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Accessibility for the Visually Impaired: State of the Art and Open Issues

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f ***Abstract*—Although much has been done in the field of accessibility, the World Wide Web is not yet for everyone. Many Internet users often find difficulties in navigating web pages. This is particularly true for people with visual impairments and blind people. In this paper, we present a review of the state of the art of the application of accessibility rules to web pages and describe which are the common problems that people with sight impairments must endure when surfing the Internet; to this aim, we use information collected during an interview with a blind user who is an expert in navigating the web using a screen reader.**

***Index Terms*—Human-centered computing, accessibility, websites, blind users**

I. Introduction

The advent of the Internet has extremely improved the possibility to reach information quickly, simply and without the need to physically move. Users can find new and old friends with social networks, book a hotel for their holidays, share photos and memories with relatives, read newspapers without leaving home to buy them, etc.

But not all users. Not always. The problem is that the users who could benefit the most from this easy connection are those who are often excluded from it [1]. People with disabilities generally experience more difficulty in traveling. e.g., visually impaired people cannot drive and may need help of a guide dog to walk in a public environment like, for example, a street. Yet, visually impaired people are also the kind of users that find major difficulties in accessing web pages, because they need a tool that reads the screen for them. Unfortunately, this tool is not always easy to use and it is not able to read all the available web pages.

Accessibility is a way to design and build products, devices, services and environments which can be *accessed* and used by everyone, independently of user's capabilities and equipment. Accessibility is particularly addressed to people with disabilities, who can experience difficulties when dealing with digital documents that are not appropriately designed [2], [3]. At the same time, accessibility is also a resource for other entities, which read the web pages looking for information and are not humans, but are very useful for humans, the search engines.

In this paper, we present a review of the state of the art of the application of accessibility rules to web pages and describe which are the common problems that people with sight impairment must overcome when surfing the Internet; to this aim, we use information collected during an interview with a blind user who is expert in navigating the web using a screen reader.

The paper is organized as follows: Section II overviews related work. Section III discusses the main accessibility issues for visually impaired users. Section IV discusses emerging research and innovations. Finally, conclusions are drawn in Section V.

II. Related Work

Other works in the literature address the problem of website accessibility. A study conducted by Hanson and Richards in 2013 [4] shows that many US top-traffic and government websites have multiple violations of the accessibility rules. Moreover, observing the websites' changes in a period of 14 years, the authors state that their improvements in accessibility are due to the use of new and more accessible technologies rather than a better focus on accessibility.

Problems related to the use of screen readers are discussed in [5]. Borodin *et al.* describe blind users not as passive consumers but as adepts at developing and employing browsing strategies that help them to overcome accessibility issues.

Carvalho *et al.* [6] focus their attention on web navigation using mobile devices. They performed a usability test studying the navigation experiences of six blind users and four mainstream users navigating in four websites. They reported 514 problems and/or violations, 409 experienced by blind users and 105 by normal-vision users. The most common and severe problems are related to the lack of navigational aids, not clear interaction and absence of text alternative for images.

Problems related to navigation are also described in [7], where the authors state that blind users still strongly depend on scanning navigation instead of logical navigation. The paper describes an automatic analysis method for web page usability as well as a fine-grain analysis of user's behaviors and advocates the use of simple structures.

A possible solution to this kind of problems is proposed by Tonn-Eichstädt [8], who defined an interaction model for blind users' interaction strategies that can be used to measure accessibility of a website and the time required to execute a task for this particular kind of users. The model helps to choose the best alternative among layouts. Unfortunately, the model has not been verified so far.

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Although there has been a long way in defining accessibility rules and the World Wide Web Consortium (W3C)[1] has defined the Web Content Accessibility Guidelines (WCAG) [9], there is still a lot to do in this direction. Dattolo and Luccio [10] studied the problem of accessibility for people with Autism Spectrum Disorder (ASD). Despite many studies have shown the positive impact of using computer technologies on supporting lives of people with ASD, only few websites are accessible for them. The authors proposed specialized guidelines for designers/developers of websites and mobile applications for users with ASD.

Power *et al.* [11] describe an empirical study conducted with 32 blind users which shows that many problems encountered by these users cannot be captured by the WCAG. The users were asked to navigate 16 websites and reported 1383 accessibility issues. Only 50.4% of these issues are covered by the WCAG 2.0. Therefore, even if the biggest problem is that very few developers know and implement the WCAG, this paper shows that another big problem is that the WCAG are still insufficient to guarantee accessibility. The paper suggests to move from a problem-based approach towards a design principle approach.

III. Main Accessibility Issues

Unfortunately, many accessibility problems encountered by visually impaired people when using computers and smartphones are not yet solved. They can experience very different issues related to the areas of computer science or not, from the acquisition of accessibility tools, i.e., a screen reader, to obstacle in the exploration of even seemingly simple websites designed and developed only for normal-vision users.

During our research we had the possibility to interview a specialist in accessibility for blind people that actively contributes in the NVDA project, an open source screen reader that is nowadays the most popular non-paid viable solution. We asked him a set of question about his experience with using a computer or a mobile device to navigate a website.

Thanks to this interview, we were able to divide the possibly encountered issues in four different areas: *Tools for Accessibility, Guidelines for Accessibility, Captcha* and *Mobile Interfaces*.

A. Tools for Accessibility

The first obstacle that blind people and people with strong visual impairment encounter is related to the high prices of software and hardware accessibility tools. The easiest way to navigate an operative system and its programs is by using a screen reader. From this point of view, the most accessible operating system is macOS thanks to the integrated VoiceOver software. When a blind user buys an Apple computer, the VoiceOver software is available out-of-the-box and it does not require an Internet connection to work or the help of other people for any additional download, installation or configuration; it just starts the first time the user turns on the computer.

[1]http://www.w3.org

Unfortunately, macOS is tightly binded to Apple computers and laptops, that are more expensive than the Windows or Linux counterparts with the same hardware specifications. However, our interlocutor evidenced that, from his experience with these computers, the integrated macOS screen reader is not compatible with some fundamental applications. For this reason VoiceOver is no *panacea*, but the user has to install another screen reader. Furthermore, some applications are not available for macOS so it becomes necessary to install other operating systems like Windows to fill the gap. This is a general problem that afflicts also normal-vision people, especially when we are speaking of business softwares. So, the non trivial task of installing another operating system can result in being even more difficult for people with visual impairments.

Recently, the latest version of Microsoft operating system, Windows 10, also integrates a screen reader called Microsoft Narrator that is now available out-of-the-box when a user buys a new computer and, like VoiceOver, it starts as soon as the user turns on the computer. The deep integration of Narrator in the operative system is a recent introduction in the Microsoft offer also due to the development of the personal digital assistant Cortana, but like VoiceOver in macOS, the compatibility is limited to only some applications. Therefore, even in this case, it is necessary to buy a dedicated software that is capable to properly work with a wider range of applications.

The most famous screen readers are Jaws[2] by Freedom Scientific, Dolphin[3] by Dolphin Computer Access Ltd. Technology House, System Access[4] by Serotek and the open source project Non Visual Desktop Access, NVDA[5]. Table I compares prices and features of these screen readers.

All these softwares, with the only exception of NVDA, are softwares that require the purchase of a license and their prices range between 400$ and 1300$. There are also various policies for the updates of the software and sometimes, future major releases are not guaranteed when purchasing a software license.

Instead, NVDA is a totally free software for the final user and, like the paid screen readers, provides very useful features such as the OCR and a portable version. Unfortunately, like many other open source projects, its development depends only on the community of developers and on the monetary support of the contributors. Moreover, the support for a specific natural language is usually committed to the local community of users. Better voice synthesizer can be bought providing a better experience at a very low cost.

Braille monitors are additional accessibility tools available for blind users. As can be seen in Figure 1, they are electromechanical devices to visualize the contents of web pages through Braille characters. These devices are bars on which the Braille characters are disposed in line and composed of a combination

[2]https://www.freedomscientific.com/Products/Blindness/JAWS
[3]https://yourdolphin.com/screenreader
[4]http://www.serotek.com/systemaccess
[5]https://www.nvaccess.org/

TABLE I
COMPARATIVE TABLE OF THE MOST FAMOUS SCREEN READERS

Name	Developed by	Prices	OCR	Portable Version	Updates	Braille Display Support	Supported Languages
JAWS	Freedom Scientific	From 1020 to 1300 $	Included	Not available	Updates for the purchased version, no major releases	Yes	30
Dolphin	Dolphin Computer Access Ltd. Technology House	Around 800 $	Included	Included	Updates and major releases for the next 2 versions	Yes	35
System Access	Serotek	From 400 to 1200 $	Not included, 300 $	Not included, 500 $	Updates and major releases included	Yes	Only English
NVDA	NV Access	Free	Included	Included	Updates and major releases included	Yes	43

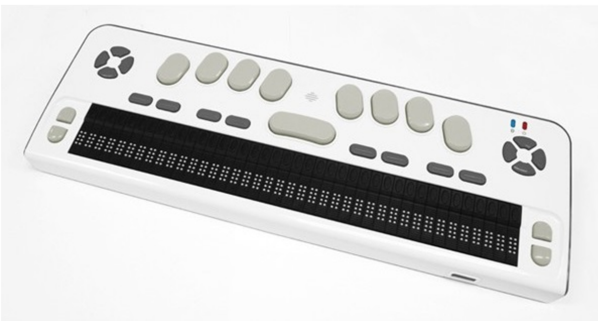

Fig. 1. An example of Braille monitor with a display of 40 characters

of refreshable dots. There are several models on the market that differ for the quantity of Braille characters, called cells, that they can show. Each cell is composed of 8 points that can represent all the 256 characters of the ASCII extended code. Even if Braille monitors are a very good way to help blind people to access the web contents, they are very expensive devices that have prices varying from 900$ to 3000$. They also require that the users are familiar with the Braille language, which could be very difficult to learn for people that are not blind from their birth. Furthermore, their use is very slow. For all these reasons, even Braille monitors do not represent a perfect solution.

B. Guidelines for Accessibility

In the last years, a lot has been done for the accessibility of the web. The World Wide Web Consortium (W3C) defined accessibility standards [9] to create websites explorable by all categories of users, so also blind and visual-impaired people. Unfortunately, as many countries have not legislated yet in order to make these standards observed, it is still common to find websites with a badly implemented or even absent accessibility.

The most frequent issues that a blind person can encounter while navigating websites are related to various elements:

- wrong labeling of contents' language;
- bad design of tables;
- buttons with wrong or no context,
- images with empty or prolix description.

Wrong labeling of contents' language consists of not properly set the language of a web page or of a portion of it. For instance, think of a web page with a text written in Italian but also including a quotation in English. If the change of a language is not explicitly reported, the screen readers are usually not able to autonomously recognize that they have to temporarily switch to English.

Tables represent an obstacle in the navigation for blind people since, especially if they are blind from their birth, they are not used to access bi-dimensional data. Designing a good table is not a difficult task and making mistakes or lazy design choices could create difficulties especially if a table contains a lot of entries. It is then crucial to properly label rows/columns, to avoid nested tables and to limit the use of huge quantity of text in a cell.

The buttons in a web page have to be contextualized in relation to their functions and the contents that they refer to. At the same time, it is suggested to avoid to provide too much information as it can break the navigation flow of the contents. Moreover, the instruction must avoid visual information, e.g., *"click on the red button"*.

If, on the one hand, the absence of a text description of an image can cause the user to lose information, on the other hand, an overload of the information can be annoying for blind people forcing them to speed up the reading of a web page. Indeed, blind users often encounter prolix descriptions of images, logos and icons. Our interlocutor reported that describing logos and especially icons is not a good practice because they are not useful information and just slow down the reading. Moreover, adding an excessively long description to an image breaks the navigation flow; it is suggested instead to use the specific HTML attribute "longdesc" for a more detailed description of the images.

C. CAPTCHA

One of the most commonly used techniques to block malicious entities that could threaten a website is to use a countermeasure called CAPTCHA, i.e., Completely Automated Public Turing-test-to-tell Computers and Humans Apart. As the acronym says, a CAPTCHA is a test of one or more tasks that has the goal to establish if the user is a human being or a computer in order to prevent the access of the latter to specific contents or areas. One of the features that can help to better distinguish a computer from a human is the ability to use his/her senses. For this reason, one of the most commonly adopted technique is to use tasks based on the image recognition. This is due to the fact that image recognition is generally a difficult task for computers. Unfortunately, this clearly embodies a significant challenge also for the blind people who, like computers, cannot use the sense of sight, and thus are excluded from accessing the contents. This problem has been deeply investigated in literature [12], [13].

In Figure 2 we can observe some examples of the visual CAPTCHAs that users can frequently encounter during a web navigation session. Figure 2a shows a CAPTCHA based on the recognition of specific objects among a set of various images that can change during the task. Figure 2b, instead, depicts a visual CAPTCHA based on the resolution of a simple mathematical task on the base of the numbers shown on the dice faces. Figure 2c represents one of the most commonly used CAPTCHA and requires to identify the letters and numbers shown in the figure that are usually overlapped or distorted to make the task harder for non human agents. Finally, Figure 2d is a CAPTCHA based on the recognition of an intruder among a series of symbols. Clearly, all these tasks based on visual CAPTCHA cannot be solved by a blind user.

Acoustic CAPTCHA embodies an interesting alternative created by web developers. This technology is certainly a big improvement with respect to the image-based ones but far from being a flawless solution. To avoid computers to recognize the acoustic CAPTCHA, the web developers have to introduce a certain level of noise in the sound that the human being has to recognize. If the surrounding environment is acoustically quiet and the user possess good audio speakers, earphones or headphones, he/she can easily solve the required task. On the contrary, if the environment is noisy or the audio speakers are not good, the task can become quite difficult to solve.

With the fast diffusion of CAPTCHA, this technique has become a serious issue to address in order to guarantee a good usability of the websites for blind people. According to [14] the task success rates of audio CAPTCHA is below 50% while CAPTCHA implemented by Microsoft and Yahoo have been defeated at a success rate of higher than 60% [15]. This means that current CAPTCHAs do not eliminate the problem of non human agents [16], while creating access limitations for people with disabilities.

Few months ago, W3C published a working draft [17] that deals with the problem of CAPTCHAs, in particular with using tasks that do not inherently exclude many people with disabilities, resulting in an incorrect denial of service to these users. The draft examines current solutions that allow systems to test for human users, and the extent to which these solutions adequately accommodate people with disabilities, showing that there is not a single ideal solution; rather, the use of emerging federated identity systems currently provides the most accessible option.

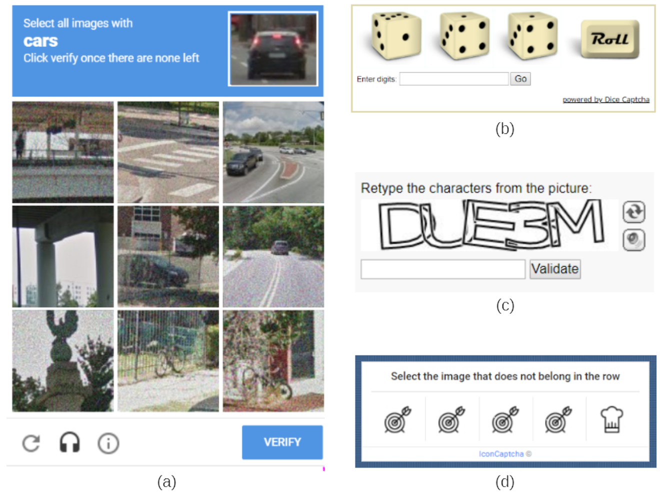

Fig. 2. Some examples of visual CAPTCHA. (a) Image recognition, (b) simple mathematical task, (c) letter and number recognition, (d) find the intruder

D. Mobile Devices

The last big identified issue is related to the interfaces used in the mobile smart devices. Currently, there are not precise guidelines to design an accessible mobile interface even if both Apple [18] and Google [19] provide guidelines to design interfaces; yet, these guidelines deal more with graphics and style and do not properly address problems related to accessibility. Once again, W3C is trying to define some guidelines to help the development of accessible mobile web pages [20] but like in case of the ordinary web pages, it is an obligation of the single countries' government to legislate in order to make these standards respected.

From the feedbacks provided by our interlocutor, iOS currently results the most accessible mobile operative system but, like macOS, it is an exclusive of Apple iPhone, a quite expensive smartphone model with a very slow depreciation. The reason for this good implementation of accessibility is the presence of the screen reader VoiceOver, the same that is embedded in the macOS but adapted to be usable through a touch interface.

Instead, Android smartphones are still in the initial state from the point of view of the accessibility because of the horizontal and vertical fragmentation of the market. The horizontal fragmentation is related to the presence on the market of many hardware manufacturers that often heavily personalize and modify the base operating system. As a result, the user interface can greatly vary from brand to brand, with different implementations of basic functions such as navigation buttons, notifications or settings organization. This represents a problem because the integrated Android screen reader, TalkBack, cannot be totally compatible with all these personalizations.

The vertical fragmentation instead, is related to the adoption of new versions of the Android operative system by different smartphone models. Unlike iOS, it may happen that even

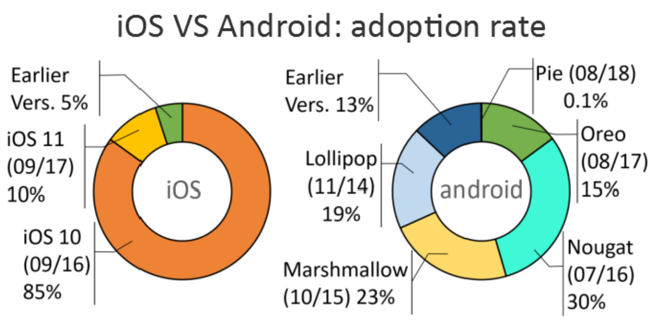

Fig. 3. Operative System adoption rate for iOS devices versus Android devices on September 2018 [21]

relatively new Android smartphones do not receive official updates or, even worse, that new smartphone models are launched in the market with an old version of Android (Figure 3). In this way, bug corrections, improvements or new features related to the accessibility could not reach the user's device. As previously mentioned, Android is currently endowed with the mobile screen reader TalkBack. This reader is developed by Google itself and, like VoiceOver for iOS, it is designed to interact with the users through a touch interface. It is also interesting to note that the two softwares share a similar set of gestures to navigate the device.

Finally, there is one more issue that is emerging in the latest years. Even if VoiceOver and TalkBack are specifically developed to work with a touch interface, the fact that most of the hardware manufacturers are removing physical buttons for aesthetic reasons makes the interaction with smartphones more difficult for blind people.

IV. Current Offer and Future Solutions

As shown in Section III, the issues encountered by a blind user in the everyday use of technology are various and very different from each other. Fortunately, there are new and interesting research and innovations that in the next years could greatly improve the accessibility for this category of users. What is required from developers is to think outside of the box and to create new ways of interaction with blind users by listening to their needs and directly collaborating with them, the so called user-centric design.

Personal Digital Assistants (PDAs) are, for example, a very useful instruments to help both visual impaired and normal-vision users in the everyday life. They use a totally vocal interface that interact with the user by speaking to him/her and executing his vocal commands. We can find PDAs in the most successful electronic devices such as computers, smartphones or smart house appliances and even if they are still very simple and with limited functions, they can facilitate some fundamental tasks like reading the daily news, making an appointment or even buy goods from on-line shops. Some examples already available on the market are Siri[6] for iOS and macOS, Google Assistant[7] for Android and Google Home speakers, Cortana[8] for Windows 10 and Alexa[9] for Amazon Echoes speakers.

Another type of interface that could increase the accessibility for blind people is the one that exploits the vibration function of smartphones and smartwatches. This technique is called haptic feedback and consists in communicating with the users by utilizing different combinations of vibration signals on the base of what is happening on the device or in the users' environment. Even if it is not commercially spreaded, we can already find some examples of interfaces developed in this way and possible implementations are various. For instance, the project "StepByWatch" [22] is a smartwatch application that helps blind people in navigating the city by suggesting the path to follow due to the vibration signals. The application uses also crowdsourcing as a source of information in order to provide users with even more information, such as obstacles, closed streets or dangers.

Another application which exploits the crowdsourcing paradigm is embodied by "Be My Eyes"[10], an application that tries to offer visual assistance to blind people through a network of volunteers. The interfaces used in this case are audio and video: after registering to the service, the users interact with a verified real person by showing to him/her the element that they are not able to interpret. When a volunteer accepts the task, he/she will provide real time instructions to solve the problem. A concrete example of such a situation could be solving a non-accessible CAPTCHA.

As discussed in Section III, designing an accessible website is not a simple task for various reasons. Beside the difficulties in thinking and pretending to act as a blind person, the web developers have to deal also with the fact that the websites validators are often not totally prepared to detect problems related to accessibility. More accurate or even dedicated tools could mitigate the problem of non accessible websites and, at the same time, educate the web developers to better understand the problematics of blind users.

Finally, chat bots are tools that in the past years had a lot of success in providing help and information also to normal-vision users. They can be considered as the forefathers of PDAs because of their limited functions and the interaction interface. They generally interact with users through text messages, exactly like a chat session with a human being, and the questions that the user can ask them to it could be predefined or open. In the latest years, they have been often substituted with even more efficient tools; yet, for specific services, they are still a good solution to provide an assistance even to blind people navigating a website.

V. Conclusion

Despite the big advancements in the latest years, the accessibility of web contents for visually impaired users is still an

[6] https://www.apple.com/siri/

[7] https://assistant.google.com/explore

[8] https://www.microsoft.com/en-us/cortana

[9] https://developer.amazon.com/alexa

[10] https://www.bemyeyes.com/

open issue. In this paper we identified various kinds of different problems encountered by blind people during the daily usage of computers, smartphones and other electronic devices. However, the most concerning aspect is that there is not only a design barrier related to the creation of web pages suitable for visually impaired users, but also a monetary barrier. The real problem with the accessibility tools like screen readers and braille monitors is that they are generally very expensive, e.g., a good braille monitor can cost even 3000$ and does not completely solve the problem. Furthermore, if a blind person wanted a more accessible operating system than Windows or Android (for smartphones), the only possible alternative would be to buy Apple devices like iPhones or Macbooks but, again, they are very expensive if compared to other devices with a similar hardware.

Fortunately, there are emergent solutions for the discussed problems, solutions that are trying to build a more accessible and inexpensive digital environment. The community that is building the open source NVDA screenreader is very active and spreads it around in a lot of countries around the world. Moreover, W3C is building guidelines also for mobile websites and CAPTCHAs and the PDAs are being integrated in an increasing number of devices.

There are also new ways of designing interfaces by exploiting the physical outputs of devices such as the vibration, or applications that use crowdsourcing as a way to overcome visual barriers.

However, there is still a long way to go for a more accessible web; the creation of tools that can help web designers and developers in this task could greatly improve the current situation.

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