Mobile App Prototype Supporting People With Special Needs

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Abstract **– The article analyses current mobile applications designed for people with special needs. They are aimed at improving routine daily activities and services non-disabled users would not experience significant difficulties. The purpose of the article is to develop and promote a mobile application for people with impaired vision or hearing. In this paper, a mobile application prototype has been designed and developed that would also be useful for anyone wishing to learn sign language. It is compatible with both Android and iOS operating systems. The methodology involves conducting preliminary research and interviews with potential clients. A survey on current mobile applications in the targeted area has been carried out. Functionalities offered by the prototype ensure that the needs and requirements of 'different' users are largely met. As for non-disabled users, the app has the potential to enhance their communication with those specific user groups.**

Keywords **– Mobile application, vision impairments, blindness, deafness, special needs.**

1. Introduction

Technological advancements in software development and communications have played an important role in the transformation of mobile devices.

In recent years, they have become an inseparable part of people's daily lives as well as some of the most sought-after items. Different age groups across the globe are using them more and more frequently. Today, people use a number of mobile apps on their smartphones to complete various tasks [1]. The number of similar mobile applications developed for a specific area is also increasing. As a result, mobile technologies have become more accessible to 'different' users, which present an excellent opportunity to enhance the independence of people with disabilities [2].

There is no doubt that mobile devices give significant advantages to people with various disabilities. They facilitate their social inclusion. Despite arguments for and against the use of those from an early age, in some cases this process is inevitable [3].

Software technology and the Internet are crucial in supporting people with disabilities today. They are indispensable for communication and connection with the rest of the world as well as for assistance with daily activities. These users acknowledge the benefits of accessing mobile devices and services not just for themselves but also for other disabled individuals in a positive way. Thus, they do not feel isolated and neglected by society, family, and loved ones [4].

2. Methodology

The purpose of the report is to examine various mobile apps that aid disadvantaged individuals, such as those with impaired vision or hearing, in their daily activities. Based on a critical comparative analysis of strengths and weaknesses of those apps, the authors' task is to develop and test a similar mobile application in this area in Bulgarian.

The research is based on qualitative methods and involves studying various publications as well as mobile apps for individuals with visual or hearing impairments.

A significant role in this research is played by the study of modern mobile devices and applications running on Android and iOS operating systems in their use by a certain group of people with visual impairments and hearing loss.

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Tests have been carried out on the accessibility features that are built-in and how they work with various applications to benefit people with different disabilities. Ordinary users who wish to learn sign language have approved the tests of the developed mobile app.

As a result of the research, it can be concluded that modern mobile devices enable this specific group of users to do many of their daily activities more easily. This became apparent especially during the time of the COVID-19 pandemic and the imposed restrictions, when many challenges arose for people with visual and hearing impairments in the daily performance of routine tasks.

3. Related Work

The additional software specialized for people with disabilities have a 'multimodal interface' for smartphones. This is a customized layer on top of the standard software already available on these devices. As an example, a 'Personal Social Assistant' can be employed for the role of 'assistant software'. It provides analytically meaningful menus with icons, text-to-speech and a scalable interface. The easy-to-use touch screen also enhances the usability and accessibility of these devices. Additional devices to assist people with special needs are shown in Fig. 1. [5].

Figure 1. Devices to help people with special needs

The use of mobile devices by individuals with intellectual disability, including people with autism , have also been observed [6], [7]. Apps are being developed specifically for people with intellectual disabilities and autistic children to improve their communication skills. The software's available features allow users, particularly young children, to operate by using buttons, images, or directional labels [8]. The applications are user-friendly and have an intuitive interface for easy access to their components. Users cannot only perform basic actions, but also medical care and therapy activities like learning or working through the phone (Fig. 2) [7]. Based on observations and tracking of the performance of these user groups, applications are being developed with increasingly user-friendly and intuitive interfaces.

Figure 2. Application interface for people with autism

At present, visually impaired and totally blind people have the opportunity to live better owing to the development of technology and mobile devices. Some time ago, they would have relied mainly on friends, professional assistants or guide dogs to meet their everyday needs, to get around, shop and make payments. Nowadays, however, there are numerous technological devices and gadgets, which make it easier for them to cope. With the rapid advancement of mobile technology, smartphones appear to be a more accessible option for the visually impaired than computers. A mobile device is lighter, smaller, and often cheaper than a laptop, so disadvantaged individuals also prefer to use one when performing a wider range of daily visual activities [9].

In the recent past, blind people faced problems in the learning process as well. Similar challenges also arose in their professional life – when using computer devices, reading or writing electronic messages and documents.

These users can now benefit greatly from the availability of validated computer software and mobile applications for speech-to-text or audio voice guidance systems. According to statistics, the majority of available mobile apps are entirely in English and have a user-friendly interface. There are some that provide support for languages like Hindi and Kannada [10]. The user chooses the language to handle text, messages or documents through speech selection, for example Hindi (Fig. 3) [10].

It is still challenging some blind people to achieve safe and independent mobility. While a large percentage of older users appreciate their practicality, they find it difficult to work with mobile applications compared to the younger generation. There are many applications today that allow for independent reading, writing, navigation, learning, and other activities. According to studies, it would be good if a group of blind people refined and tested every specialised mobile application. This would make it easier to generalise usability and provide effective usage instructions so as to avoid any associated issues [11].

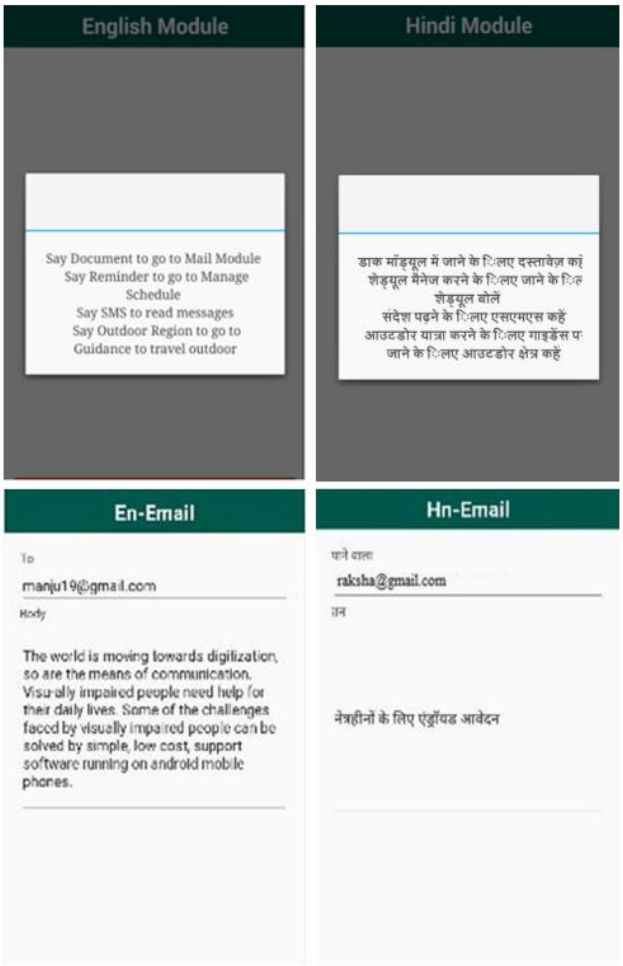

Figure 3. Mobile application interface for the visually impaired

People with hearing impairment encounter a similar problem. It is thought they do not need a telephone due to their hearing loss and inability to speak. There are still no accurate statistics on a demographic sample about the number of people with partial or profound deafness living in a particular settlement. It is only through public employment offices, organisations or companies that the number of registered people with hearing disability can be obtained. According to the World Health Organization (WHO), over 5% of the world's population or more than 430 million people, including 34 million children, need rehabilitation for the treatment of disabling hearing loss. It is reported that more than 700 million people, or one out of 10, will be suffering profound hearing loss by 2050 [12]. Most of them typically use hand gestures to communicate. Until recently, hearing loss has either been inherited or caused by disease. Today, however, it is observed in users due to their excessive use of headphones or other modern devices. Ignoring their worries, many of them want to use phones just like everyone else. Numerous apps have been developed to serve primarily non-disabled users, thus not gaining much popularity among people with hearing impairment. However, there is a growing trend towards flexibility and the inclusion of additional features to assist the latter [13].

A decade ago, mobile apps for people with hearing loss were created to help them avoid potential problems in everyday life. They would warn them with visual or vibrotactile alerts in case of an indication of audio events happening around. Examples include broken glass, fallen objects, an activated alarm or message, a vehicle passing by and opening or closing doors [14].

There is a limited number of applications providing a simple interface, for example, when medical assistance is required or used in health emergencies. In the event of an emergency, individuals receive get help by pointing at or touching the relevant image in the app [15].

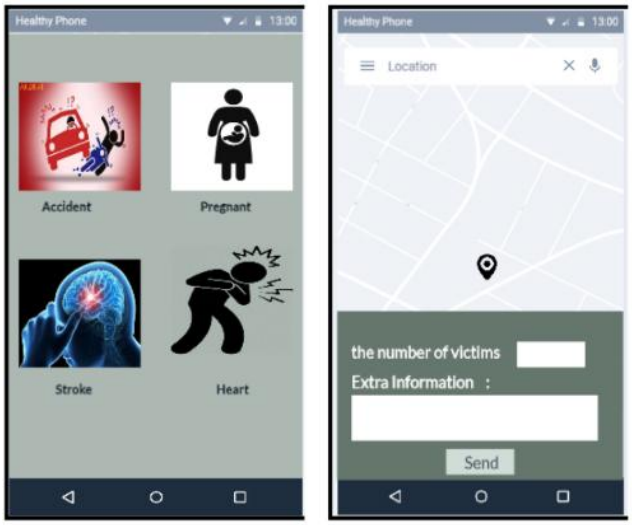

Figure 4. Interface of application for the visually impaired [15]

The need for more comprehensive mobile apps for individuals with hearing impairments has been researched over the years. Their usefulness depends on the inclusion of additional features; not only are graphical and text elements recommended to be incorporated but also a sign language interpreter as well [13].

However, the needs of the hearing impaired cannot be met by all the available applications today. For example, social communication apps like Messenger, Viber and WhatsApp, which are universally recognized, present no challenge for non-disabled users. They do not have a direct user interface for those with hearing impairments [16]. When communicating, most people with hearing loss use signing in the language of the country they live in, but it is hardly understood by non-disabled people.

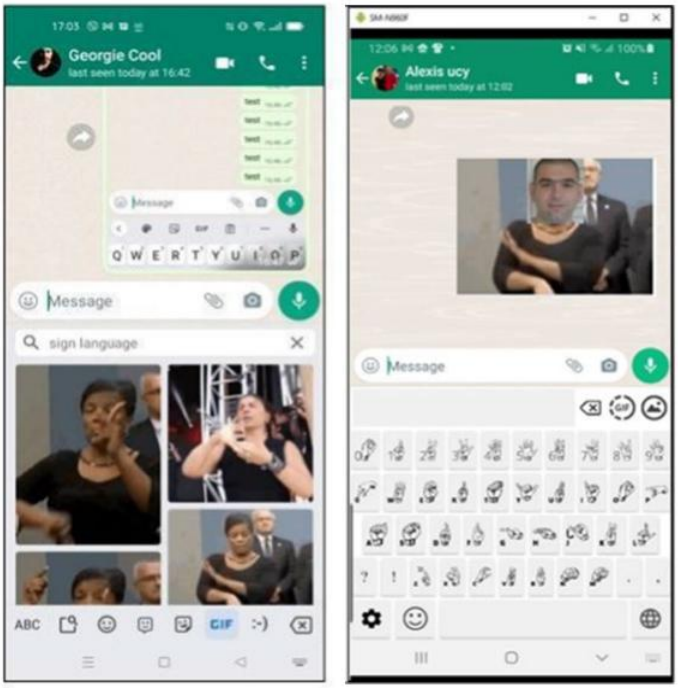

Figure 5. Interface of application for the hearing impaired [16]

In their study, Ribeiro *et al.* [17] documented the experience of students who developed and tested various mobile applications to assist hearing impaired patients. The results show that the apps activate both awareness and communication, and also support the thesis that healthcare professionals can help with Brazilian Sign Language (BSL) signalling not only in healthcare settings but with the deaf community, too [17].

In order to avoid isolation from family and social environment, people with hearing impairments must have access to specialised software applications. These are to be practical tools that provide help in daily life, teaching mimicking signs, working and communicating with non-disabled individuals. However, the number of such software applications still remains small. The inclusion of useful functionalities in them, such as sign language interpreter, libraries, forums, interactive videos and a video user interface is necessary for those with hearing impairments. The existing mobile applications are entirely in English. There are also those that support rarer languages, for example with the possibility of embedding Indonesian language with its specific sign characters [18].

4. Overview of Current Mobile Apps for People with Disabilities

In their publications, a number of authors determine the necessity for people with disabilities to use mobile applications and technologies. The potential for future improvements in their functionality and content is also discussed [9], [13], [15], [19].

Mobile devices and applications are mainly developed for non-disabled users and require additional software to be adapted for use by people with disabilities. A number of mobile apps for people with visual and hearing impairments, which help them overcome everyday difficulties in real-life environments, such as object recognition, reading texts and improving mobility, have been studied. Current mobile applications for transforming speech to text and vice versa – from speech to mimicking gestures – have been analyzed. Despite their shortage, they are aimed at helping individuals with different levels of hearing loss communicate both with each other and with the rest of people. Table 1 compares four popular mobile apps in the study area available on Google Play.

Table 1. A comparison of mobile applications for visually impaired users

	Be My Eyes	Moovit	Lazarillo GPS	Envision AI
Logo				
Released on	4 Oct 2017	28 March 2012	8 September 2016	13 August 2018
Downloads	1,000,000+	100,000,000+	100,000+	100,000+
Rating	4,8 out of 5	2,9 out of 5	4,6 out of 5	4,5 out of 5
Updated on	23 May 2024	23 May 2024	13 May 2024	14 May 2024
Price	Free	Free version	Free version	Free
Difficulty of use	Moderately difficult	Relatively easy	Moderately difficult	Moderately difficult

Google Play and Apple App Store offer numerous apps specifically designed for visually impaired people. The following is a summary of some of them.

Be My Eyes

The popular Be My Eyes mobile app, used by over a million people across countries, is designed to run on Android [20] and iOS [21] devices. It also serves as a social platform, helping visually impaired individuals in contacting non-disabled peers via their personal phones. Once they make contact, they can request assistance for services through an audio or video connection. The application has other useful features such as reading digital displays and help with operating household appliances. When sending an image, e.g. a product label, its voice description is returned to users.

Moovit

Both Android [22] and iOS [23] devices can run this mobile application. Information about public transport, vehicles' timetables, routes stops and different transportation lines like bus, tram, metro, and bicycle is provided to its users.

Lazarillo GPS

This app gives information about close-to-location objects while users are on the move by communicating streets and intersections' names. Lazarillo GPS gives out voice notifications of objects nearby, institutions, banks, shops, etc. It is designed for Android [24] and iOS [25].

Envision AI

The application helps with shopping, using public transportation, recognizing objects, reading text from documents and any surface in real time. Envision AI can detect the language of the text and read it with the correct speech synthesizer. It is intended to be used with both Android [26] and iOS [27].

There are still not enough implemented and promoted applications for users with hearing impairments. Key characteristics of five of the most popular ones as of May 2024 are shown below.

Hand Talk

The mobile app is made for Android and iOS, and automatically translates text and audio in BSL and American Sign Language via artificial intelligence. 3D virtual assistants Hugo and Maya (Fig. 6) carry visualization into effect. App users can review different signs and start learning them [28], [29].

StorySign

StorySign, which uses artificial intelligence, is designed for children who have hearing impairments. The main problem is that deaf children have difficulty learning to read and connecting printed words to concepts. By using the app, they can learn to read more easily (Fig. 7). The app translates children's books into sign language. It supports around 10 sign languages – English, French, German, Italian, Spanish, Dutch, Portuguese, Irish, Belgian Flemish, and Swiss German [30].

Figure 6. 3D virtual translator Hugo

ASL Sign Language Pocket Sign

The mobile app offers short lessons for all levels of American Sign Language (ASL) proficiency. Learning new phrases and vocabulary can be achieved through its accessibility tools, and short exercises, while also testing acquired knowledge. Gamification features are made use of in the sign language mobile app to encourage users to keep learning. A 'treasure trove' of extra opportunities when testing what has been learned is won by those who correctly answer seven questions in a row. The visual dictionary containing 10,000 ASL word clips complements ASL Sign Language Pocket Sign's lessons, which are both concise and engaging. Pocket Sign is considered one of the best apps for learning sign language vocabulary due to this aspect [31].

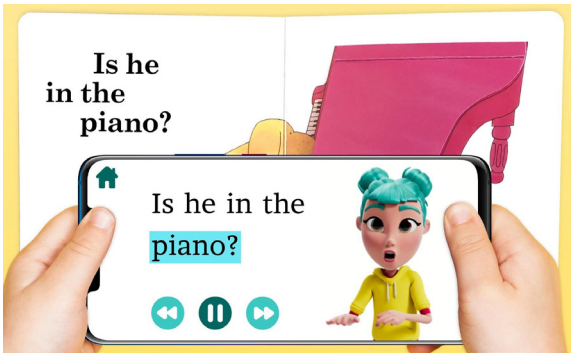

Figure 7. StorySign interface

Rogervoice

The Rogervoice app is used to provide transcription in more than 100 different languages during live phone calls. Phone use is an option for individuals with hearing loss or speaking difficulties to communicate with others. They see on their device a text of what the other person is saying [32]. The application is available with a barcode on the developer's site.

SOS za gluve

The SOS for Deaf app is designed to make communication and daily life easier for hard-of-hearing individuals. It allows users to make video calls. A Serbian sign language translator can translate conversations with the desired person or institution to the user simultaneously. Additionally, the user can create a list of the contacts that are most frequently used [33]. To guarantee the application's smooth operation, registration with a personal mobile phone number is required.

Table 2. A comparison of mobile applications for hearing impaired users

	Hand Talk	StorySign	Sign Language ASL Pocket Sign	Rogervoice	SOS za gluve
Logo					
Released on	25 July 2013	30 Nov 2018	5 June 2020	19 Oct 2015	9 Nov 2022
Downloads	5,000,000+	100,000+	1,000,000+	50,000+	500,000+
Rating	3,4 out of 5	4,3 out of 5	4,8 out of 5	3,9 out of 5	-
Updated on	22 May 2024	30 Mar 2023	20 May 2024	7 May 2024	23 Dec 2023
Price	Free	Free	Free	Free	Free
Difficulty of use	Relatively easy	Moderately difficult	Relatively easy	Relatively easy	Relatively easy

5. Results

This paper focuses on the creation of a mobile application prototype that can help individuals with partial or profound hearing impairment. The objective is to tackle gradually communication and understanding issues between individuals with hearing impairment and those who can hear. A mobile application with a simplified design meant to facilitate interaction with users and easier access to content, has been one of the main tasks for the developers and fortunately, it has been accomplished.

The sign language mobile app is a kind of software designed to help users learn and communicate through sign language. Four main screens are provided by the app that exhaust the possibilities of learning and communicating through gestures.

On the *Home screen*, the user is greeted with a welcoming screen that introduces them to the basic functions of the application.

Select Direction screen: the user has to select one of two possible directions: 'To learn' or 'To communicate' (Fig. 8).

The *Learning screen* offers the user the opportunity to learn the Bulgarian alphabet and popular phrases in the Bulgarian language (Fig. 9).

The *Communication screen* allows users to communicate through chat, where a virtual translator converts text into images representing gestures.

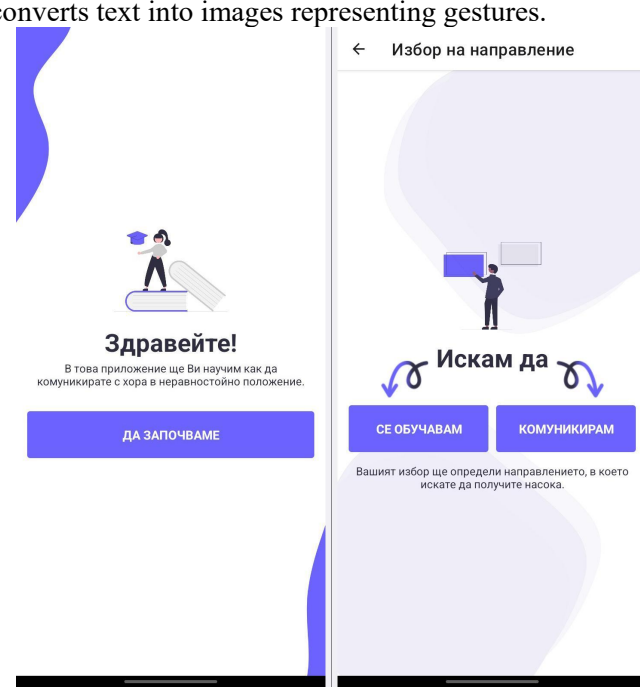

Figure 8. Home screen and direction selection

Figure 9. Communication and learning screens

In Fig. 10 a fragment of the programme code for switching between the main screens by user's choice is shown.

The hardware and software requirements for the mobile application that has been developed are described below as well as its primary features.

- *Platform*: Android and iOS are both supported by the mobile application.

- *Operating System Version*: Android 8.0 and above; iOS 11 and above.

- *Technologies used*: The app was developed using Expo. Expo is a mobile app development framework that facilitates the creation of universal iOS and Android apps using JavaScript and React Native. Expo provides a set of development tools and utilities that ease the process of developing and testing mobile apps.

Recommended resolution: at least 720x1280 pixels.

App's size: approximately 50MB, but it can vary depending on the platform and version.

```
import { SafeAreaView } from "react-native"
import { NavigationContainer } from "@react-navigation/native"
import { createNativeStackNavigator } from "@react-navigation/native-stack"
import { StatusBar } from "expo-status-bar"

//screens
import Welcome from "./screens/welcome"
import Chose from "./screens/chose"
import Translate from "./screens/translate"
import Learn from "./screens/learn"

const Stack = createNativeStackNavigator()

export default function App() {
  return (
    <SafeAreaView style={{ height: "100%" }}>
      <StatusBar translucent backgroundColor="transparent" />
      <NavigationContainer>
        <Stack.Navigator
          initialRouteName="welcome"
          screenOptions={{
          >
            <Stack.Screen
              name="welcome"
              options={{
              component={Welcome}
            />
            <Stack.Screen
              name="chose"
              options={{
              component={Chose}
            />
            <Stack.Screen
              name="translate"
              options={{
              component={Translate}
            />
            <Stack.Screen
              name="learn"
              options={{
              component={Learn}
            />
        </Stack.Navigator>
      </NavigationContainer>
    </SafeAreaView>
  )
}
```

Figure 10. Welcome screen styled – JavaScript code

Future developments:

- *Pedestrian traffic light signal recognition*: Implementation of functionality for recognition of pedestrian traffic light signals using artificial intelligence has been planned. This will allow users to receive messages or traffic instructions by hearing an audio signal from the mobile device (image-to-speech) based on the current state of traffic lights. This feature will directly target people with disabilities.

- *Integration with object recognition systems*: The addition of real-time object recognition functionality. This could assist users in their daily lives.

6. Discussion

The topic of discussion is quite relevant because of the necessity for easier adaptation of people with disabilities to society and family. The development of technology and the widespread use of mobile devices have partially solved some of the problems that accompany their daily lives. Many professionals, including mobile application developers, are engaged in facilitating people with disabilities to do various activities.

Based on the analysis, the authors of the paper have found out that not all applications meet the needs of persons with hearing impairment and blind users. It is necessary to improve mobile applications for use by individuals without hearing or visually impaired. Difficult communication and understanding between persons with hearing impairment, without hearing individuals, and blind individuals, is one of the primary limitations.

In the article, the authors detail their research, analysis, and testing of apps that have been designed for people with disabilities. The lack of up-to-date mobile apps for users in Bulgaria is another obstacle inspiring the current study. Its limitations include the need to validate the usability of the developed prototype with statistically proven results.

Work is still underway to design and implement mobile applications that are useful for 'different' users. Research and development involve companies, medical teams and research institutions, all of which continuously contact and interact with 'different' users. The inclusion of artificial intelligence is important for the future creation of quality and usable software in this field.

Unfortunately, some people with disabilities live on a tight budget and the possibility of them owning a mobile phone is quite limited. Work is also underway to address one of the main issues for learners and workers with a hearing impairment – communication in learning and working environments. Many teachers and co-workers do not understand sign language.

The main result of the present paper is the developed mobile application prototype that satisfies users who want to learn sign language. As a contribution, the functionality enabling learning and recognition of facial gestures as text in the Bulgarian language can be mentioned. This would be beneficial for numerous families, educational institutions, and companies by making it easier for teachers, colleagues, and parents to approach people who are in need more easily.

7. Conclusion

Software innovations have made a positive contribution in building modern mobile applications, which achieve their main goal of meeting their users' needs, including people with hearing or visual impairments. In the future, it would be good for app developers to be aware of the habits of 'different' users. This would result in creating more useful apps aimed at people with disabilities, which are not only used by them but are also promoted by organizations, companies and institutions.

In recent years, efforts have been made to reduce communication issues that people with hearing and visual impairments face when interacting with others. A significant number of employees in various institutions are unfamiliar with sign language and the habits of people with visual impairment. There are not many applications available to transform speech to text and vice versa, from speech to mimic gestures. Their purpose is to assist individuals with different levels of hearing or sight impairment in communicating not only among themselves but also with the rest of the world. Life for them could be made easier. They could get closer to non-disabled people concerning daily activities, work, or recreation.

The article's real strength lies in its authors' analysis and the summarized advantages of popular mobile applications for people with disabilities. Consequently, a mobile application has been developed and tested to facilitate communication using sign language for Bulgarian users. Owing to the modern technologies used, the mobile application is available on both Android and iOS. Not all of the functionalities planned by the authors have been included in the prototype yet. The main drawback is the absence of a rich multimedia library.

The addition of a module to help people with disabilities in an urban environment has been planned for future development of the project – recognition of objects, for example traffic lights and alerting users depending on the fast-changing environment. By integrating artificial intelligence into the mobile application, it can be enhanced with even more features.

References:

[1]. Sayal, R. et al. (2020). Mobile app accessibility for visually impaired. *International Journal of Advanced Trends in Computer Science and Engineering, 9*(1), 182–185. Doi: 10.30534/ijatcse/2020/27912020.

[2]. Korczak, P., & Zwierzchowska, A. (2020). Using mobile applications in the process of enhancing and restoring abilities in individuals with intellectual disability and other disabilities – a literature review. *Postępy Rehabilitacji / Advances in Rehabilitation, 34*(4), 36–41. Doi: 10.5114/areh.2020.100774.

[3]. Kraleva, R., & Kralev, V. (2018). An Evaluation of The Mobile Apps for Children with Special Education Needs Based on The Utility Function Metrics. *International Journal on Advanced Science, Engineering and Information Technology / International Journal of Advanced Science, Engineering and Information Technology, 8*(6), 2269–2277. Doi: 10.18517/ijaseit.8.6.6309.

[4]. Jahan, N. et al. (2020). Inclusion and Independence: The impact of Mobile Technology on the Lives of Persons with Disabilities in Kenya and Bangladesh, *2020 IEEE Global Humanitarian Technology Conference (GHTC)*, Seattle, WA, USA, 2020, 1–8. Doi: 10.1109/GHTC46280.2020.9342934.

[5]. Verstockt, S., Decoo, D., Van Nieuwenhuyse, D., De Pauw, F., & Van de Walle, R. (2009, May). Assistive smartphone for people with special needs: The Personal Social Assistant. In *2009 2nd Conference on Human System Interactions*, 331-337. IEEE. Doi: 10.1109/HSI.2009.5091001.

[6]. Dekelver, J., Kultsova, M., Shabalina, O., Borblik, J., Pidoprigora, A., & Romanenko, R. (2015). Design of mobile applications for people with intellectual disabilities. *Communications in Computer and Information Science*, *535*, 823-836. Doi: 10.1007/978-3-319-23766-4_65.

[7]. Iparraguirre-Villanueva, O., Almeyda-Saravia, E.S., Araujo-Jayo, K.J., Huaringa-Cruzado, D., Palomino-Guevara, A.F. (2024). Design of a Mobile Application to Improve the Therapy Process in Children with Autism. *International Journal of Interactive Mobile Technologies (iJIM), 18*(03), 16–31. Doi: 10.3991/ijim.v18i03.46821.

[8]. Skiada, R., Soroniati, E., Gardeli, A., & Zissis, D. (2014). EasyLexia: A Mobile Application for Children with Learning Difficulties. *Procedia Computer Science, 27*, 218–228. Doi: 10.1016/j.procs.2014.02.025.

[9]. Pundlik, S., Shivshanker, P., & Luo, G. (2023). Impact of apps as assistive devices for visually impaired persons. *Annual Review of Vision Science, 9*(1), 111–130. Doi: 10.1146/annurev-vision-111022-123837.

[10]. Nayak, S., & C B, C. (2020). Assistive Mobile Application for Visually Impaired People. *International Journal of Interactive Mobile Technologies (iJIM), 14*(16), 52–69. Doi: 10.3991/ijim.v14i16.15295.

[11]. Griffin-Shirley, N., Banda, D. R., Ajuwon, P. M., Cheon, J., Lee, J., Park, H. R., & Lyngdoh, S. N. (2017). A Survey on the Use of Mobile Applications for People who Are Visually Impaired. *Journal of Visual Impairment & Blindness, 111*(4), 307–323. Doi: 10.1177/0145482x1711100402.

[12]. World Health Organization: WHO. (2024). *Deafness and hearing loss*. https://www.who.int/en/news-room/fact-sheets/detail/deafness-and-hearing-loss [accessed: 24 May 2024].

[13]. Nathan, S. S., Hussain, A., & Hashim, N. L. (2016). Studies on Deaf Mobile Application: Need for functionalities and requirements. *Journal of Telecommunication, Electronic and Computer Engineering, 8*(8), 47–50.

[14]. Ketabdar, Hamed & Polzehl, Tim. (2009). Tactile and visual alerts for deaf people by mobile phones. In *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility (Assets '09). Association for Computing Machinery, New York, NY, USA*, 253–254. Doi: 10.1145/1639642.1639701.

[15]. Risald, R., Suyoto, S., & Santoso, A. J. (2018). Mobile Application Design Emergency Medical Call for the Deaf using UCD Method. *International Journal of Interactive Mobile Technologies (iJIM), 12*(3), 168–177. Doi: 10.3991/ijim.v12i3.8754.

[16]. Yeratziotis, A., Achilleos, A., Koumou, S., Zampas, G., Thibodeau, R. A., Geratziotis, G., Papadopoulos, G. A., Iasonas, I., & Kronis, C. (2023). Making social media applications inclusive for deaf end-users with access to sign language. *Multimedia Tools and Applications, 82*(29), 46185–46215. Doi: 10.1007/s11042-023-17196-7.

[17]. Ribeiro, P. L. L., Corrêa, R. P., Moreira, I. B. G., Nascimento, D. L. C., Correa, M. S., Braga, C. B., Meirelles, F. A., Shinoda, T. T., da Silva, A. M. A., Tavares, B. P., de Freitas, R. J., da Cunha Teixeira, M., dos Santos Vasconcelos, J. P., Abreu, P. A., & Castro, H. C. (2023). Development of Mobile *Apps* for Deaf Patients by Nursing Students: Let's Consider the Difficulties through Deaf's Perspective. *Creative Education, 14*(09), 1880-1892. Doi: 10.4236/ce.2023.149120.

[18]. Setyawan, A., Naphan, G. X., Dynata, K., Friry, J. E., & Warnars, H. L. H. S. (2022). Deaf Helper Mobile Application for Interaction of Hearing Disorders Communities. *2022 Second International Conference on Artificial Intelligence and Smart Energy (ICAIS)*. Doi: 10.1109/icais53314.2022.9742988.

[19]. Senjam, S. S., Manna, S., & Bascaran, C. (2021). Smartphones-Based Assistive Technology: Accessibility Features and Apps for People with Visual Impairment, and its Usage, Challenges, and Usability Testing. *Clinical Optometry, 13*, 311–322. Doi: 10.2147/opto.s336361.

[20]. Google play. (n.d.). *Be My Eyes - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.bemyeyes.bemyeyes [accessed: 01 May 2024].

[21]. App Store. (2014). *Be my eyes*. App Store. https://apps.apple.com/us/app/be-my-eyes/id905177575 [accessed: 24 May 2024].

[22]. Google play. (n.d.). *Moovit: Bus & train schedules - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.tranzmate [accessed: 02 May 2024].

[23]. App Store. (2012). *Moovit: all transit options*. App Store. https://apps.apple.com/us/app/moovit-all-transit-options/id498477945 [accessed: 03 May 2024].

[24]. Google play. (n.d.). *Lazarillo accessible GPS - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.lazarillo [accessed: 04 May 2024].

[25]. App Store. (2016). *Lazarillo - accessible GPS*. App Store. https://apps.apple.com/us/app/lazarillo-accessible-gps/id1139331874 [accessed: 05 May 2024].

[26]. Google play. (n.d.). *Envision - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.letsenvision.envisionai [accessed: 06 May 2024].

[27]. App Store. (2017). *Envision AI*. App Store. https://apps.apple.com/us/app/envision-ai/id1268632314 [accessed: 07 May 2024].

[28]. Google paly. (n.d.). *Hand Talk Translator - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=br.com.handtalk [accessed: 08 May 2024].

[29]. App Store. (2013). *Hand Talk: ASL sign language*. App Store. https://apps.apple.com/us/app/hand-talk-asl-sign-language/id659816995 [accessed: 09 May 2024].

[30]. Google play. (n.d.). *StorySign - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.storysign.storysign [accessed: 10 May 2024].

[31]. *Google play.* (n.d.). *Sign language ASL Pocket Sign - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.mobireactor.signlanguage [accessed: 11 May 2024].

[32]. Google play. (n.d.). *RogerVoice phone subtitles - apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=com.rogervoice.app [accessed: 12 May 2024].

[33]. Google play. (n.d.). *SOS za gluve - Apps on Google Play*. Google play. https://play.google.com/store/apps/details?id=rs.relay.app [accessed: 13 May 2024].