

COMPARATIVE ANALYSIS OF MOBILE PHONE APPLICATION SOLUTIONS ACCESSIBILITY FOR INFORMING VISUALLY IMPAIRED PERSONS IN TRAFFIC ENVIRONMENT

Marko Periša, Ivan Cvitić, Rosana Elizabeta Sente
 Faculty of Transport and Traffic Sciences
 Vukelićeva 4, 10000 Zagreb, Croatia
 marko.perisa@fpz.hr; ivan.cvitic@fpz.hr; rosana.sente@fpz.hr

Abstract

Visually impaired persons are constantly faced with various problems while creating movement routes using application solutions on their mobile terminal devices. These problems are: nonadaptable mobile phones, application solution and available content. Application solutions depend on different operating systems, their characteristics and performances of mobile terminal devices. In this research, the accessibility of mobile terminal devices and applications for informing visually impaired persons in traffic environment were analyzed. Analysis was conducted on the basis of available scientific and technical literature in order to identify the most common operating systems and their characteristics for providing accurate information to the end user. In addition to the characteristics of the operating system, hardware components of mobile terminal devices such as an accelerometer, gyroscope, GPS, etc. have great importance in informing the users of the transport network. Accessibility of available application solutions and hardware devices important for making accurate and accessible information were analyzed according to the recommendation of universal design. Using comparative analysis, the selection of the optimal operating system and application were made to provide accurate information about the movement and direction of the user (personal digital assistant).

Keywords

Assistive technologies, universal design, mobile phones, operating system

INTRODUCTION

The use of mobile phones is a part of everyday life for many years. Mobile phones changed the ways of how people communicate or how they get needed information. They also changed the ways of receiving requested information while moving through transport network. According to the World Health Organization, there are 285 million people with visual impairment, of which 39 millions are blind and 246 million have some form of visual impairment. [1] Visually impaired persons are divided on blind and low sighted persons, and the size of visual impairment is often measured with the width of the rest of the vision and the width of the vision field. In Croatia, there are 17 356 visually impaired persons. [2] The subject of this research are visually impaired persons that belong to the targeted group of users (TGU).

Users are constantly confronted with the accessibility problems of mobile phone content which can affect on their orientation in exterior field. Products/devices/services should

be accessible to them so that they could actively participate in the community and carry out daily activities.

The development of technology greatly affects on the Quality of Life (QoL) of TGU, in the way that there are so many opportunities to make accessible product/device/service which can ensure reduced isolation from society. One of these currently available solutions are touchscreen mobile phones. Persons without disabilities can easily use mobile phones, while for visually impaired persons these devices are difficult to use. The main reason is the lack of the buttons that can help visually impaired to know with certainty that they pressed the right number/letter. The accessibility of available application solutions and the delivery of accurate information to end users can greatly affect on their movement in the traffic network. In addition, it is necessary to provide real time information to users to maximize their movement safety.

This research is focused on comparative analysis of operating systems (OS) and the accessibility of mobile phones. Based on that distribution, the accessibility of application solutions which can provide necessary information for easier orientation in traffic network was also analyzed. The aim of this research is to show what kind of mobile phone, depending on OS, is accessible for visually impaired persons and point to the problems which still exist in available solutions. The purpose of this research is to give necessary information to visually impaired on suitable mobile phone solutions and simple choice of OS for simpler usage and informing in traffic network.

The methodology used in this research is an analysis of the current scientific literature from which were obtained information about used technologies, mobile phones and their accessibility. Historical method was used for short description of mobile phone development, their accessibility and how did the development of technologies affected the increased number of services offered to users. With comparative and compilation methods, the accessibility of Android, iOS and Windows Phone mobile phones were analyzed as well as the possibilities of application solutions for informing users in traffic environment.

PREVIOUS RESEARCH

A number of research is focused on the accessibility of mobile phones and application solutions for visually impaired. There are also researches that examined which services are often used on mobile phones and customer

satisfaction of certain services/applications/devices. Information about the use of mobile phones, application solutions and their accessibility is conducted with mentioned research.

The research [3] was conducted in 2008, and 413 respondents participated in the query that were between 18 and 80 years old. One participant did not declare his vision disability, while 10 of them does not have any kind of visual impairment. Of all respondents, 380 of them use mobile phones. The most popular device among respondents was Fujitsu F882iES which used 159 of respondents. Another popular mobile phones were Fujitsu F881iEs and F762i. They have physical buttons that users can feel while using the mobile phone which greatly affects on the simplicity of use. The respondents, 63,2% of them, use mentioned mobile phones to search the Internet and 98,2% of them use them for making calls. Text to speech functionality use 86% of respondents, 54,2% of them use increasing the text size and 31,1% of them use the accessibility function to change color contrast.

The research [4] was conducted in order to gather information on how visually impaired persons control touchscreen devices and their need for that. Respondents declared that physical keys and other reference points are necessary for better navigation on mobile phones, exactly the thing that is minimized in today's smartphones. The organization of commands and functionalities is very important to them. That is the reason why visually impaired persons mostly used Nokia Symbian devices, because of their accessibility. Another important feature was simplicity and usefulness of common functions, for example to locate a menu button or search that follows a logical layout.

Collection of information on visually impaired persons and their use of touchscreen smartphone devices was conducted in the research [5]. The study includes 25 people from 24 to 75 years. According to the results, 625 of them use smartphones with physical buttons (Nokia and Motorola) and 38% of them use touchscreen smartphones (Apple, Nexus, Samsung, HTC, LG): Four of them use both versions of mobile phones. The most common operating system is Symbian (62%), followed by Android (21%) and iOS (17%). Of the 14 users which use mobile devices with physical buttons, two of them use mobile phones to obtain information of public transport and voice recorder, while one person use navigation and notes. Touchscreen devices are used by 11 respondents and 8 of them use them for navigation, 2 for obtaining information of public transport and voice recorder and one person uses Braille keyboard. Navigation services that respondents use are information about public transport, available navigation maps on devices, navigation application solutions (Blind Square, GetThere, HERE maps, DotWalker, Navigon) and the calling center for helping in navigation. The result of the research was that the users do not want to use touchscreen smartphones because they think that they won't be able to run some functionalities quick enough.

The management of smartphones using tactile gestures was researched in [6]. The study included 36 participants who were blind or had low vision. None of the respondents used touchscreen devices before they suffered a vision loss. The accuracy of tactile gestures on Android and iOS OS were examined, as well as the management of VoiceOver and TalkBack applications. According to the research, visually impaired persons use iOS devices (57%) more than Android

mobile phones (28%), while the rest of the respondents use other devices. VoiceOver provides to users a lot more options that are connected with the management of mobile phones, but respondents find them complicated to use in relation to the TalkBack service.

The application solution accessibility was researched in [7]. The study included 10 participants with visual impairment that used 3 different Android devices and 4 different applications. The aim was to collect information on how easy is to use the device, whether it is necessary to make a great effort to learn how to use mobile phone, how much error is caused when performing certain actions, what is the intelligibility of voice that provides feedback and the efficiency of the application. One of the hypothesis of the research has been that the most visually impaired persons benefits Symbian OS and the other was the assumption that they will be more comfortable to use smartphones with the help of application solutions. One of the tested application solutions was Blind Navigator where 80% of respondents with simplicity understood where are application icons because they got quality voice feedback. When reading the message, 30% of respondents encountered obstacles in understanding the message because application can only read messages in English language. They had more difficulties while writing a text messages because the respondents were not familiar with the QWERTY keyboard. The study confirmed the first hypothesis because respondents believe that smartphones do not provide enough information. The second hypothesis was also proved to be true, because with the help of mobile phone application solutions, respondents were able to do certain tasks.

In the [8], the quantitative analysis of using Amazon Echo, Apple Siri and OK Google services was conducted. There were two different studies, where the second study investigated how users use Siri, Ok Google and Cortana. Of 518 respondents, 44% use iPhone, 40% use Android devices while 2% use Windows Phone or Blackberry. Other users do not use smartphones. Most users were using Siri (79%), then Ok Google (65.2%) and 38% of them used Microsoft Cortana. Siri and Ok Google are mostly user for searching the Internet, navigation and making calls with voice commands. A slightly less than 80% of respondents were very satisfied on how virtual assistants recognize the voice of the user and how accurate the feedback information was.

The accuracy of Siri, Google Now and Cortana was tested in [9]. All virtual assistants had to perform certain tasks, such as sending SMS messages and unlocking Wi-Fi services. Results showed that Siri offered the most accurate answers, while Google now and Cortana had slightly less correct answers.

From above mentioned research, it can be concluded that the most used mobile phones among visually impaired are the ones that have physical buttons which can be used for writing text messages or number. Today's smartphones have touchscreens and different ways to provide accessibility. While using smartphone applications, users were able to perform certain actions, although there were no physical buttons available to control the device. That was possible because the application solution was accessible to visually impaired persons. The general population was most interested in Google Now, Siri and Cortana virtual assistant solutions that are available on Android, iOS and Windows Phone mobile phones. Since the application solutions are

used for searching the internet, navigation, making calls and texting, it shows that they can affect on the movement of visually impaired through the traffic network and provide them with the sense of safety. [7]

TECHNOLOGY AND DEVICE DEVELOPMENT

With constant development of technology, mobile phones and available applications are changing and provide even more options to end users. In recent years, more attention is paid to people with disabilities and how to make content more available to them. Today's smartphones have many technical improvements which sets them apart from dumbphone devices. Some of them are more advanced Central Processor Unit (CPU), data storage capacity, screen size and functionalities such as a Web browsing, downloading applications and others.

The development of smartphones starts from 1993, when IBM Simon device was developed that gave its users the ability to use a calendar, address book, calculator, text editor (notepad), application for sending e-mails and simple games. [10] The device has a touch screen and can receive e-mail and fax messages, but was never called a smartphone.

Before the arrival of today's Android, iOS and Windows Phone OS on the market, the most popular OS in the world was Symbian OS, which had a major influence on the development of today's smartphones. This OS was used by the world famous mobile brands like Samsung, Sony Ericsson, Motorola and Nokia. [11] Thanks to the way Nokia was developing its mobile phones, but also capabilities of Symbian OS, today's smartphones have built-in GPS, accelerometer, Wi-Fi, OLED screens and other functionalities. All of this has contributed to the development of today's navigation services available on the mobile phones, means of communication with other devices, Web browsing, availability of content to users with disabilities and multimedia services.

The most common OS in the market are Android, iOS and Windows Phone. [12] Apple mobile phones based on the iPhone OS appeared in 2007 and represented devices easy to use. IOS term began to be used in 2008, and since then the operating system is called OS X. The first iPhone had a limited number of applications users could use. It was not until 2008, that the Apple developed the store to download additional application called App Store. [13] iPhone devices did not have a GPS which meant that they could not provide information to the user about his location. When released iPhone devices supported only 2.5G technology, at a time when devices on the market already supported 3G speeds.

A significant advantage compared to other available OS occurred with iOS version 3.0 in 2009, when iOS introduced the ability to use cut / copy / paste option. Also, Voice Memos application was added which allowed users to record voice note entries on their mobile phone. iPhone no longer only supported English but also other thirty languages. [14]

With the development of iOS version 4, mobile phones enabled more than one home screen where users were able to organize the layout of their applications. This is important as it allows users to place applications they use more often on the first screen, and others which are not used as often on other pages.[14] Siri was added with the arrival of the iPhone 4S mobile phone. Siri is a digital assistant which allows the

users the option to control the mobile phone using voice commands. With the use of Siri, users are able to voice command to call taxi service, reserve tickets for movies and restaurants and the like. Further development of Siri has become an integrated part of iOS, with additional extended options added in new versions.

In late 2011, iOS 5 was developed which enhanced the features Siri offers. Siri also became available in Japanese language, and not just English as was previously the case. [15] The development of iOS 6 introduced new features that Siri supports which made the control of mobile phone easier for the users. When notifications appear on the screen, Siri got a new option to read the notification which meant it was easier to receive information. Until the advent of iOS 6, Apple has used Google Maps navigation which it replaced by native maps application. Use of Apple maps was reported as a negative aspect of iOS 6. [16] Users were faced with the problems of incorrect or incomplete data, poor signal coverage and low quality of satellite images. [17]

iOS 7 introduced enhancements in look and feel of users interface. Also, users were given the option to use biometric protection as an option when unlocking the mobile phone. This made unlocking the mobile phone easier. [18] iOS 8 and iOS 9 development introduced additional language support for Siri. The latest available OS is iOS 10 which had a positive impact on customers primarily due to connection between Siri and other applications that are available on mobile phone. With new version of operating system mobile phone accessibility has been improved as well.[19],[20]

Android OS was developed with the intention of competing with the previous Symbian OS. Today it is considered the biggest rival of iOS. Android operating system has so far released 10 versions, each of which brings a variety of functions. With the arrival of the 1.6 version of the OS, most important feature for the users is Quick Search box because. It made browsing the Internet easier in a way that only one click on the screen is needed to use the service. [21]

In version 2.1, an important feature was Speech-to-text which allowed users easier ways to enter text in the message or e-mail. [22] A disadvantage of this application is poor support for foreign languages and for this reason it is not applicable around the world. Speech-to-text is a precursor for Ok Google service. It is important to note that from this version of the OS mobile phones are used for navigation. First application which was developed had only support for navigating user in a car. Later versions allowed support for navigating user while walking and also introduced voice support to provide information about users location. In version 2.2 Frojo, an important feature is the Voice actions which allowed users to use voice commands to control mobile phone. [22] They were able to ask for directions to a location, record notes, set an alarm clock and the like. The above is considered to be a very good solution when accessibility is considered as it removes the need for the user to actually see or use touch screen to open applications or use navigation. Near Field Communication (NFC) technology was added in version 2.3, which when introduced did not contribute to accessibility and ease of use for people with disabilities. Later, with technology advancements it has contributed to the realization of contactless payments, as well as the method for informing consumers by using NFC tags and a mobile phone. [23]

Honeycomb version of the Android OS has brought disadvantages for users. Making the navigation touch keys (System Bar) as part of the touchscreen did not constitute a suitable solution for visually impaired. [21] With 4.0 version, users got the possibility to adjust the home screen to their needs. This enabled to put the most important functionalities on the first home screen such as text messaging, navigation, calling, internet browsing, notes, etc. [22]

Jelly Bean (4.1 version) presented a personalized assistant, Google Now. In KitKat version comes Ok Google which is considered as one of the better solutions for controlling mobile phones because users could send text messages using voice commands, search for information to get to certain locations with the possibility of navigating the users and other various features. [23]

Android 5.0 provides users to use NFC and Bluetooth technologies for transferring required data, images applications, etc. from one device to another. Google Now service can be run with voice command Ok Google and users don't have to have unlocked mobile phone to use it. This enables ease of use of application solution for all users. [24]

The last available version of Android OS is 6.0 version which provides users to unlock their device with fingerprint. The above solution is suitable for users, particularly blind because they don't have to worry if they will be able to unlock their mobile phone or not. It also provides them a higher level of data security. [25]

Windows Phone OS is also designed for smartphones. Windows Phone 7 appeared in 2013, much later compared to iOS and Android. To be able to compete iOS and Android on the market, it is presented as an OS that is in many ways different from them. Android and iOS have a similar startup screen that contains number of rows of application icons, and Windows Phone devices have a different home screen. [26]

Among other OS, it differs in dynamic tiles that besides text can contain pictures. Windows Phone 7 had a TellMe functionality which enabled users to call someone, browse the internet or run the applications using voice commands. Users had the possibility to install additional applications using Windows Phone marketplace. Because it appeared on the market much later than iOS and Android, Windows Phone had a small number of applications available on

marketplace. Windows Phone 7 did not have developed accessibility for persons with disabilities. [27]

The next generation that emerged in 2012 was the Windows Phone 8 which used NFC technologies for contactless payments and content sharing. [28] The emergence of Windows Phone 8 OS places their devices to the third place on the world market. With this version came the accessibility, especially for the visually impaired. Users could change text size, use magnifier glass, voice commands, color contrast etc. Users could also turn on ease of use functionality and manage their mobile phone on the home page. [27]

At the end of the 2013, Windows Phone 8.1 was developed which brought Cortana, a personal virtual assistant which was very similar to Apple's Siri. Users were enabled to control their mobile phones with their voice which enabled them to get information more easily such as: navigating them through traffic network, calling, texting, browsing the internet, etc. Cortana is not only intended for mobile phones but also for laptops and personal computers, so all notes and information that provides on one type of the device, it can provide them on the other one. This enables users to have available notes on their computers and phones, no matter which one they used to make a note. This version brings notification screen which provided greater control of mobile phone. Cortana was only available in the USA, and later expanded into the area of UK, China, Australia, India and Canada. [27],[28]

The last OS on the market became available in 2015 under the name Windows Phone 10. This is the first OS that successfully combines OS that is available for computer, tablets and mobile phones. Live tiles can be completely changed according to the user needs and all important applications can be put on the home screen in a much bigger way compared to the irrelevant applications. Cortana gets new improvements in terms of functionalities that she can provide, better voice recognition, etc.

Table 1 shows analyzed OS that are used in different mobile phones and technologies which are used for providing different services. It is noticed that hardware components were changed and thus increases mobile phone functionalities

Mobile phone	Nokia 808 PureView	Samsung Galaxy S7	iPhone 6S	Nokia Lumia 925
Operating System	Symbian	Android	iOS	Windows Phone
Sensor Technologies	Accelerometer, Proximity sensor, Compass	Accelerometer, Gyroscope, Digital Compass, Ambient Light Sensor, Proximity Sensor, Gravity sensor, Rotational Vector Sensors, Barometer, Photometer, Thermometer, Orientation sensors, Magnetometer, Step Counter, Fingerprint sensor, Heart rate, SpO2	Fingerprint sensor, Barometer, Three-axis gyro, Accelerometer, Proximity sensor, Ambient light sensor, Digital compass, Magnetometer, Pressure sensitive display, Step counter	Accelerometer, Compass, Gyroscope, Proximity sensor, Magnetometer, Ambient light sensor
Connection Technologies	Bluetooth, Wi-Fi, NFC, Radio, GPS, USB	Bluetooth, Wi-Fi, NFC, GPS, USB	Bluetooth, Wi-Fi, NFC, GPS, USB	Bluetooth, Wi-Fi, NFC, Radio, GPS, USB
Battery	540 h	288 h	240 h	440 h
Personalization features according to the disability of user	Yes (Visually impaired)	Yes (Visually impaired, Deaf, dexterity and interaction)	Yes (Visually impaired, Deaf, Dexterity and interaction)	Yes (Visually impaired)
Functionalities	Nokia Screen Reader	TalkBack, Voice Access, BrailleBack, Google Now	VoiceOver, Zoom, Speak Screen, Siri	Narrator, Screen Magnifier, Cortana
Languages of digital virtual assistant	/	89	41	13

Table 1. Technologies and functionalities of analyzed mobile phones

Samsung Galaxy, as one of the analyzed mobile phone, is the only one that has temperature sensor so it has additional functionalities which can be provided to end users. Battery life span was much more higher in the mobile devices based on Symbian OS than in Android or iOS. Windows Phone mobile phones have a much more greater battery life span than the other two OS. This is due to the increased number of functionalities that mobile phones provide and technologies which are used for connection.

The table also shows that the number of sensor technology which is built in mobile phones is changing comparing to previous mobile phones. GPS, orientation sensors, accelerometers, gyroscope, barometer, magnetometer, thermometer, proximity sensor, camera and touchscreen are just some of the sensors that are integrated within the mobile phone.

All of the mentioned technologies can be used in the form of assistive technology for providing environment information and providing travel and pretravel information. It is not yet exploited the full potential of these components, but with the further development of new applications and new devices, these potential will be greatly exploited.

ACCESSIBILITY OF MOBILE PHONES

The development of OS influenced on the development of mobile phone applications and on the development of mobile phones. All of the above mentioned could not be possible without information and communication technologies. Each of mentioned OS provides much more functionalities which are not listed, but briefly are mentioned some of the most important for visually impaired persons. As the mobile phones became devices with minimum number of physical keys that are available for them, so the accessibility of mobile phones had to change according to their needs. Mobile phones are used daily, not only for calling and messaging but for navigation applications and informing in traffic environment. Mobile phones need to have properly developed accessibility of applications so that they can obtain information properly. The accessibility of mobile phone is also important to them. Users demand services in real time and it is necessary to provide them information in the faster and easier way.

Each of the devices based on one of the three previously mentioned OS have a similar constructed accessibility. Accessibility of a devices refers on the ways how persons with disability have access to electronic information stored on it. The first mobile phones were intended for messaging and calls and the accessibility was not a big problem since users could navigate through mobile phone by using physical buttons. With the arrival of touchscreen displays, navigating through mobile phone was more difficult and for that reason it was necessary to develop their accessibility.

IOS, ANDROID AND WINDOWS PHONE ACCESSIBILITY

The basic accessibility of mobile phones refers to possibilities for visually impaired to change the font size, contrast color, grayscale, use of magnifiers, screen readers, etc. [29] Screen size of mobile phones for visually impaired is very important because it affects on the displayed font size.

The downside is that it is more difficult to manage mobile phone with one hand. Universal design defines seven principles for making accessible product/service [30][31]:

- **Equitable Use** - the design is made in such a way so that the users with different abilities can use them. Privacy, protection and safety of users must be the same for all groups of users. All functionalities of mobile phones must be available to visually impaired persons and persons without disability.
- **Flexibility in Use** – users must be able to choose how to use mobile phones. Even though smartphones have touchscreen displays, they have developed accessibility which ensures their usage for visually impaired. Because they cannot see the content displayed on the screen, they have the ability to use screen reader.
- **Simple and Intuitive Use** – users need to have a wide range of language options supported on their mobile phones. In addition, it is necessary for visually impaired to enable easier usage of mobile phones in a way to avoid unnecessary complexity of the devices and their functionality.
- **Perceptible information** – it is necessary to provide maximum readability of important information. Visually impaired persons have the option to choose the font size and adjust the contrast of the background and the letters in order to get better way to read the displayed content.
- **Tolerance for Error** – threats that can affect on the user must be kept to a minimum. It is necessary to provide warning of the danger and possible errors.
- **Low Physical Effort** – it refers on making minimum repeated actions. Visually impaired person have the option to easily use mobile phones which allows them to set the main settings and functionalities on their home screen.
- **Size and Space for Approach and Use** – mobile phones should be suitable for use regardless of the place where it is used or the way it is used.

In addition to universal design, there are recommendations for developing accessible Web sites. Web Content Accessibility Guidelines 2.0 (WCAG) defines guidelines that provide accessibility of Web pages for persons with disability and if the pages are made according to the guidelines, users have no difficulties in navigation through the content of the website. The four basic principles of accessibility are [31]:

- **Perceivable** – information and user interface must be presented in a way that users can “see”. This means that the user must be able to obtain information that is presented on his device.
- **Operable** – user must have the ability to manage components on the user interface and navigation through it. The user interface should not contain activities that the user can not perform.
- **Understandable** – information and operations of user interface must be comprehensible.
- **Robust** – the content must be clear enough so that different softwares could interpreted it reliably, including the assistive technologies. The user must

be able to access the content regardless on how much technology progresses.

Each of above mentioned principles contains guidelines and success criteria that help to make accessible content to visually impaired persons.

Android based phone devices have different possibilities that provide accessibilities to visually impaired such as TalkBack, Access Switch, Voice Access, BrailleBack, Captions and setting to adjust the screen of a device. These services are available in the 7.0 OS version.

TalkBack (Voice Assistant) service is available on Android devices since 4.0 version and enables users to receive feedback in a voice recording about what is presented on the screen of their device. [32] By swiping across the screen, the service reads the content. TalkBack service allows users to “glide” from letter to letter while writing the message and reads aloud the picked letter. If the user wants to know what he has written, he can use volume up and volume down buttons to turn that option. Users can also turn on the option to get phonetic description of each letter. TalkBack service is useful for searching the home screen which provides them informations about navigation, search bar, notifications, applications, folders and other services. It also supports variety of gestures that allow easier navigation through mobile phone. When browsing the Internet, TalkBack reads the content which is contained on the web page, depending on which part of the content user wants to be read. [6]

Voice Access is a service that allows visually impaired persons to control their mobile phone using voice commands and it is available since 5.0 OS version. It enables users to open applications and even to write textual messages by using voice commands. [34]

BrailleBack service allows users to connect Braille display with Andorid device using Bluetooth technology. BrailleBack can work in combination with TalkBack service to provide quality feedback. Users can input text using Braille display and enables them to easilly use and navigate through mobile phone. [34]

Android devices have several settings that enable visually impaired people to better see the displayed information. Users have the choice of seven different font sizes, possibility to use magnifier, change contrast of text and background, color inversion and color blind feature. Given the fact that blind persons can not see what is on the screen of the device, they have the option to include the black screen setting and thus prevent others from reading what’s on their screen. In addition, visually impaired can use feature to get the feedback while writing passwords so that the user knows exactly if he wrote something wrong. Android devices have Google Now virtual assistant which enables easier control of phone devices, not only for visually impaired but for all users.

Apple devices have similar accessibility features. Users can use VoiceOver and Zoom, change color of the background, change font size and thickness of the letters, increase the contrast of colors, etc. VoiceOver is a screen reader which uses text to speech option and in that way provides information to end users about what is on their display, makes it easy to nabigate through websites, and also through applications which are integrated part of iOS devices. It also gives informations about status of a battery life and informations about caller ID. VoiceOver can be controlled by using set of tactile gestures. Just like Android,

iOS devices have the possibility to enable black screen feature. For web browsing, VoiceOver has a rotor, virtual control button with which user can easily switch between different parts of webpage and gain information about titles, external links, pictures, etc. VoiceOver is compatible with over 70 Braille displays which can be connected via Bluetooth. iOS provides a wider selection of font sizes, 12 of them and provides them to have bold letters which is appropriate for visually impaired. [6]

Zoom is a built-in magnifier which works with any application downloaded from the App Store. When the feature is turned on, one part of the screen is zoomed while the other one presents the layout of the screen in actual size. It is often confused with another feature of the mobile phone, digital magnifier. Digital magnifier gives users possibility to use camera to increase the size of text, images or anything that is in front of them. [34]

Speak Screen option provides users to read them what is on their screen. It works with Siri. Users are able to use voice commands to write messages, e-mail, notes or to visit certain websites without typing on mobile phone. [34]

Like previously devices based on iOS and Android OS, Windows Phone devices also enable users to change the size of the text that appears on the screen, providing them eight different possibilities of text size. Neither Windows Phone nor Android OS mobile phone provide the feature to bold the text as iOS mobile phone devices provide. Setting high contrast allows users to easily read the information available to them on the mobile phone, where font color and background color turn in black and white mode.

To be able to compete with Android and iOS on the market, Windows Phone has a screen reader, Narrator, that gives voice feedback information about what content is on the user’s display. It can also read out e-mails, text messages, content on the websites, etc. It works in the same way as previously mentioned screen readers. [35]

Users can increase certain content on the screen by using magnifier. If some webpages do not allow zoom-in or zoom-out of their content, Windows Phone devices allow that. In addition, users that use Speech features can make calls, send text messages or e-mails, open applications, create notes or browse webpages with voice commands. The users can use the feature only by touching the screen which considered as a bad option in relation to the voice launc. As Siri and Google Now, Windows Phone mobile phones have available personal virtual assistant called Cortana who has the ability to make it easier for visually impaired persons to control mobile phones. [36]

	iOS	Android	Windows Phone
Contrast colors, text size	Yes, Bold text	Yes	Yes
Screen reader	VoiceOver, SpeakScreen	TalkBack	Narrator
Voice commands	Siri	Google Now, Voice Access	Cortana, Speech
Magnifier	Yes	Yes	Yes
Braille support	Yes, Braille Displays	Yes, BrailleBack	No

Table 2. Accessibility of mobile phones based on different OS

With accessibility analysis of mobile phones it is shown that mobile phomes based on iOS, Android and Windows

Phone OS are accessible. Windows Phone mobile phones have developed accessibility later compared to iOS and Android mobile phones. According to Table 2, it is clear that mobile phones which use the above mentioned OS provide people with visual impairments the ability to change the contrast of the background, font type and font size. Only iOS devices have the ability to bold letters. Also, they all have different applications for screen reading which allow people with visual impairments easier way to getting information. Only Windows Phone mobile phones do not have support for braille display which is a disadvantage in ensuring the accessibility of mobile phones.

SIRI, CORTANA AND GOOGLE NOW VIRTUAL ASSISTANTS

As a result of the research, it was concluded that Siri, Cortana and Google Now are the most common application solutions that provide ability to perform tasks on mobile phones using voice commands. [37], [38] In the Laboratory of Development and Research of Information and Communication Assistive Technology at the Faculty of Transport and Traffic Sciences, the functionalities of Siri, Google Now and Cortana applications were tested. Mobile phones that have been tested are the iPhone 6S, Samsung Galaxy S7 and Nokia Lumia 925. All devices language preferences were set to English.

Siri is a virtual assistant that is manufactured by Apple and is older than Google Now and Cortana virtual assistants. For this reason, the research [9] has showed that it has the highest percentage of correct functionality because Apple had more time to solve problems that the Siri previously encountered. It is only available on iOS devices and it is possible to start it with the Hey Siri voice command. For the users, this can be a good solution because they do not have to type on the device to launch Siri and do not have to constantly keep mobile phones in their hands to get the necessary information.

Siri provides many options for the end users, such as: Internet search, send/read text messages, voice calls, opening applications, FaceTime calls, updating status on social networks, application proposal and contacts, create events, set alarms, change device settings, search navigation routes to specific location, information on public transport, information on nearby restaurants, shops and attractions, taxi service, information about traffic conditions and many others. [39] Siri can greatly help users to navigate to specific location and provide the necessary information about it. All the user has to do is execute voice command and ask Siri what to do. Figure 1 shows an example of how Siri guides the user through a certain route.

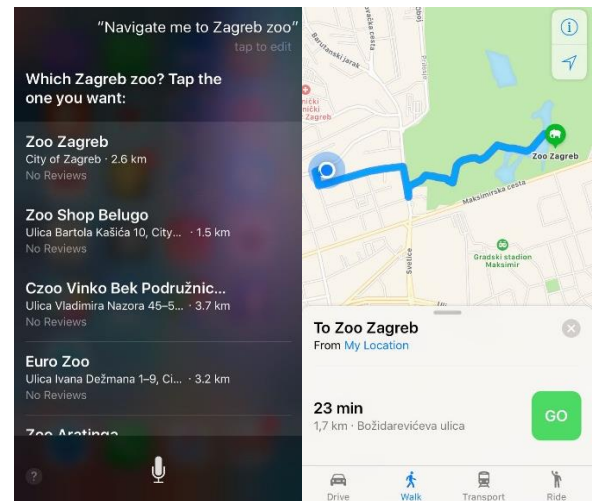


Figure 1. Navigation by using Siri

After Siri finds more than one destination, the user can ask for the destination he wants, and after his selection, Siri starts to explain to the user the way he will need to take in order to reach the destination. After that, the user can select Go and navigation will begin. It is important to mention that Siri does not recognize Croatian language and Siri can barely detect certain streets in Zagreb. Siri has the ability to connect to the Uber account and if the user needs a taxi, all that is required is that the user issues a command to Siri that he needs Uber. Siri will determine the time it takes for a taxi to get to him based on his location. When a person with visual impairment can not orientate on the street, he can ask Siri where he is and Siri will provide feedback on the user's location. User may at any time seek feedback from Siri about remaining time to the destination. As for the public transport, Siri has the ability to provide feedback on various options of public transport that goes to the specified location and at what time. If the user wants to go to a nearby restaurant, he may request Siri to show the available restaurants and their reviews and to book a table for the user at the restaurant he likes. However, at the moment all of the features that Siri offers are not available in every country. Apple seeks to improve with constant upgrades.

Cortana is a virtual assistant designed for Windows Phone mobile phones and has the ability to run it with voice command Hey Cortana. Just like Siri, Cortana provides many functionalities: search weather forecasts, launch applications, search websites, make voice calls, write text messages and e-mail messages, set alarms, create events, provide information on public transport, location of the user and numerous others. [38]

Cortana can provide users with easy navigation in traffic due to its capabilities to receive voice commands and voice informing the user. If the user cannot orient in traffic and do not know where he is, he may request Cortana to provide information about his location. Also, the user can request the location of a certain place and a route that would take him to the destination and Cortana will provide necessary information about route and how to get there. Figure 2 shows an example of how Cortana provides information about the route to a specific destination.

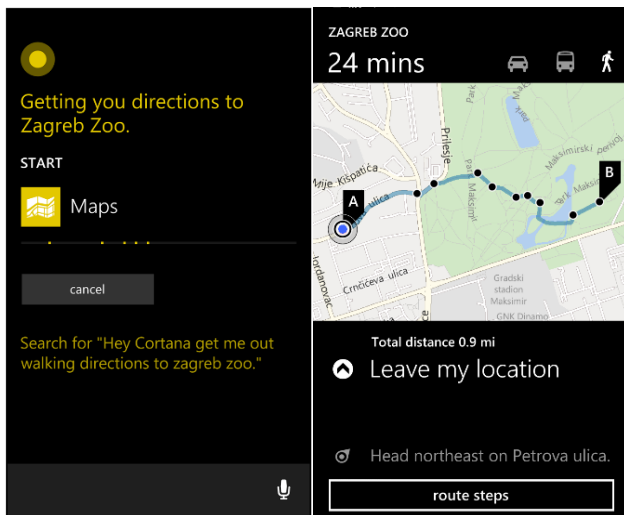


Figure 2. Navigation by using Cortana

Once a user requests a navigation to a specific destination, Cortana provides voice feedback information about the route to a particular destination and guides the user to the destination.

Information about public transport are provided in a very good way. When the user is on the tram or bus, and if turn-by-turn navigation feature is turned on, the user can receive feedback on which station he is currently located, i.e. how many stations he still has to drive in order to know when to get off the tram/bus. One common problem is that often in public transportation it can be very hard to hear voice responses and use voice commands, and for persons with visual impairment this means that they might not know where the station is located. Cortana has successfully solved this problem. User can at any time ask for the time it takes to arrive at his destination and based on user's location Cortana will calculate the arrival time. The mentioned functionality works only in certain cities.

Information about restaurants/shops/events, Cortana provides information to users based on their location and how long it takes a user to reach the destination on foot, by car or public transport. If the user wants to use taxi, Cortana can call Uber based on user data that is available within the Uber app on mobile phone. It provides the user with feedback on the type of car, the driver and the time it takes to taxi to arrive. Information on road conditions, traffic jams, collisions, closed roads, etc. Cortana can provide them at the moment when user asks for directions to a specific destination or when he wants to know such information. It is noteworthy that the Cortana is available on iOS, Android and Windows Phone devices.

Google Now is designed for Android devices, but is also available for use on iOS devices with some limited functionality. It can be run by using the command Ok Google, which means that users do not have to constantly keep mobile phone in their hands in order to use its functionality. As previously mentioned, Google Now virtual assistant also provides a number of options such as making a call, send a message, write notes, browse the Internet, provide information on public transport, reminders, run applications, etc. [38]

User can order a taxi using voice command. Uber application supports voice ordering through virtual assistant. It returns the information about where the taxi is and how

long will it take to get to the users location and to the destination. Before the user can use this service, he needs to associate his accounts (virtual assistant, Uber) so that he can use voice commands to execute this task.

In addition to already mentioned services, users can ask information about nearby restaurants, stores, events and similar. In that way they get information about what is happening at their location. Google Now can also present to the user reviews of restaurants, their distance and other information the user is interested in. User can then ask for directions to specific destination and the assistant will provide options to get to that location. Figure 3 shows how Google Now responds on a command to navigate to certain location.

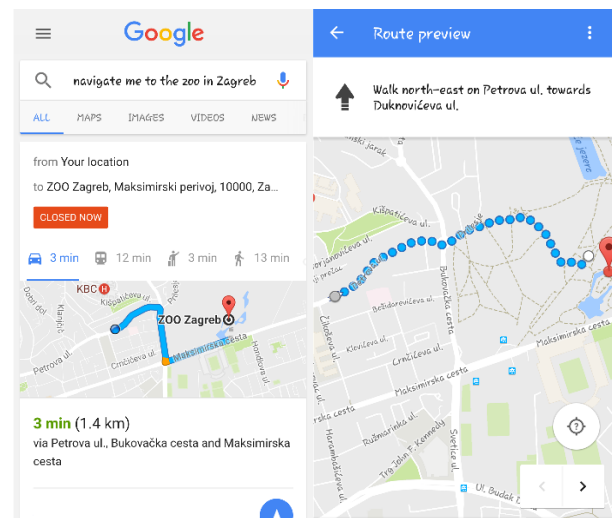


Figure 3. Navigation by using Google Now

If specifically user wants information about walking or public transport lines, he can use simple commands to ask the assistant to provide the information. Assistant use voice informing as a way to provide return information to the user. This can involve reading the route to the customer or informing the customer about options for different routes. Google Now also offers information about current location of the user.

Based on the location of user, Google Now can offer information about current status of traffic in the users vicinity, which means that information is delivered in real time. Users can also get information about public transportation, which bus or tram lines will take them to the destination. Information about public transportation are delivered in real time so the users know if their bus, tram or train is late and when the last one will leave from certain location.

Table 3 contains short outline of which services related to navigating or informing users in traffic personal assistants can offer. It is important to mention that all three assistants have limitations in languages they support so it's not possible to use all functionalities in whole world. Also, it is important to mention that each of the mentioned personal assistants has problems in understanding voice commands so users need to repeat some commands many times so that assistant can execute what is expected of it.

Functionalities	Siri	Cortana	Google Now
Voice activation	+	+	+
Uber	+	+	+
Information about public transport	+	+	+
Information about traffic	+	+	+
Information about current location	+	+	+
Information about restaurants/events/shops	+	+	+
ETA	+	+	-
Information about public transport stations	-	+	-

Table 3. Functionalities of virtual assistants

Smart personal assistants have capabilities to offer realtime information of traffic status and provide this information to people with disabilities. Even though there are still certain disadvantages and mistakes which often appear when processing user's requests, those will be lowered with constant upgrades to OS.

CONCLUSIONS

Today's mobile phones offer large number of capabilities to users across the world, regardless of their disabilities. First mobile phone which supported the needs of users with disabilities had physical buttons which users could feel. In that way they would know how to navigate through mobile phone and find required and necessary information. With technology advancement, mobile phones started to change and have evolved into smartphone devices with touch screens.

Mobile phones were developed in a way that a number of physical buttons has been brought to minimum which caused issues for persons with disabilities because they had no orientation for finding information they need. Development of mobile phone accessibility recommendations ensured that mobile phones are even more accessible to persons with disabilities than when they had physical buttons.

With constant improvements in technology, current operating systems can utilize components to provide users with accessible content and various services like voice control, voice dial, finding route to destination, traffic status, etc. Windows Phone, Android and iOS accessibility has been developed in similar way where each one of them offers a wide range of functionalities. Each one of the mentioned operating systems has virtual assistant which makes using mobile phone easier for persons with visual impairment.

Comparative analysis showed which services for informing users in traffic are offered via Cortana, Siri and Google Now. Each of the mentioned virtual assistants offer required information to the user to make their way in traffic easier. Cortana stands out because it offers its users ability to get information about each station in public transportation. Even though virtual assistants have issues because of language limitations and speech misunderstanding, they can still offer information which can help persons with disabilities to navigate in traffic easier. As a conclusion, it is advisable for persons with disabilities to use Google Now, Siri or Cortana application to improve quality of life, get accurate and reliable information and to make navigation in

traffic easier. In the future, Android will release its own virtual smart assistant called Bixby. Its capabilities will need to be assessed once it is released.

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