 ACCESSIBILITY VARIABLES

According to Culnan's (1984) work, there is an essential parameter that influences the user's acceptance of a technology, accessibility of the online resource. This parameter

consists of two dimensions: information accessibility and physical accessibility. Easy one of these dimensions is physical accessibility. This dimension refers if a device is available to the user. Cell phones, tablet computers and personal computers are the examples from the point of accessing websites. Users that want to access websites have to use electronic devices or physical accessibility. The other dimension is information accessibility. Information accessibility dimension means that a user can use the system to access the information.

According to Culnan, the second dimension, information availability, can be categorized into three sub-dimensions: ease of use, convenience, and reliability. First sub-dimension is ease of use means that a user finds the technology easy to use. In addition, this sub-dimension includes the concepts of user friendliness, flexibility and handling the mistakes of users, such as writing an unexpected string or clicking an incorrect button. Second sub-dimension is convenience provides users to access the information without barriers and convenient. The last sub-dimension is reliability refers a system that consistent, error free and access the information reliably. In addition, there are some studies in the literature that support the Culnan's work.

4. HYPOTHESIS

According to acceptance models, when all the parameters are equal in two systems, using the interactive system is easier than the other system and it requires less effort (Davis, 1989). This interactivity is absolutely relevant to sighted users. In addition, the Internet technologies tend to have more graphic-intensive content. These developments are generally for the sighted people. As mentioned, lack of design issues prevent visually impaired people from accessing to certain information. There are kinds of applications to provide them certain information, however, with the design problems and interactive pages, job of these applications are complicated. Screen readers are the most common applications and JAWS is a screen reader application developed for the Windows operating systems and widely used around the world (Earl and Eventual, 2000).

According to Nielsen, usability is actually a quality property, which shown in Table 2, how a system can be used easily. A web site or a project is usable if it satisfies five criteria shown in Table 4.1. This leads to the following hypotheses. We hypothesized that three essential point to access certain information; task performance, error rates and user satisfaction. The first parameter learnability and the third parameter memorability are ignored and can be used for long-term memory tests. Long-term memory tests are out of scope of this research.

Table 4.1: Nielsen's quality components

Learnability	How easy is it for users to accomplish basic tasks the first time they encounter the design?
Efficiency	Once users have learned the design, how quickly can they perform tasks?
Memorability	When users return to the design after a period of not using it, how easily can they reestablish proficiency?
Errors	How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
Satisfaction	How pleasant is it to use the design?

Based on these issues and researches, developing a new application can provide more utilities for the users, not only for visually impaired people but also for sighted, to access certain information without hands and eyes. In addition, all these information leads to the following hypotheses:

H1 : Efficiency
H2 : Errors
H3 : Satisfaction

The performance of the newly developed application is expected to be superior compared to JAWS, a control application, in terms of task completion time, error rates, and satisfaction.

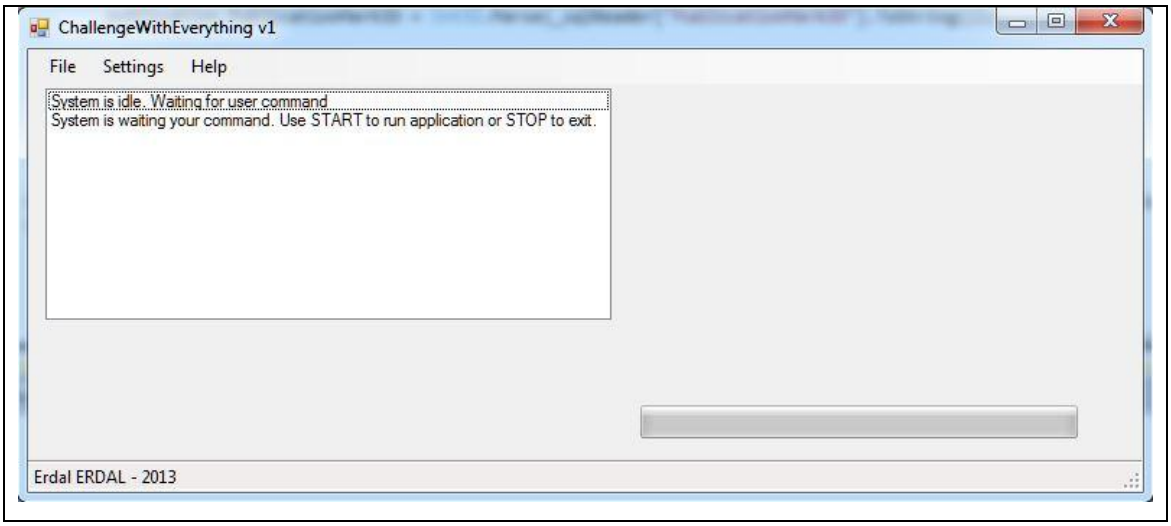
5. METHODOLOGY

5.1 THE EXPERIMENTAL TASK

5.1.1 The Software

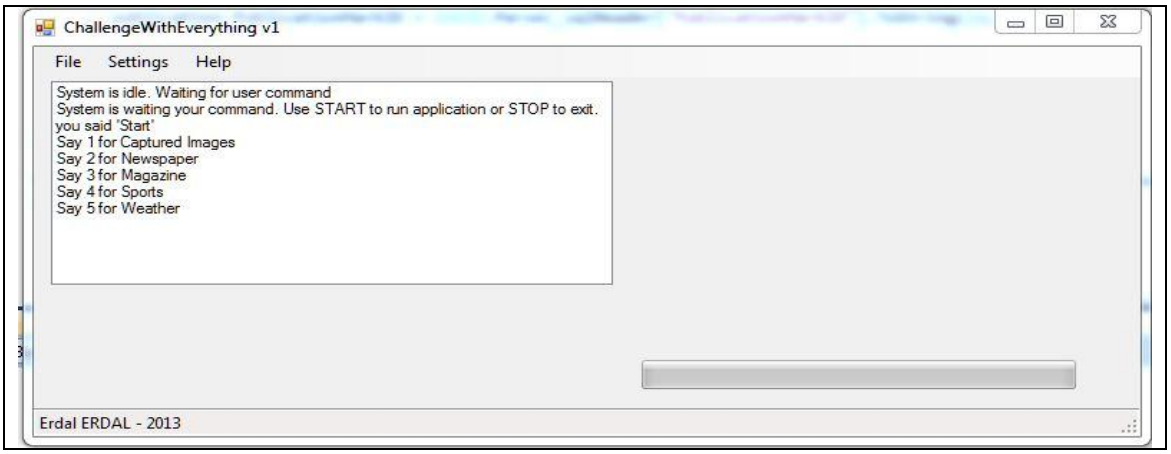
The newly developed application's features and development life cycle details are explained. The newly developed application started to run with the command of "Start", this keyword is a predefined command that starts the application. Until the users say "Start" keyword, the application waits idle and alert the users that "I'm waiting you" as shown in Figure 5.1.

Figure 5.1: Application start



"Start" command runs the application. The application starts to explain the first menu. The users can select the type of the information that they want in the first menu as shown in Figure 5.2.

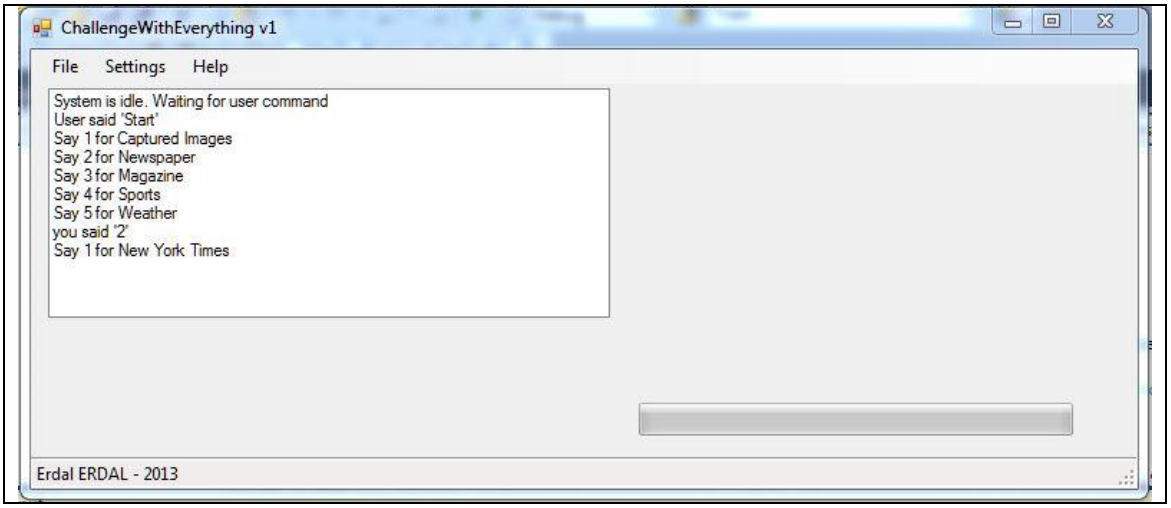
Figure 5.2: Application information type selection



The system is also waits for the second selection in the idle status. In this status, another predefined keyword may be commanded by the users; the idle status ends and predefined keyword operation starts.

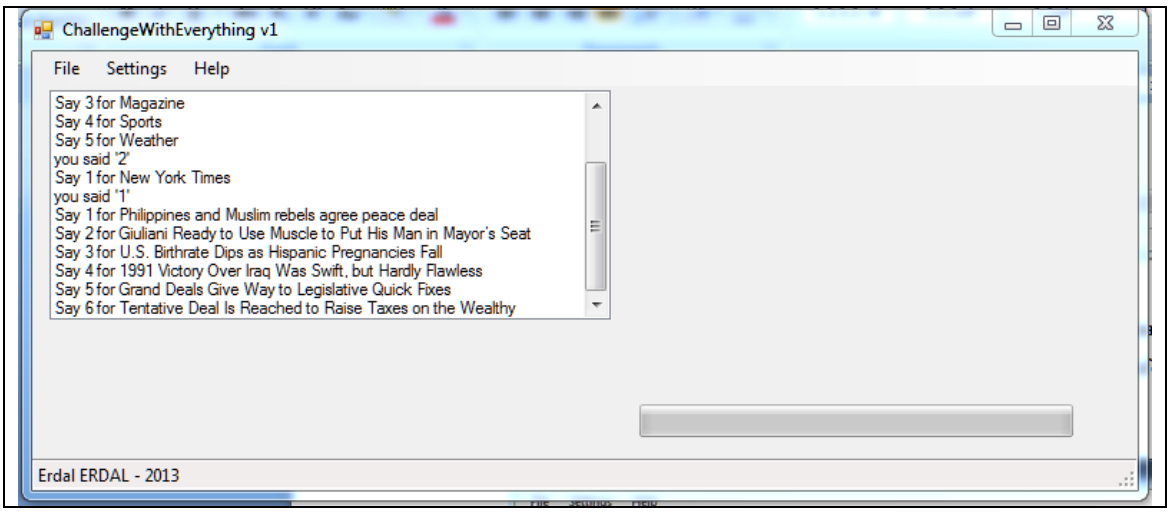
Second selection is the sub category listing the brands of the information selected previously. Brands of the selected information are listed as shown in Figure 5.3.

Figure 5.3: Application information brand selection



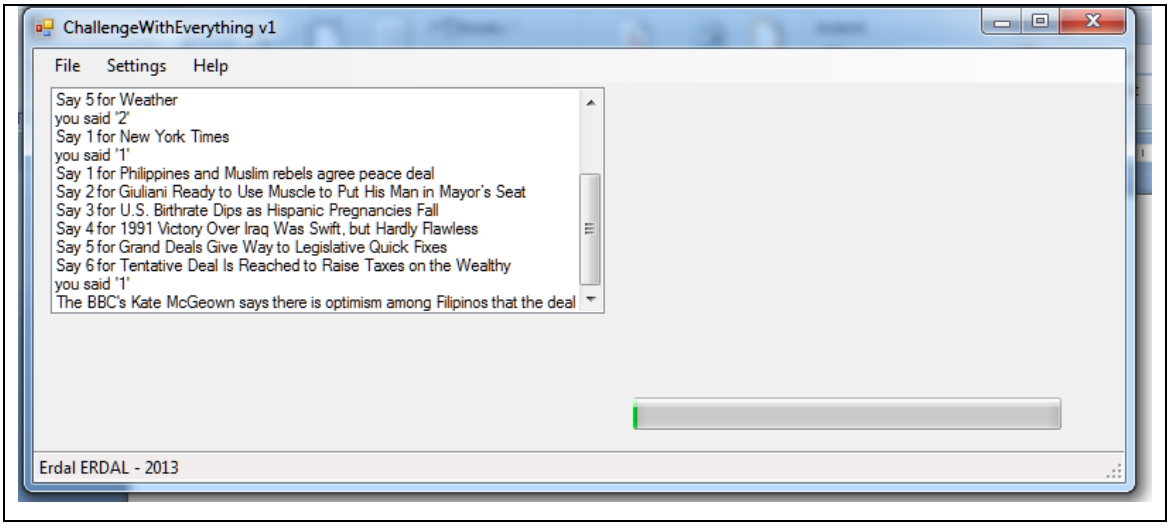
The users select the information type and the brand of the information in order, the subject headings are listed for user's selection. The users select the information that they want access.

Figure 5.4: Application subject heading selection



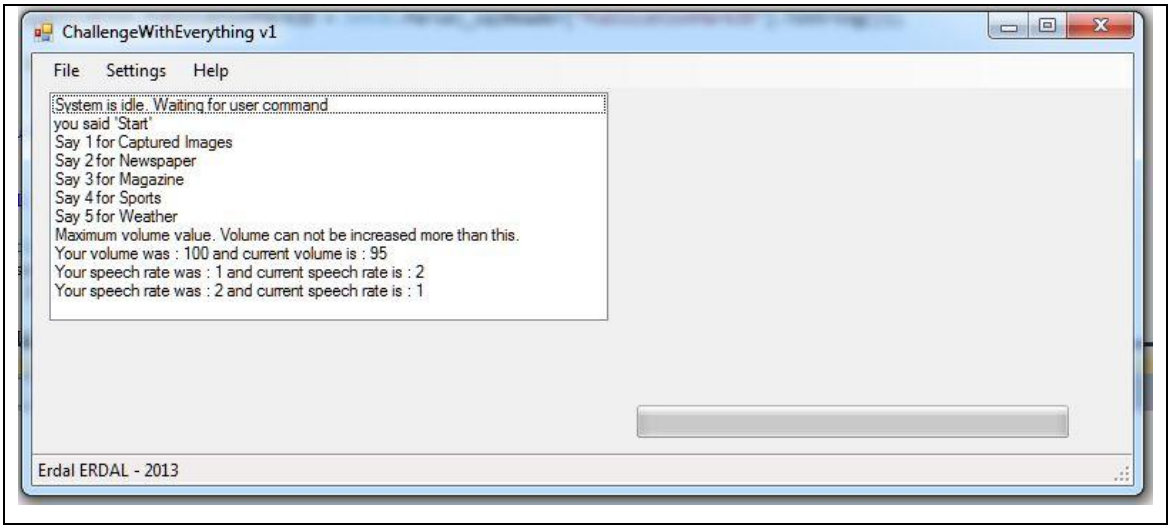
The subject headings are listed and the user selection is waiting in this status. The users select the subject heading and the application start to read the selected information as shown in Figure 5.4.

Figure 5.5: Application certain information reading



The setting of the application can be configured by the user with predefined words. Settings can be configured by user with the spoken predefined commands. Speech volume and speech rate can be increased or decreased by the users. (Figure 5.6) Training of setting configuration is a part of the training sessions.

Figure 5.6: Application settings



5.1.1.1 Aim of software

The main goal of developing new software is to provide certain information to visually impaired people. Because visually impaired people have no ability to use computers with sighted people. They cannot use input or output devices like mouse, keyboard or monitors. Using a computer to access the certain information can be possible via voice recognition technologies.

The software can be used via headset and microphone. Just start the software and wear the headset and microphone is enough to access the certain information. Just start-up the software with the command keyword, like start or go, then the software enumerates all the options can be selected by the users. Users select the options until they find the information that they want to access. This workflow based on the logic of fishbone diagrams. Application can also be closed with a command like “Stop”.

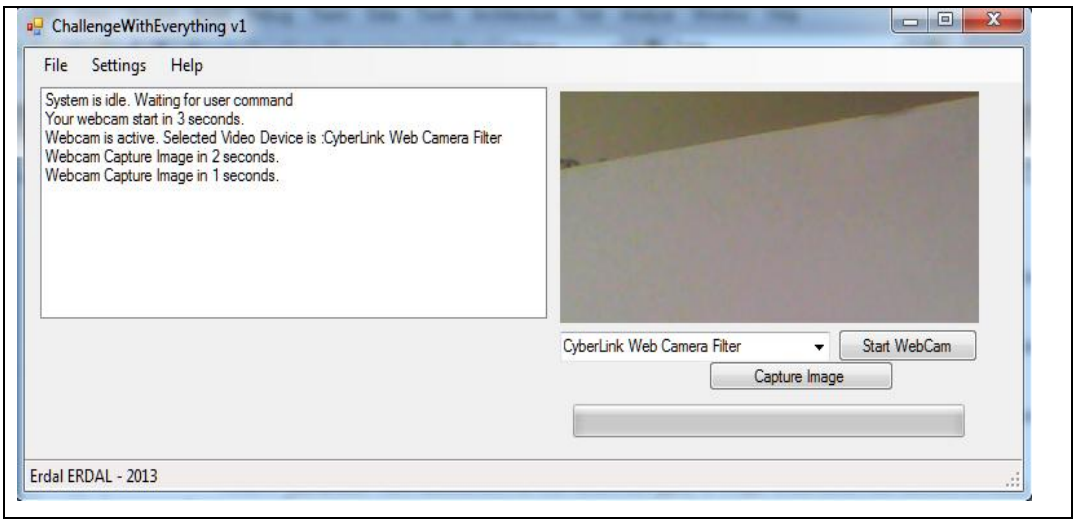
The software was developed as a windows form application, so it can only be used on Windows based platforms. The reason for selecting Microsoft technologies is the widespread usage and compatibility. Microsoft .NET framework (http://www.microsoft.com/net) provides convenience and easier use. C#.Net was selected as the programming language. Microsoft SQL Server (http://www.microsoft.com/en-us/sqlserver/) is used because of the relational

technology between Windows forms. However, this does not mean that entire the data are static. Data can be inserted dynamically via SOA technology like web services. This dynamism helps the application to stay up-to-date. Charity organizations, social responsibility organizations, companies such as newspapers or televisions can supply certain data in a stated format.

Features of the developed application are listed below:

i. Application can be started via a predefined keyword.
ii. Application can be stopped via a predefined keyword.
iii. Entire menu is read by the software.
iv. Entire menu is automatically ordered in a sequence and it is enough to say sequence number for selection.
v. The users can volume up/down of speaker via their own voice.
vi. The users can speed up/down of speaker via their own voice.
vii. The users can save the record that listened.
viii. The users can go to the main menu.
ix. The users can take a photograph and the application save the original photo. Then the Optical Character Recognition (OCR) operations save the texts on the photo. User can access the text saved to database for the future readings. OCR operation enables users to read scanned or photographed documents.

Figure 5.7: Application ocr operation

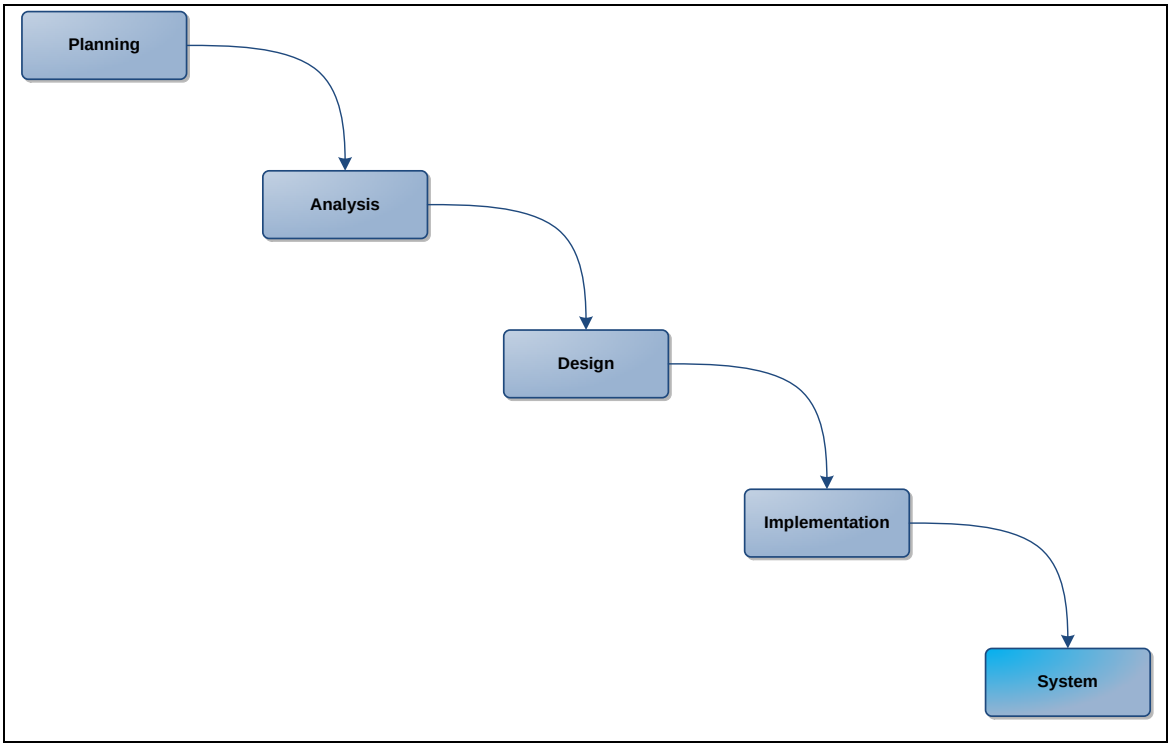


Developed features can provide visually impaired people to access the certain information without hands or eyes.

5.1.1.2 Waterfall model as a software development model

For developing an information system, System Development Life Cycle (SDLC) provides the foundation for the processes. There are formalized approaches to implement SDLC named methodology. Also, there are many kinds of methodologies that can be varied by the scale of the information systems. One of the methodologies is Waterfall Development that is used widely. With waterfall development, all the phases of software development are proceeding sequentially. (Figure 5.8) (Dennis et al, 2009)

Figure 5.8: Waterfall model



Waterfall model has some advantages. Analyzing and planning phases are completely finished before the development phase. This approach reduces the number of changes required throughout the project. This model has also some disadvantages, all the phases take time to finish, and this means that there may be problems about this like forgetting the main purpose of the project.

In addition, there are some criteria that can help developers to select the best methodology. As shown in Figure 5.9, there are the methodologies that can be selected to use and benefits of methodologies towards some parameters (Dennis et al, 2009).

Figure 5.9: Methodology selection

Usefulness in Developing Systems	Waterfall	Parallel	V-Model	Iterative	System Prototyping	Throwaway Prototyping
with unclear user requirements	Poor	Poor	Poor	Good	Excellent	Excellent
with unfamiliar technology	Poor	Poor	Poor	Good	Poor	Excellent
that are complex	Good	Good		Good	Poor	Excellent
that are reliable	Good	Good	Excellent	Good	Poor	Excellent
with short time schedule	Poor	Good	Poor	Excellent	Excellent	Good
with schedule visibility	Poor	Poor	Poor	Excellent	Excellent	Good

There are two reasons to select the Waterfall Model in this development process. First; all the requirements are clear, technology is familiar to developer and users, and there is no time restrictions in development phase, in addition, this system is complex and reliable. Second reason to prefer waterfall model is widely used and still the most useful model.

5.1.1.3 Requirements analysis

The basic process of the analysis consists of three steps:

i. Recognize the current situation (the as-is system),
ii. Identify development needs,
iii. Explain necessities for the new system (the to-be-system).

The most important ability of this session is critical thinking. In this session, recognizing strengths and weakness can enforce the project status. Some of the assistive technologies are examined; advantages and disadvantages of them are defined clearly. They are insufficient in the face of this development. After that, requirements of the to-be-system are determined.

Finally, decision made on development model of the software development is waterfall. Waterfall methodology assigns major time to understand the as-is system and recognize enhancements before moving to detention of requirements for the to-be system.

5.1.1.4 Software design

In this phase of software development, how the new system will be operated is determined. The aim of the analysis phase is to understand what the business needs. But, the main aim of the software design phase is to conclude how build it. Actually, software design phase consists of the determination of system architecture that must satisfy the system's requirements.

The system acquisition strategy is determined as packaged software. Packaged software is software that has been coded; it consists of parametric structures that enable users or system administrators to configure some of the features. However, it doesn't provide a custom solution. Developing this type of software is efficient, easy to install and useful. Based on the information gathered, developing Windows form application arguably is the best possible development environment. These types of applications allow us to develop package software; in addition, development and coding of the applications can be done easily. There so many providers to support the application and database independent structures simplify the development.

5.1.1.5 Implementation and integration

In this phase, building of the new system starts. Developing the new system's software or basically coding phase is the largest part of this phase that requires time, effort and money. In this phase, it is significant to develop a system that is appropriate for development. During the improvement of the application, modularity is the most important constraint. In general, modularity has an essential role in development phase of all package software.

While we are developing the application, there are some essential parameters that must be considered. These parameters are;

i. Modularity : Application can be separated and recombined. According to modularity parameter, we are trying to develop the application that all the functionalities are independent and consist of interchangeable modules. By this parameter, it is easy to implement or develop the application based on developers' requests.

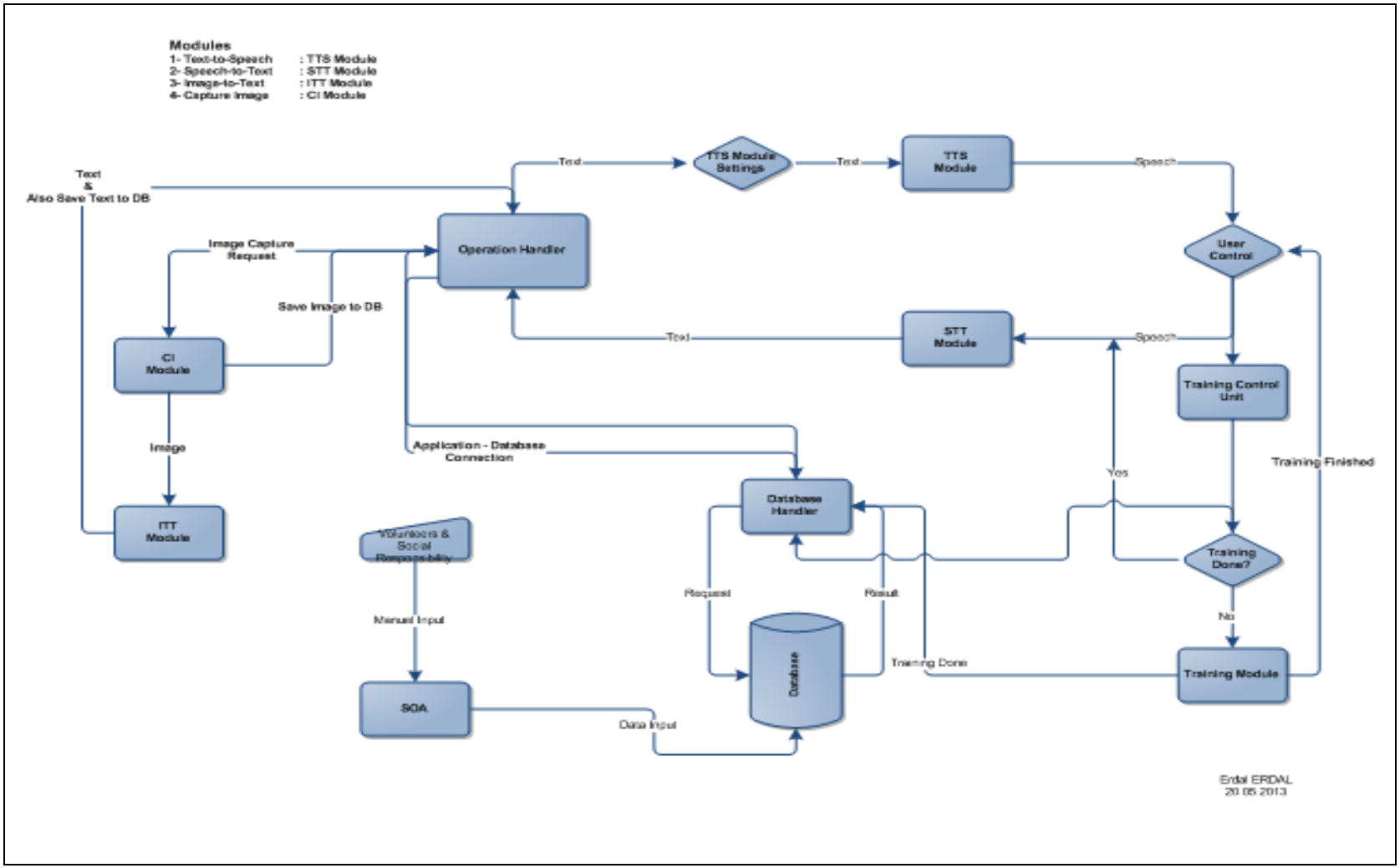
ii. Customization: There might be some modifications required while the application communicates to the user. Such as, there are some messages in the application that inform the users, if all of these messages identified in the code of application as static variable, it is too hard to change all of them. But in the application, all kind of messages or variables identified dynamically. This dynamism provides environment to handle software changes easily.

iii. Flexibility : Thanks to modularity attribute, when external or internal changes occur in the application, it is easy to handle it in a timely and cost-effective manner.

iv. Reusability : This attribute plays an essential role in the application. Owing to reusability, new functionalities require less effort to develop. This attribute reduce implementing a new function time. Increasing in the testing time is the disadvantage of reusability but it has more advantages than its disadvantages.

Our application is developed under all these conditions and information. Technical infrastructure can be shown in the Figure 5.10. Considering all these attributes or known issues can increase the quality of software development and future development.

Figure 5.10: Technical infrastructure



5.1.1.6 Testing

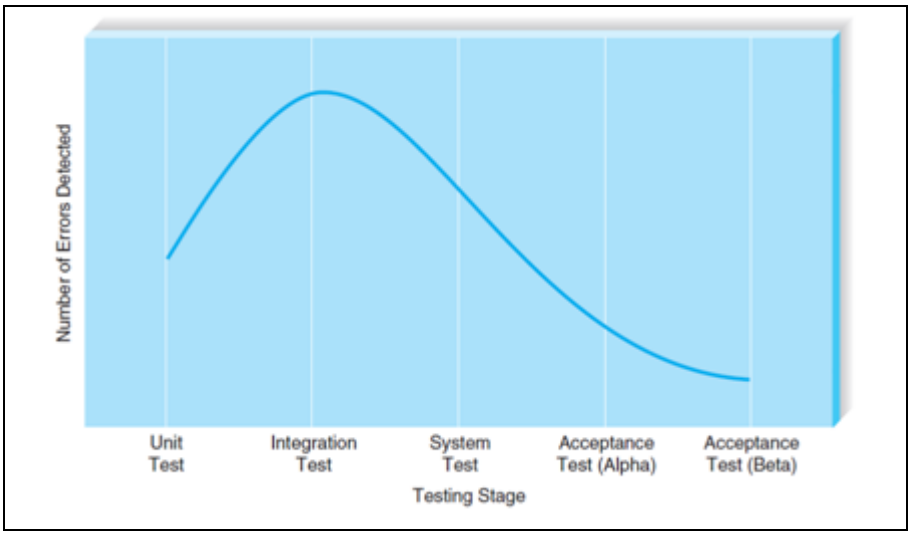
After the implementation, the next step is the testing phase. Testing phase is at least as important as implementation phase. Giving an example may show the importance of testing, software bugs are estimated to cost to the U.S. economy $59.5 billion annually. (NIST Report, 2002) In addition to this example, any single problem can stop the work flow and prevents visually impaired and partially sighted user to benefit from the application.

Until the application passed its testing, it cannot be considered as finalized. In this phase, all the modules of the application are tested. Actually, testing operation is done module by module. After all test cases are finished, software integration process is tested.

There are four general stages of tests; unit tests, integration tests, system tests, and acceptance tests. According to error discovery rates as shown in Figure 5.11, different steps are taken for the different test stages. (Dennis et al, 2009)

i. Unit Tests : Module by module tests is finished. In this test, each module or function control that performs each function or not.
ii. Integration Test : After modules are integrated, a group of modules are working or not. Set of modules have to work together with no error. This test is also done.
iii. System Test : In this phase of test, all the modules or functions are tested that they are working together without an error.
iv. Acceptance Test : This test is not appropriate this phase. Because it's planned that this test is done in the following sections of study.

Figure 5.11: Error discovery rates for testing stages



(In Dennis, 2009, p. 441)

Although, the application is developed especially for visually impaired people, for the testing purpose a small screen is used to observe the processes. This screen enables to see the words or sentences of application and user selections. By this feature of the application, consistency and reliability of the application is tested.

5.1.1.7 Maintenance

After all the phases of development, a maintenance necessity has been occurred. So the application is debugged to improve performance or/and other attributes. In testing phase, some bugs are discovered and they are debugged during the test.

In addition, some performance problems are detected and they are fixed as well. Once the users start using the application regularly, there might be more errors including error correctness, enhancements of capabilities and optimization.

5.1.1.8 Planned future developments

Development of the application has been finished; however, there are some planned future developments for the application like creating an application that is platform independent. This application can retrieve data from the various internet sources like

online newspapers, magazines or blogs. However up-to-date data can only be provided by these companies. And some companies might even provide audio books etc. Developing a new application which consists of all these features can change the user experience positively.

5.1.2 Training

User may need a learning curve before they start using the application. However, to adapt the application users need prior training. Necessary skills to use the application properly can only be achieved after appropriate training. The developed application may be easy-to-use or user friendly, but the users always show resistant. Training is the best option to solve this problem.

The main aim of the training is helping the users to complete their tasks rather than teaching the systems. There are types of training approaches. As packaged software, computer-based training (CBT) is the best model. In this model, computer supported training is provided to users. The planned training session flow diagram is defined in the Figure 5.12.

The developed application starts with a small training for the beginners. Application controls users' first experience and then automatically redirects users to training mode as shown in Figure 5.13. In this mode, general information has been given to users and real-time training is provided.

As shown in figure 5.11, general flow of the application can be described step by step as follows. The training operation greets the user and checks the voice input and output devices. Once the input and output devices are set, working properly and approved by user with the spoken word "yes", then user asks the application to proceed. Training process asks users to say some certain keywords and application make users repeat after the application itself. The application includes nine predefined keywords and users can configure the settings of the application with these predefined keywords. It is expected from the users to increase the volume level of the application and decrease the speech rate of the application with those predefined keywords. Upon completion of the first part of user training; application expects from the user to select certain topics and

information listed under these topics to complete the training. This part is a simple demo of the developed application. Once users finish the training session and system redirects the users to the main application.

After the completion of the user training, user will be registered to the system as “trained” and won’t be asked for the training session the next time the application run. If the users want to do a training session again, it is enough to say "training" which a predefined keyword is.

Figure 5.12: Training session flow diagram

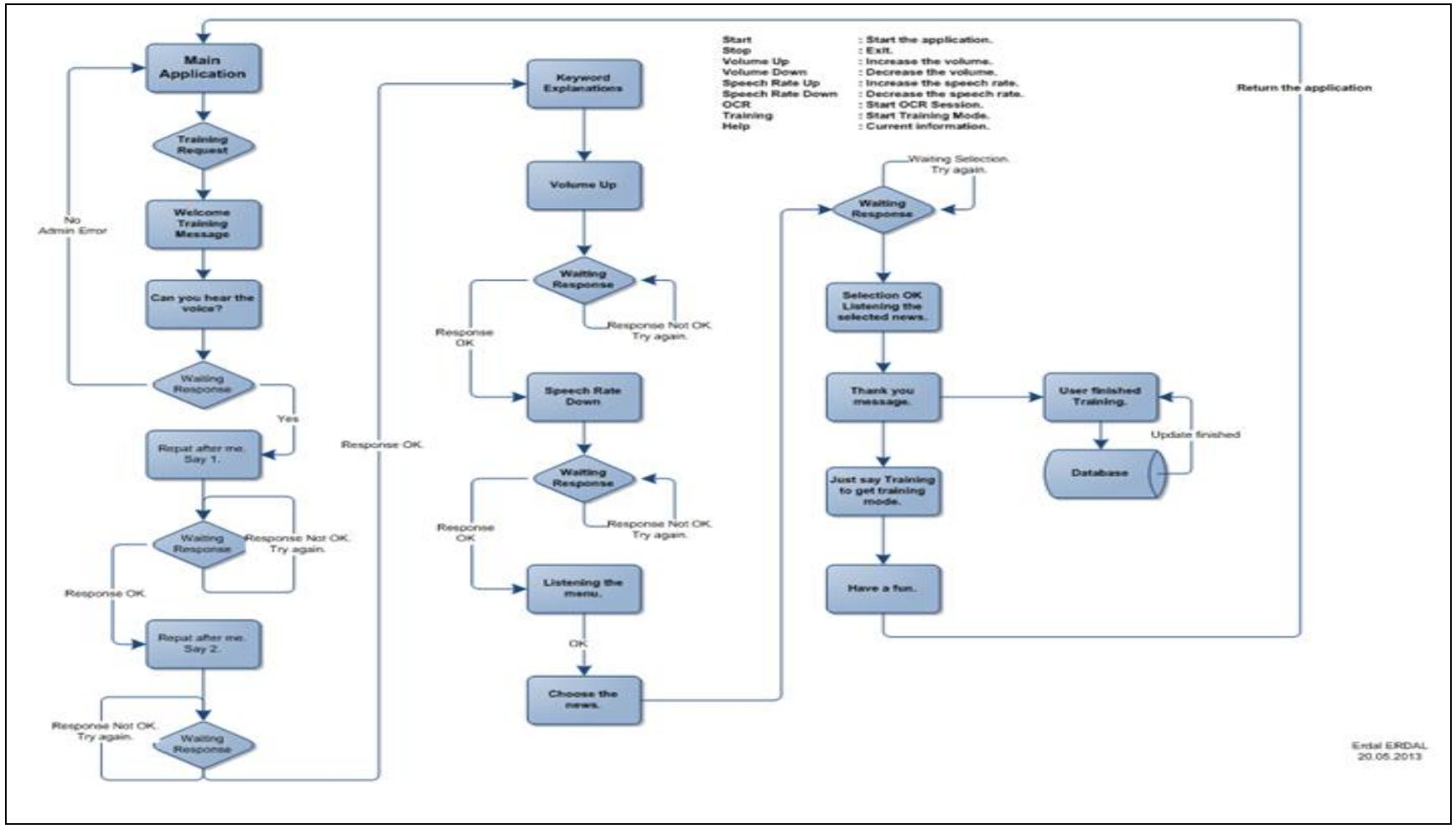
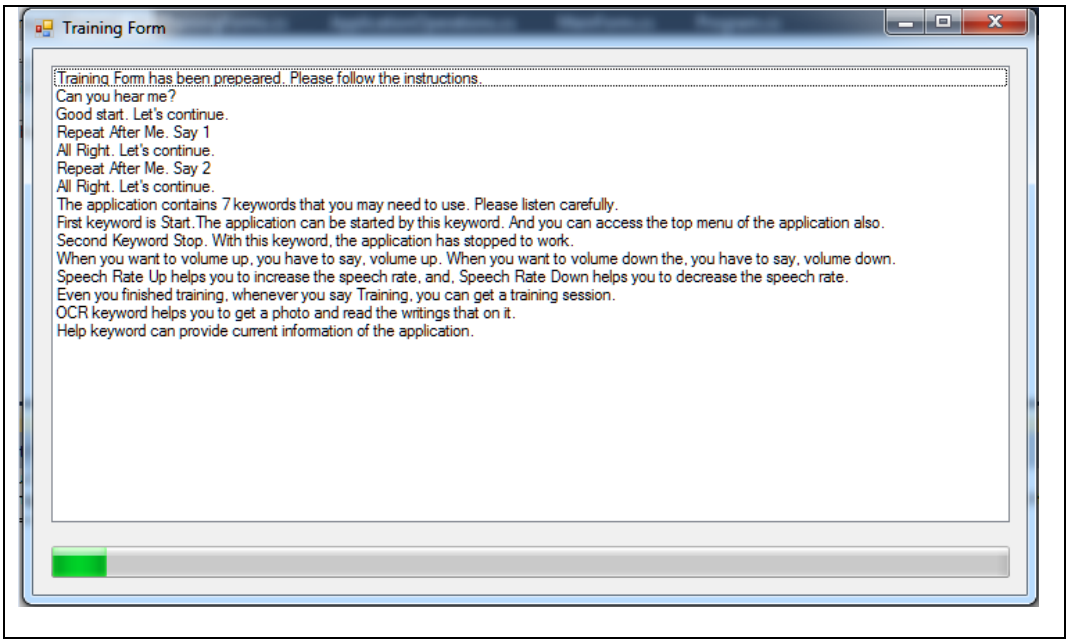


Figure 5.13: Application training mode



5.2 APPARATUS AND MATERIALS

Samsung RF510 notebook computer was used for developing and the experiment. Mentioned computer's specifications are; Intel Core i7 1.60 GHz CPU, 6 Gb Memory, 600 Gb hard disk, 4095 Mb shared Nvidia GeForce GT 420M video card, 15.6 inch screen with 1366 x 768 recommended pixels resolution. Even though this system is very powerful, application can run on simpler computers. This application is not tested for the minimum requirements. In the development phase, external Samsung monitor, Logitech mouse and Microsoft keyboard are used. In the development and experiment phases, Logitech H150 Stereo Headset is used as an audio input and output device.

5.3 PARTICIPANTS

Participants are the indispensible parts of this study. However, the application developed in English, and it's too hard to find participants who can speak English fluently therefore participant study was the major setback of the study. Yet, control application is in English, both applications will be tested in English. By this means; both applications will have equal advantage or disadvantage through tests.

All the participants need to be legally blind to be able to participate in these tests. (Less than 2% remaining vision). Eleven participants were recruited for the experiment. Due to the setbacks of the study, it's too hard to find the appropriate participants. It's an obligation to understand English language; hence, all the participants should be educated and able to use computers. As mentioned, a small training is done for the developed application, but after these detected setbacks, it's planned to train them for the other control application.

Eleven participants were recruited for the experiment. All the details can be shown in Table 5.1. Six of these participants (P1, P2, P3, P4, P5, P6) my colleagues and they are volunteered for this study. Three (P7, P8, P9) of them are friends from the university and the rest (P10, P11) are close friends of mine who can speak English and also volunteered for this study.

Table 5.1: Participants information

Participant	Gender	Age	Educational Years	Computer Experienc	Experience of Screen Reade	Frequency of Web Browsin	Nature of Web browsir
P1	M	24	16	Used	Yes	Daily	Work, Email, Social
P2	M	51	16	Used	No	Weekly	Looking things up
P3	M	22	16	Used	No	Daily	Work, Email, Social
P4	F	28	18	Used	Yes	Daily	Work, Email, Social
P5	F	21	18	Used	No	Daily	Work, Shopping, Study
P6	M	33	16	Used	Yes	Daily	Work, Email, Social
P7	F	21	18	Used	Yes	Daily	Work, Email, Social
P8	M	27	16	Used	Yes	Daily	Work, Email, Social
P9	M	28	17	Used	No	Daily	Work, Social
P10	F	23	18	Used	Yes	Daily	Work, Email, Social
P11	F	29	17	Used	Yes	Daily	Work, Email, Social
Avarage		27,91	16,91				

The average age was approximately 28 years (Range: 21–51), the average education years was approximately 17, more than 90 % of them browse the web sites daily and the gender distribution was 58% male and 42% female.

5.4 EXPERIMENTAL PROCEDURE

An experiment was conducted to evaluate the newly developed system in terms of task performance, error rates, and perceived user satisfaction. The experimental procedure was explained to the subjects in details. It was performed in a controlled environment with the guidance of the facilitator. Each session by the subjects was observed and the

experiments were recorded by a handy cam for further analysis. A computer with the suitable compatibility, and a headset were provided. Each participant was asked to attend single session to perform the given tasks on both applications; newly developed one and the control application.

5.5 TASK AND PROCEDURE

The developed application provides information to visually impaired people. The software has a database which can store the entire information that user requests. The visually impaired users can access the information with the voice commands. In this study, the developed application is examined by three areas:

5.5.1 Task Performance

Task Performance is one of the most important subjects in software development and also it is playing an essential role in the evaluation part of this study. Task performance covers the subjects of the speed, capacity and reliability of the system. To test this subjects, three tasks is defined that must be completed by the users. These three tasks will be tested with each application; developed application and control application. These two applications will be assessed in terms of task performance.

i. Accessing one of the determined daily news and details.
ii. Accessing one of the determined sports news and details.
iii. Accessing the current city weather information.

A sample timer is started for each task and each application. Amount of time calculated for each operation, and compared between two applications. This comparison gives the task performance result of each application.

5.5.2 Average Number of Errors

All the errors that were observed during task performance execution are saved. All of the error messages are logged with the error message details and task details. With these

logs; errors can be analyzed statistically, but for statistical analyze, errors must be occurred more than once.

5.5.3 Subjective Evaluation of the User Satisfaction

Many applications target the users and try to provide service to larger population of visually impaired people. So the user satisfaction has an essential role on usability of the developed software. For these reasons, a user satisfaction survey and comparison is required between the applications. There are some articles that contain similar survey sessions (Loiacono et al, 2012) (Molnar, 1996). The survey questions are not evaluated from these articles but some of them are written because of the authenticity of the study.

Because of the time constraints, instead of using complex satisfaction scale, five-point Likert Scale is selected for all the evaluations. In addition, five-point Likert scale was chosen to ensure familiarity: In Turkey the school scores use a five-point scale.
In the prepared survey, not only user satisfaction is measured but also user satisfaction comparison is measured between the developed application and control application. To avoid the users from bias results and to provide fair results, which application is the first application or the second application is not declared to them.

6. RESULTS AND ANALYSIS

The developed application and control application were used for analyzing and getting the accurate results between two applications. Eleven participants were recruited for the experiment. Three tasks were defined to each participant. These three tasks are repeated both on newly developed application and on control application for each participant. Sixty-six different experiment events were created and recorded. Numbers of errors were identified. After each participant finished the six experiments, they attended a survey that was used to measure the user satisfaction.

Data is statistically examined. Statistical Package for the Social Sciences (SPSS) statistics software package was used for statistical analysis. Gathered information was used as a dataset in SPSS.

Two different datasets were created. Task performance and average number of errors were evaluated in the first dataset. Variables schema was created with the parameters experiment id, group no, task no, participant id, task completion time, number of errors, participant's age and participant's gender. Gathered dataset is shown in Appendix Table A.1a. Another variables schema was created for user satisfaction which includes questions and group id columns. User satisfaction values were examined in the second dataset as shown in Appendix Table A.1b. General results of user satisfaction parameter also can be shown in Appendix Table A.1c. Each datasets were analyzed using SPSS but using different methods because datasets were different from each other.

Analyzes were done by considering the task performance, error rates and user satisfaction parameters.

The three variables in this research included two performance variables, task completion time and errors, and one user satisfaction. Each variable were analyzed.

6.1 TASK PERFORMANCE

Task performance means the total time of each task. Each task's completion time was recorded by the facilitator. Defined completion time unit is "seconds". Task completion time of each task saved to SPSS and analyzed with independent-sample t test. Independent-samples t test selected as a t test type because this test is the suitable test for our data.

A hypothesis was created for comparing the mean scores in a task between newly developed application and control application.

Hypothesis: There is a significant difference between the mean score by the task completion time of newly developed application and control application.

Independent-sample t test wants us to select the grouping variable and test variables. Group variable is experiment "group no" for our dataset because each task is experimented on each group. Group variables value, group no, were defined that 1 represents the newly developed application and 2 represents the comparison application. Test variable is selected task completion time. Independent-samples t test executed. Output of the test was shown in the output window of the SPSS. (Table 6.1)

Table 6.1: Task completion independent samples test results

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Task Completion Time	Equal variances assumed	65,977	,000	-8,226	64	,000	-323,9848	39,3844	-402,6641	-245,3055
	Equal variances not assumed			-8,226	32,714	,000	-323,9848	39,3844	-404,1396	-243,8301

Independent-samples t tests show us two results from different t-tests, one assumed equal variances and the other unequal variances. Which result to use, depends on the result from the Levene's test because the experiment has more than one group. Levene's test for equality of variances p-value (Sig.) is ,000 in the table. This value is less then ,005 (p <= ,005) we can assume that the variances of two groups are not the same. We have to use unequal variance results.

Definition of the results that is used, t-test results can be evaluated. The value of Sig. (2-tailed) of t-test for equality of means is ,000. Since the p-value for Sig. (2-tailed) is ,000 (,000 < ,005), we accept the hypothesis and conclude that there is a significant difference between the mean score of newly developed application and control application. This hypothesis can be interpreted that we can say 95% of trust, there is difference between two applications.

We found that there is a significant difference between these two applications belongs to completion time values. Group statistics is a table that is evaluated by SPSS. (Figure 6.2)

Table 6.2: Task completion group statistics

Group Statistics

	Experiment Group No	N	Mean	Std. Deviation	Std. Error Mean
Task Completion Time	Newly Developed Application	33	57,509	23,7595	4,1360
	Control Application	33	381,494	224,9949	39,1666

The group statistics table may show the difference between these two applications clearly. By the task completion time, newly developed application mean value is 57,5 and control application mean value is 381, 4. This statistics are proving that, by the task completion time, newly developed application is better than control application.

6.2 NUMBER OF ERRORS

Number of errors means that the total number of errors in each task. Each task's error numbers were recorded by the facilitator during the sessions. Number of errors for each task saved to SPSS and analyzed with mann-whitney u test which is the non-parametric equivalent of independent sample t test. Instead of parametric tests, using a non-parametric test is decided by the help of the kolmogorov-smirnov test.

Hypothesis was created for comparing the mean scores in a task between newly developed application and comparison application.

Hypothesis: There is a significant difference between the mean score by the number of errors of newly developed application and comparison application.

Group variables and test variables are given to SPSS. Group variable is experiment "group no" for our dataset because each task is experimented on each group, like the task performance analysis. Group variables value, group no, was defined that 1 represents the newly developed application and 2 represents the control application. Test variable is selected number of errors. Mann-whitney u test operation started.
Output of the test was shown in the output window of the SPSS. (Table 6.3)

Table 6.3: Number of errors test

Test Statistics[a]

	Number of Error
Mann-Whitney U	445,000
Wilcoxon W	1006,000
Z	-1,547
Asymp. Sig. (2-tailed)	,122

a. Grouping Variable: Experiment Group No

The value of Sig. (2-tailed) of t-test equality of means is ,122. (,122 > ,005), we cannot accept the hypothesis. We can say that there is no significant difference between the mean score by the number of errors of newly developed application and control application.

We cannot find a result by the number of errors between these two applications, but group ranks can give us an idea about general perspective. (Figure 6.4) According to group ranks and details, newly developed application has more errors than control application. But it is impossible to claim a significant difference between them.

Table 6.4: Number of errors ranks

Ranks

	Experiment Group No	N	Mean Rank	Sum of Ranks
Number of Error	Newly Developed Application	33	36,52	1205,00
	Control Application	33	30,48	1006,00
	Total	66		

6.3 USER SATISFACTION

Six defined tasks were completed by each of the participants. Three of the tasks were completed with newly developed application; three of the tasks are completed with control application. Participants participated in a survey which consists of eleven questions. Participants were participated the survey for both of the applications. All the answers were saved by facilitator and saved to SPSS. Contrary to, task completion time and number of errors analysis, paired-samples t test is applied.

Hypothesis was created for comparing the mean scores in a task between newly developed application and comparison application.

Hypothesis: There is significant difference between the mean score by the users' satisfaction score of newly developed application and control application.

Group variables and test variables are given to SPSS. Output of the test was shown in the output window of the SPSS. (Table 6.5)

Table 6.5: User satisfaction test results

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	NewlyDeveloped Application - ControlApplication	,94182	,35264	,10633	,70491	1,17873	8,858	10	,000

The value of Sig. (2-tailed) of t-test for equality of means is ,000. Since the p-value for Sig. (2-tailed) is ,000 (,000 < ,005), we accept the hypothesis and conclude that there is a significant difference between the mean score by the users' satisfaction of newly developed application and control application.

We found that there is a difference between these two applications belongs to users' satisfaction mean values. Group statistics is a table that is evaluated by SPSS. (Table 6.6)

Table 6.6: User satisfaction group statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	NewlyDeveloped Application	4,1064	11	,18364	,05537
	ControlApplication	3,1645	11	,36806	,11097

As can be shown in the group statistics of user satisfaction, by the user satisfaction, newly developed application is better than control application.

7. DISCUSSION

The results of our study show that all of the hypotheses were proven except one. Task performance and user satisfaction hypotheses were supported and proved with the help of the analysis tests. Unlike our expectations, number of errors did not play a significant role and it cannot create a difference between developed and control application.

Task performance and user satisfaction results are what we were expected. Analysis of these two quality components shows us that completion time or task performance and user satisfaction create a big difference between newly developed application and control application.

The one hypothesis that cannot be proved was number of error quality component. The reason for an unsuccessful component was the application development problems. The newly developed application is developed with lack of necessary skills since it was the developer's first to time to code an assistive application. In addition, task performance and user satisfaction parameters were worth more than number of errors. Number of error parameter was not considered enough. These findings are worth further discussion. If a second application developed, it is estimated that number of errors hypothesis can be supported and a better application could be created.

Newly developed application is a platform dependent application. This platform dependency has some advantages that allow application to be spread around the world and possibly make it a successful application in the international arena. Although, this has some advantages, unfortunately it has more disadvantages by comparison. Newly developed application, needed to be developed with licensed software and on paid platforms. While the application has unlimited support, it cannot run on all the computer or mobile devices. This is a big obstacle for the application. Developing a platform independent or open source application may be useful for the improvement of this project. This open source project can be supported by the volunteers and charities and this creates more opportunities for the application to be improved.

In addition, for more accurate results, number of participants must be higher. Increasing the number of participants' ideas was limited by the developed application language. It is too hard to find English speaking visually impaired participants.

The application that is used as a control application is a licensed application. And license fee is almost $900. Payment of this fee might be a problem for visually impaired people. All features of the newly developed application discussed, a new help channel is created for the visually impaired people. It is irrefutable that such applications are a necessity for visually impaired people and we have to remember them.

8. LIMITATIONS AND FUTURE WORKS

As with the other experiments, it is difficult to reach to a result since there were multiple limitations. Future researches must extend the scope of the research and overcome of these limitations explained below.

For this research; an alternative assistive application has developed. Analysis and evaluations are accomplished. Study, where 11 participants took part, analyzed and evaluated. It is believed that number of participants directly influences the result of the research. For the future researches and the developments, number of the participants must be increased. However, it is too hard to find the English speaking visually impaired participants. This limitation becomes known with the language of the application. English language, language of the science, is determined as the language of the application; however, finding visually impaired people whose mother tongue is not English and fluent in English is too hard. Future plan is develop a multi languages supported application, at least with support of English and Turkish. New version of the application can help my country's visually impaired people to take the advantage of the application. And it would be a lot easier to find participants for the research.
In addition, the application is a windows based application. However, it can be possible to reach more people with developing a platform independent application. If the application could be a platform independent application, it can be spread easily and rapidly. Unfortunately due to budget issues platform independent application couldn’t be developed for this project.

To test the success rate of the developed application in a wide range of area, whole the Nielsen’s five quality components can be considered. Learnability and memorability quality components are the out of scope of this study. However, these two components may be considered for the future works. The success rate of the developed application would be better. As the same reasons, the number of application, using as a comparison application, can be increased to get better results. In this study, one of the assistive

technologies is evaluated with the developed application. More than one application can help the evaluation of the developing application.

So, to actually understand visually impaired users and their requirements, future researches will need to contain these suggestions in the development and test phases. To develop an assistive technology and to access visually impaired people is a critical part for future work.

9. CONCLUSION

Auditory sense is used for visually impaired and blind people as the primary sense while controlling with computers and other electronic devices. A new application is developed in this study. Application is designed as a real time information assistant for visually impaired people. The developed application is compared with a control application which is the most used application in the world and needs a license fee.

The study contributes to developments of similar applications in a different perspective. Needs of visually impaired people were taken into account. It is hoped, this application may provide other developers or researchers that pay attention to this issue.

Analyzing the developed application helps us to consider the study objectively. Results are good as supporting the developers and researchers who want to study in this area. Three usability components are analyzed and two of them proved to match our expectations about developed application. By developing such an assistive application, we were better capability to comprehend access issues for visually impaired people.

Accessing to information is a human right and it shouldn’t be a privilege. Information must be provided to all kind of people regardless if they are impaired or not.

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APPENDICES

APPENDIX A. TABLES

Table A.1: Gathered information

Table A.1a: Task performance and error numbers data

Experiment ID	Groups	Tasks	Participant ID	Time	# of Errors	Age	Gender
1	Developed Application	Daily News	P1	57,3	0	24	Male
2	Developed Application	Sports News	P1	33,4	1	24	Male
3	Developed Application	Weather Information	P1	28,6	0	24	Male
4	Control Application	Daily News	P1	301,6	0	24	Male
5	Control Application	Sports News	P1	600,3	0	24	Male
6	Control Application	Weather Information	P1	120,3	0	24	Male
7	Developed Application	Daily News	P2	76,3	1	51	Male
8	Developed Application	Sports News	P2	41,7	0	51	Male
9	Developed Application	Weather Information	P2	34,1	0	51	Male
10	Control Application	Daily News	P2	365,3	0	51	Male
11	Control Application	Sports News	P2	651,3	1	51	Male
12	Control Application	Weather Information	P2	129,3	0	51	Male
13	Developed Application	Daily News	P3	61,3	0	22	Male
14	Developed Application	Sports News	P3	34,8	0	22	Male
15	Developed Application	Weather Information	P3	27,1	0	22	Male
16	Control Application	Daily News	P3	378,5	0	22	Male
17	Control Application	Sports News	P3	700,6	1	22	Male
18	Control Application	Weather Information	P3	127,1	0	22	Male
19	Developed Application	Daily News	P4	95,4	1	28	Female
20	Developed Application	Sports News	P4	84,6	1	28	Female

21	Developed Application	Weather Information	P4	45,3	1	28	Female
22	Control Application	Daily News	P4	400,6	1	28	Female
23	Control Application	Sports News	P4	850,3	3	28	Female
24	Control Application	Weather Information	P4	178,9	1	28	Female
25	Developed Application	Daily News	P5	58,6	0	21	Female
26	Developed Application	Sports News	P5	38,6	0	21	Female
27	Developed Application	Weather Information	P5	27,8	0	21	Female
28	Control Application	Daily News	P5	389,3	0	21	Female
29	Control Application	Sports News	P5	596,1	0	21	Female
30	Control Application	Weather Information	P5	110,3	0	21	Female
31	Developed Application	Daily News	P6	98,6	1	33	Male
32	Developed Application	Sports News	P6	75,5	1	33	Male
33	Developed Application	Weather Information	P6	33,2	0	33	Male
34	Control Application	Daily News	P6	402,3	0	33	Male
35	Control Application	Sports News	P6	563,2	0	33	Male
36	Control Application	Weather Information	P6	120,3	0	33	Male
37	Developed Application	Daily News	P7	85,6	1	21	Female
38	Developed Application	Sports News	P7	78,1	1	21	Female
39	Developed Application	Weather Information	P7	78,2	1	21	Female
40	Control Application	Daily News	P7	398,6	0	21	Female
41	Control Application	Sports News	P7	601,4	0	21	Female
42	Control Application	Weather Information	P7	124,6	0	21	Female
43	Developed Application	Daily News	P8	65,3	0	27	Male
44	Developed Application	Sports News	P8	48,5	0	27	Male

45	Developed Application	Weather Information	P8	37,1	0	27	Male
46	Control Application	Daily News	P8	298,6	0	27	Male
47	Control Application	Sports News	P8	576,3	0	27	Male
48	Control Application	Weather Information	P8	126,3	0	27	Male
49	Developed Application	Daily News	P9	58,6	0	28	Male
50	Developed Application	Sports News	P9	37,6	0	28	Male
51	Developed Application	Weather Information	P9	30,2	0	28	Male
52	Control Application	Daily News	P9	315,8	0	28	Male
53	Control Application	Sports News	P9	678,6	1	28	Male
54	Control Application	Weather Information	P9	137,9	0	28	Male
55	Developed Application	Daily News	P10	59,4	0	23	Female
56	Developed Application	Sports News	P10	34,9	0	23	Female
57	Developed Application	Weather Information	P10	57,6	1	23	Female
58	Control Application	Daily News	P10	300,6	0	23	Female
59	Control Application	Sports News	P10	589,6	0	23	Female
60	Control Application	Weather Information	P10	109,6	0	23	Female
61	Developed Application	Daily News	P11	110,3	3	29	Female
62	Developed Application	Sports News	P11	85,6	2	29	Female
63	Developed Application	Weather Information	P11	78,6	1	29	Female
64	Control Application	Daily News	P11	452,3	1	29	Female
65	Control Application	Sports News	P11	761,3	1	29	Female
66	Control Application	Weather Information	P11	132,2	0	29	Female

Table A.1b: Data user satisfaction data

NewlyDevelopedApplication	ControlApplication
3.91	3.18
4.00	3.27
4.18	3.45
3.91	2.82
3.91	2.64
4.36	3.36
4.36	3.82
4.00	3.45
4.27	2.73
4.27	2.82
4.00	3.27

Table A.1c: Data user satisfaction results

ParticipantID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	GroupID	Mean Value	App. Mean Value
P1	4	4	3	4	3	3	4	4	4	5	5	Developed Application	3,91	
P2	5	3	4	4	3	4	5	3	5	4	4	Developed Application	4,00	
P3	3	5	4	5	4	3	3	4	5	5	5	Developed Application	4,18	
P4	4	3	3	4	5	4	4	4	4	4	4	Developed Application	3,91	4,09
P5	4	4	4	3	3	3	3	4	5	5	5	Developed Application	3,91	
P6	5	4	5	4	4	5	4	5	4	4	4	Developed Application	4,36	
P7	5	4	4	5	3	5	5	3	4	5	5	Developed Application	4,36	
P8	4	4	5	3	4	5	3	4	4	4	4	Developed Applicatio	4,00	

												n		
P9	3	5	4	4	3	4	4	5	5	5	5	Developed Application	4,27	
P10	4	5	3	5	3	5	5	4	3	5	5	Developed Application	4,27	
P11	5	4	4	5	4	3	3	4	4	4	4	Developed Application	4,00	
P1	2	4	4	3	3	2	5	3	3	3	3	Control Application	3,18	
P2	3	3	3	2	2	3	3	5	4	4	4	Control Application	3,27	
P3	4	3	3	4	4	4	2	3	4	4	3	Control Application	3,45	
P4	3	3	2	2	3	3	1	4	3	4	3	Control Application	2,82	
P5	2	2	1	2	2	3	3	5	4	3	2	Control Application	2,64	
P6	3	4	3	3	4	3	4	3	3	4	3	Control Application	3,36	3,17
P7	4	5	3	4	4	4	3	3	3	5	4	Control Application	3,82	
P8	2	4	3	3	2	3	4	5	4	4	4	Control Application	3,45	
P9	1	2	2	2	4	3	3	3	3	4	3	Control Application	2,73	
P10	3	4	1	1	3	4	2	4	2	4	3	Control Application	2,82	
P11	1	2	1	3	5	4	5	4	3	5	3	Control Application	3,27	

Table A.2: Survey questions

1. **Application is easy to learn.**
2. **I enjoy using the application.**
3. **I feel confident using the application.**
4. **I find the application suitable for my needs.**
5. **I learned a lot using the application.**
6. **While using the application I felt comfortable.**
7. **It took a little time to use/learn the application.**
8. **The time and effort used to learn the applications is well spent.**
9. **The overall usability of the application is good.**
10. **I want to use the application again and its future versions.**
11. **I suggest the application to all the visually impaired people.**

CURRICULUM VITAE

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