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Current Perspectives on Linux Accessibility Tools for Visually Impaired Users

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Abstract. The development of user-oriented technologies is related not only to compliance with standards, rules and good practices for their usability but also to their accessibility. For people with special needs, assistive technologies have been developed to ensure the use of modern information and communication technologies. The choice of a particular tool depends mostly on the user's operating system. The aim of this research paper is to study the current state of the accessibility software tools designed for an operating system Linux and especially used by visually impaired people. The specific context of the considering of the study's objective is the possibility of using such technologies by Bulgarian users. The applied approach of the research is content analysis of scientific publications, official documentation of Linux accessibility tools, and legal provisions and classifiers of international organizations. The results of the study are useful to other researchers who work in the area of accessibility of software technologies, including software companies that develop solutions for visually impaired people. For the purpose of the article several tests are performed with the studied tools, on the basis of which the conclusions of the study are made. On the base of the comparative study of assistive software tools the main conclusion of the paper is made: Bulgarian visually impaired users are limited to work with Linux operating system because of the lack of the Bulgarian language support.

Key words: software accessibility, assistive technology, screen reader, visually impaired users, Linux.

1. Introduction

The concept of accessibility is quite extensive. It may affect areas of art through transport to computer systems and technologies. Regardless of the field, the term describes the possibility of an environment, product or service being "reached or seen" (*Accessible*, 2018). (Hansen, 1959) defines the term as „potential of opportunities for interaction and is a measure of the intensity of the possibility of interaction“. (Litman, 2017) supports the opinion of „the ease of reaching goods, services, activities and destinations, which together are called opportunities “. The term is often used for people with special needs. Their access to the environment in which they live and work is ensured by the so-called “assistive technologies”. ((ATIA), 2018) define the assistive technologies as „products, equipment, and systems that enhance learning, working, and daily living for persons with disabilities “. These are software products or hardware devices through which individuals overcome barriers to access to information. They create conditions for people with disabilities to: lifelong learning; finding a job; full inclusion in public life.

World Health Organization supports a classifier of disabilities - International Classification of Functioning, Disability and Health (ICF). According to it, the disabilities are differentiated into the following groups (Flaherty, Zimmerman and Hansen, 2001):

- Body functions - the physiological functions of body systems (including psychological functions);
- Body structures - anatomical parts of the body such as organs, limbs and their components;
- Impairments - problems in body function and structure such as significant deviation or loss;
- Activity - the execution of a task or action by an individual;
- Participation - involvement in a life situation;
- Activity limitations - difficulties an individual may have in executing activities;
- Participation restrictions - problems an individual may experience in involvement in life situations;
- Environmental factors - the physical, social and attitudinal environment in which people live and conduct their lives. These are either barriers to or facilitators of the person's functioning.

Based on this classification, groups of assistive technologies can be identified to support people with different disabilities. There is no universal technology to help all users with special needs. To narrow the scope

of the study, this article focuses on the group of visually impaired people[1] and their specific needs for the use of computer technology. According to a publication on the official website of World Health Organization (World Health Organization, 2018) there are globally 1.3 billion people who have some form of vision impairment. There are approximately 30 million blind and partially sighted persons in geographical Europe according to a publication of the (European Blind Union, 2018).

The access to the computer of visually impaired users is dependent on the operating system, e.g. Microsoft Windows, Linux, Mac OS, etc. It is the middle level in the computer system between the hardware components and the applications which manages all resources and operations of the device. In this sense the choice of the specific accessibility tools is restricted by the type of the operating system. According to (NetApplications.com, 2019) in global perspective the most used operating system is Microsoft Windows with 87.56% users in January 2019, followed by Mac OS with 9.68% users and Linux with 2.14% users.

Although mobile technologies are gaining popularity, as some authors have pointed out, there are some major problem with them in terms of providing seamless access, namely: mobile device, mobile web browser, mobile operating system (Penchev, 2016). On this basis, the mobile accessibility remains out of the scope of the study.

In recent years, the initiative to develop free open source software has become more popular. By virtue of it, there is an ability of more and more people worldwide to work fully with a computer without being dependent on competing commercial software products. One of the not-for-profit and charitable organizations supporting the open source software movement is Linux Foundation dedicated to encourage the growth of Linux operating system.

On that base the aim of this research paper is to study the current state of the accessibility software tools designed for the operating system Linux and especially used by visually impaired people. The objective of this study is considered in a specific context - the possibilities of using such technologies by Bulgarian users.

2. Overview of Assistive Software Technologies for Visually Impaired Users

Assistive technologies can be different software products or hardware devices that help people with learning difficulties, blind, visually impaired, deaf, and so on. Examples of software include teletext, screen magnifiers, screen readers, speech synthesis programs, etc. Examples of hardware are large monitors, braille displays, braille keyboards, braille printers, telecommunication devices for deaf, audiometer [2], etc.

((ATIA), 2018) generally divided the computer software assistive technologies to screen readers and communication programs. (Mordini et.al., 2018) have conducted an in-depth research of the different groups of people with disabilities and on this basis offer a classification of assistive technologies used by blind and visually impaired people. The study is conducted by the European Parliamentary Research Service, which is part of the European Parliament. The latter is based on the application of the users’ daily life activities:

- haptic aids;
- travelling aids;
- assistive technologies for accessible information and communication;
- assistive technologies for daily living;
- phone and tablet applications for blind and visually impaired people.

In view of the objective in the present study, the interest is focused on the tools belonging to the third group of the classification proposed by the European Parliamentary Research Service of the European Parliament. The most common combination of software tools which visually impaired people use in their daily interaction with the computer is a screen reader and a speech synthesizer.

The *screen reader* can be defined as a software application which identifies and interprets what is displayed on the computer screen or recently on mobile device screen too. Feedback to the user is communicated through speech or braille output. Screen readers are form of assistive technology used by blind, visually impaired people or people who have learning difficulties. It is used in combination with other assistive technologies such as screen magnifiers or speech synthesizers.

Access to the content of the display is provided through the accessibility APIs available for the target operating system. For Linux, this is the Assistive Technology Service Provider Interface (AT-SPI), which is a set of tools that provide accessibility to applications designed as GNOME projects. AT-SPI can be used to automatically test user interface with tools like Linux Desktop Testing Project and Dogtail. This API is part of the GNOME Accessibility Framework.

The choice of screen reader depends on many factors, such as platform, cost, and the role of organizations such as charities, schools, and employers. Because of the variety of operating systems, screen readers are

[1] This kind of disabilities belong to the group of the Impairments.
[2] A device used to measure hearing loss.

increasingly associated with the distribution of the operating system. In Microsoft Windows Narrator is included, Apple Mac OS X includes VoiceOver, and the console-based Orca for Linux. Examples of open source screen readers are Linux Screen Reader for GNOME, NonVisual Desktop Access (NVDA) for Windows, browser extensions such as Fire Vox, ChromeVox, etc. In the English-speaking market, the one of the most commonly used screen readers are Freedom Scientific JAWS, GW Micro Window-Eyes and Dolphin Screen Reader.

Other kind of assistive technology for visually impaired people is a *speech synthesizer* which could be a software application or hardware device. As (Hande, 2014) notes other applications of that assistive technology are: to aid to people who are for the deaf and vocally handicapped; who have learning difficulties (for example, dyslexic); for educational purposes (e.g. learning a language); in the field of the telecommunications and multimedia; and in all kind of human-machine interactions (e.g. alarm systems, desktop messages, etc.).

(Furui, 2001) points out the speech synthesis is a process that produces artificial speech for various applications, such as mobile phone service systems, banks, hotel booking systems, applications for reading public messages, reading electronic text, etc. “The speech synthesis methods enable a machine to pass on instructions or information to the user through ‘speaking’” (Furui, 2001).

The synthesizers reproduce a text of an electronic document in speech, actions performed with the arrow keys on a keyboard, a joystick or body movements [3]. Depending on the level of improvement, speech may sound unnatural or very similar to the voice of a real person.

As stated by (Onaolapo *et al.*, 2014), the application has two basic modules – Natural Language Processing and Digital Signal Processing components. The first one includes text analyzer, phonetization and prosody generation modules. The second one is responsible for the actual computer “pronunciation” of words, phrases and sentences, which are similar to human speech articulation.

Speech synthesizers have databases that store parts of recorded human speech. When joining them, the synthetic speech is created. The database size of each system and the size of the stored speech units are different. Those that have the largest source base are storing sounds or neighbouring pairs of sounds (so-called “diphones”), but they may lack clarity. The high quality of synthetic speech is achieved by storing whole words or expressions. The synthesizer combines the model of the voice system and other human voice features to create a perfect synthesized voice output.

The most important qualities of the speech synthesis system are naturalness and understandability. Naturality means the outgoing sounds of the system to come closest to human speech. Understandability is related to how much these sounds are easy to perceive. The ideal synthesizer of speech sounds both natural and understandable.

The *screen magnifier* is a form of an assistive software technology for visually impaired people too. Its main application is to increase the size of the display elements (texts and graphics). Every modern operating system has such software. It can be controlled by keyboard shortcuts, computer mouse or trackpad. The software has significantly simplified features. It can increase the entire screen or only the user-defined areas. For users who suffer from macular degeneration, it supports an invertion of the colors on the screen from black-on-white to white-on-black too. This reduces the glare of the screen and helps to users to perceive the content unhindered.

3. A Study of Accessibility Linux Tools

According to a survey conducted among users worldwide, the most commonly used as primary screen readers are Windows-based JAWS with 46.6% users and NVDA with almost 32% users (WebAIM, 2017). They are followed by 11.7% users of Mac OS VoiceOver. Unlike Windows users, those who use Linux do not have a large number of such software applications.

The Linux screen reader, which is the default accessibility tool for the most of the common distributions, is Orca. Popular target systems are Ubuntu, Debian, Fedora and the distributions based on them. It works with BRLTTY – a background process which provides access to the Linux/Unix console for a refreshable braille display and provides complete screen reader functionality (*BRLTTY official website*, 2018). It is free of cost open source software. It supports the Assistive Technology Service Provider Interface (AT-SPI). The application works with multiple Braille displays and speech synthesizers (The GNOME Project, 2019). It supports a speak multicase strings as words. Users could change the spelling of words, pronunciation of digits, configuring keyboard shortcuts.

Orca has very good capabilities to work with various major Linux applications, including office applications. It is fully adapted to Gecko engine of Mozilla which means Orca works well with Firefox browser and Thunderbird email client. Unfortunately, the support of Google Chrome is not at a good level. The application provides an access to dynamically-updated content such as on web pages and IM and IRC clients.

[3] In the case of disabilities in which a person manages a computer only by moving any part of his body, such as eyes, finger, etc.

Unfortunately, the screen reader does not support a Bulgarian version of its graphical interface. Using such software, and if it is distributed free of charge to blind people, persons will be greatly facilitated. On the other hand, as part of The GNOME Project, the application's documentation is supported in many languages, including Bulgarian.

The only screen reader created so far in Bulgarian is the DOS-based and free-distributed Echo developed by Hussein Ismail (Lyubenov, 2005). The inconvenience of this reader is that it does not have a set of functionalities to provide full access to modern computer technology.

At present, Bulgarian users can only use screen readers designed primarily for the Windows operating system. Such are JAWS and NVDA, which have good alternatives to specialized software used to enable them to work with a variety of applications that are accessible to viewers.

As mentioned in the article, in combination with the screen reader, a speech synthesizer is used. Its main function is to provide feedback to the user in the form of a synthetic speech. Linux users are again significantly restricted with regard to the variety of software in this category. The most stable and used Linux-based synthesizers are eSpeak and Emacspeak. The current study is based on the features lists of the products on their official websites and on the tests made for the research purpose by the author of the paper.

„Emacspeak is a speech interface that allows visually impaired users to interact independently and efficiently with the computer.“ (*Emacspeak - The Complete Audio Desktop*, 2019). Some of the requirements of Emacspeak are Linux-compatible sound card, a hardware or software speech synthesizer and Emacs[4] (Muhammad *et al.*, 2016).

As the official website (*eSpeak text to speech*, 2019) points out, “eSpeak is a compact open source software speech synthesizer”. The target platforms of the application are Windows, Linux, Android, Mac OSX and Solaris. Its synthesis speed is between 80 and 390 words in a minute. The naturalness and understandability of the audio output is partial, the well supported language is English. The application has a multivoice and multilanguage support.

Both programs support user vocabulary and reading from audio files and manually added text input (a usable function for users who learn foreign language). They allow adjusting the voice height and reading intensity.

Other features of eSpeak are: supporting of around 40 languages; converting a text to phoneme; possibility to extend the program's database; tracking current processes that the system performs; incomplete SSML support, etc. The product supports multiple voices as well as expanding its database.

Unlike eSpeak, which can be used on different platforms, Emacspeak is designed for Linux and mainly Debian-oriented. Both do not support a user interface in Bulgarian. Unlike Emacspeak, eSpeak can play Bulgarian texts, but unfortunately the synthesis of speech in this language is not as advanced as English support for example. It is related to the so-called "language localization of the user interface" (UI) (Todoranova, Todoranova, 2017). According to the authors, the UI localization requires both language and technical knowledge to ensure its good quality (its correctness).

The applications themselves do not support a voice installation, which can be considered as a drawback from the point of view of blind users. In order for a blind person to install a speech synthesizer on her / his own, a screen reader must be pre-installed on her / his computer with a speech synthesizer built into the operating system.

The first speech synthesizer of Bulgarian speech is Betsy. It was developed in the late 1980s by Borislav Zahariev and improved in 1995 by Toros Hovanesian (Lyubenov, 2005). The synthesizer works in MS DOS-Prompt on Windows 9x. A modern commercial application designed for the Windows NT operating system is SpeechLab 2.0. The program has existed since 2005 and was developed by the Bulgarian Association for Computational Linguistics. The voice of Bulgarian actress Gergana Stoyanova was used. The output speech sounds natural, the intonation contour of the sentences is kept, the user dictionary is maintained, allowing for the addition of abbreviations, new words, special characters, etc. Visually impaired people can get a free individual license for non-commercial use of SpeechLab 2.0 from the Horizons Foundation or the Bulgarian Union of the Blind.

Representatives of the Linux community are also developing distributions that are designed for people with special needs and specially designed for visually impaired users. These are Vinux and b-Linux. Both operating systems are based on Ubuntu with GNOME desktop environment. They work with the Orca screen reader and the built-in speech synthesizer. Visually impaired people have an appropriate contrast, increased user interface components and fonts. The performance of both operating systems is good, which makes them suitable for old machines. Unfortunately, they do not have a voice installer, which would not contribute to better user experience by blind users. In the specific context of this study, we can note as an advantage of b-Linux to Vinux the maintenance of an installer and a user interface in Bulgarian. Vinux has an official translation of only

[4] A family of text editors which are part of the GNU project.

English, Dutch, German, Portuguese and Spanish languages (VINUX, 2018). Another advantage of b-Linux to Vinux is better community support and more complete documentation, including in Bulgarian. Like any modern operating system, these two operating systems also support screen magnifiers with the basic features described in this study.

4. Conclusion

On the base of the comparative study of assistive software tools it could be concluded that the Bulgarian visually impaired users are limited to work with Linux operating system because of the lack of the Bulgarian language support. Disadvantaged people are often dependent on charitable, non-governmental and national representative organizations of people with disabilities. Within Bulgaria, the problems of computer accessibility of people with visual impairments do not seem to give a sufficiently large public response. Software assistive technologies supporting the Bulgarian language and supporting their access to information and communication technologies are limited by the operating system. As the study notes, they are designed for Windows operating system.

„Nowadays information technologies have become a major business function in almost every organization.“ (Sulova, 2018) One of the reasons companies do not direct their efforts to develop applications for Linux operating systems is precisely the Linux ecosystem problems. There is a wide variety of distributions and the variety of differences between them is equally great. In addition, a distribution can be used with a variety of desktop environments, which also create difficulties in developing software applications to such an extent that some applications are not compatible with certain desktop environments for the same distribution. One of the alternatives for Linux users to install and use Windows applications is through the environment created through the Wine application. Unfortunately, such an option does not exist for Windows-based assistive technologies because of the poor interest in these applications running in Linux.

The problems of visually impaired people worldwide have long been popularized and improvements are being made to supporting technologies in every single direction. Some of the innovations in this direction are: tactile text-to-Braille converter, Braille watch, Braille tablet, electro-tactile technology which helps blind users with orientation, mobility, and object recognition (e.g. BrainPort), etc. Such developments are expensive and in many of the cases impossible to buy by the regular user. This requires focusing open source community efforts on developing free open source applications to ensure access to information for people with vision disabilities. It is also necessary to work on developing and improving business processes and software systems in organizations in terms of participation, motivation and engagement of their users (Stoyanova, 2018). “Designing such functionality and integrating it in a more complex system varies in difficulty based on the subject area, it is highly useful if the application has many features and its scope covers various activities” (Bankov, 2016).

Access to the public resources of people with disabilities, provided by modern assistive software technologies, enables them to achieve independence and autonomy. This is also one of the conditions for achieving their better professional realization and their full inclusion in the modern dynamic life.

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