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Research Article

Qualitative Study for the Design and Fabricate of Assistive Technologies for the Visually Impaired and Blind People to Improve the Quality of Life

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Abstract:

From the distant past until now, various assistive devices and equipment have been made and marketed for the purpose of improving the life of blind people. Braille and the white cane can be noted as one of the most basic auxiliary equipment for the blind people. Over time and through the advancement of technology, a great change has taken place in the world of the blinds; and we can see everyday development of various tools which all of them are useful in improving the life of the blind people. Today, there are various helpful tools for the blind including Obstacle detection gadgets, Text reading tools, Money detection systems, Routing systems, Audio clock, Brain port, Braille tablet, Artificial eyes (bionic eyes), etc. In this article, we will have an overview of assistive devices made for the blinds. Examination of the produced medical equipment in this field will make it possible to provide more qualified assistive equipment for the blind.

Keywords: fabricate of assistive technologies; blind people; visually impaired

1. Introduction:

A person who loses his sight due to various factors such as cataracts, leprosy, trachoma, xerophthalmia, retinal detachment, inherited retinal diseases, as well as injuries caused by acquired factors such as accidents, war, etc., is called blind. According to global statistics, there are more than 285 million currently living blind people throughout the world, 90% of whom live in developing countries and in disadvantaged areas.

Considering that the blind people confront with many problems in communicating with the world around them, including encountering with obstacles, inability to recognize colors, difficulty in recognizing products in shopping and recognizing banknotes, difficulty in reading texts, etc., there have been designed and produced variety of tools and devices for these people, which will be reviewed in this article.

In general, assistive devices for the blind people can be divided into 11 general categories, including the following [1]:

1. Obstacle detection equipment
2. Text reading tools
3. Money and color recognition tools
4. Watches made for the blind
5. Brain port
6. Braille tablets
7. Braille typewriter
8. Artificial eyes
9. Audio calculator
10. Audio barcode reader and audio books.

2. Obstacle Detection Equipment:

One of the main problems that blind people face is dealing with obstacles which cause them to be isolated and limited in their activities. The oldest human invention for detecting obstacles is the white cane, which was invented in 1921, and is still used by the blind people around the world in order to facilitate walking and recognizing obstacles. After that, various devices, wearable gadgets and software were made which are separately useful in identifying the obstacles surrounding the blind person.

2-1. Obstacle Detection Glasses:

A variety of glasses have been invented and marketed to be helpful for the blind in barriers detecting, all of which basically share the same system. These glasses can easily guide the blind and help them to be aware of the obstacles around them. All of these glasses use a barrier detection module, a processing unit and a power supply.

The barrier detection module usually consists of an ultrasonic sensor. These modules have two ultrasonic sensors, including transmitter and receiver sensors. The transmitter sensor generates sound waves in the ultrasonic frequency range, and after sending the wave and hitting the objects and reflecting it, the receiver sensor receives the reflected wave. The received wave is then analyzed and the distance to the object is determined by calculating the time of sound' reciprocation motion. The information received from the ultrasonic module is then analyzed by the processing unit and the result is transmitted to the person in the form of an audible or vibrating alert. Figure 1 shows the function of these glasses. These smart glasses are kind of a portable device for the blind which are easy to use, lightweight, user-friendly and inexpensive.

Figure 1: *How the glasses detect obstacles [2].*

2-2. Obstacle Detection Tools Mounted on a Blind Cane:

There are other types of obstacle detection tools that are mounted on the white cane in order to assist the blind persons to identify the surrounding obstacles better, along with use of the white cane. Similar to obstruction goggles, these devices consist of an ultrasonic module to detect the obstruction, a processing unit, and a power supply. These kinds of barrier detection tools are easy-to-use, lightweight, user-friendly and inexpensive portable instruments for the blind, too. [3].

2-3. RFID-Based Audio Routing and Obstacle Detection Systems:

Another problem for the blind is the issue of navigation, which makes it impossible for the blind person to go from one place to another, alone. Various devices and software have been developed in this domain, most of which have used the RFID (Radio Frequency Identification) method to provide users with location information. Speech recognition modules are used in these tools. System's operation begins by providing a voice command and announcing the destination that the blind person intends to go. This system provides voice commands in order to guide the blind person along the way to reach the desired destination. Furthermore, the ultrasonic module is also used in construction types of systems, to inform the users of surrounding obstacles in addition to make them being aware of the location [3].

2-4. Obstacle Detection Shoes:

The above-mentioned obstacle detection tools assist the blind person in identifying obstacles and navigation, whereas one of their problems is unrecognizing the pits. For solving this problem, specific scanners are used in making these shoes, which first scan the surroundings and measure the height and depth. The output of the scanner is transferred to the system's processing unit, and in case of detecting an obstacle or a pit, it warns the user of the presence of obstacles and pits through sounding the alarm, as well as creating vibration in the area of the blind ankle. These tools are also lightweight and inexpensive, and allow the user to move without the help of white cane.

Figure 2: *An example of obstacle detection shoes [4].*

2-5. The Mobile Phone's Barrier Detection Software:

There is various assistive software for blind people, among them, there existed software which are designed to identify obstacles and to help the blind persons to have a better understanding of their surrounding environment. The function of all these software is based on analyzing the environment through image processing and then, transmitting information to the user through the sound. With the help of these software, a person can identify obstacles and acquire an approximate understanding of his/her surroundings. The findings of conducted researches on people who have used this software reveal that these systems are practical and usable and can guide users to avoid encountering more than 85% of obstacles [3].

3. Text Reading Tools:

The first evidence of a specialized text-reading tool for the blind is a device called an octophone that goes back to 1914. In fact, the tool consists of a miniature camera that converts printed text to audio. Since then, we have seen significant advances in designing and development of text reading tools for the blind, the latest and most advanced of which are software designed for mobile phones and a device called Finger Reader.

3-1. Use of Mobile Phone for Reading the Texts:

Various mobile apps are designed so that the blind can be able to read different texts with their help. In these applications, the text is first scanned sequentially by a mobile phone camera, the scanned image is converted to text, and finally the text is converted into a speech signal for the user. For audio control, this software usually uses Raspberry Pi and are simulated using Python software.

3-2. Wearable tool for reading the texts (Finger Reader):

Academic and industry researchers have been interested in helping visually impaired persons for reading the printed texts. In 2015, MIT researchers designed and built a wearable device for reading the texts. This device is a wearable ring that is placed on the user's index finger. In a wearable format, the body can be used as a guiding and concentrating mechanism, which is very important for blind people. In this system, the index finger is used as a guide. In designing this system, the main focus was to create a small device that does not attract attention and is easy to use. Finger Reader is a wearable device that supports reading the printed text by scanning and it converts the words into speech. In comparison to similar devices, this system is so small in size and has higher speed and accuracy. The Finger Reader design keeps the camera at a fixed distance from the text. Additionally, the device provides users with a simplified user interface because it has no buttons and can easily detect the right orientation by the camera lens. Although, finger Reader was originally designed as an aid for reading the printed text, extra features such as music reading were added to it in 2018.

3-2-1. Hardware Finger Reader

Hardware Finger Reader provides tactile feedback via vibration motors and a small video camera with high resolution. Vibration motors are located in the ring in order to provide tactile feedback for the user who must move the camera along a specified line in a proper position.

Firstly, two patterns for mounting vibration motors on the ring were examined:

1. Using four vibration motors in the ring
2. Using two vibration motors in the ring

Preliminary experiments with blind users showed that using two vibration motors is much more efficient than using four vibration motors, because in four vibration motors design, vicinity of the motors causes confusion for the user. The results led to redesigning the hardware with the use of white resin, creating more rigid segments in which vibration motors are embedded, and producing a rubber material for visible connections. As shown in Figure 3, this design provides flexibility in the ring, and it also helps in reducing vibration and confusion for the user.

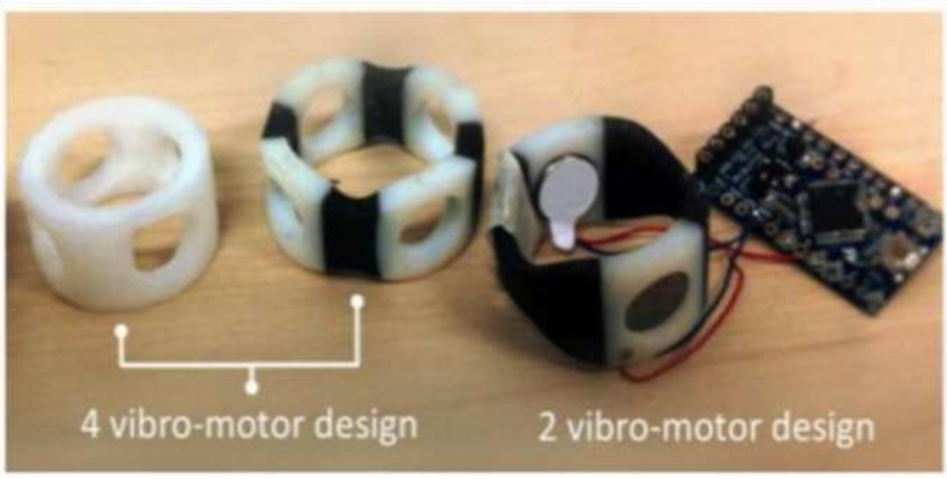

Figure 3: *Finger Reader hardware image in case there are 4 vibration motors in the ring and in case there are 2 vibration motors in the ring [5].*

3-2-2. Software Finger Reader

Finger Reader algorithms and software include a sequential text reading algorithm, hardware control driver, OCR layer, and text-to-speech converter unit. After achieving a stable display, the system seeks to find characters, words and lines. To find the first line, the user can scan the page until the audible signal of that text is found. Word extraction is performed by the OCR engine on image blocks of detected text. The OCR engine is instructed to extract only one word. Words which are extracted with high reliability will be preserved and recited aloud for the user [5].

4. Money and Color Detection Tools for the Blind:

One of the main problems that blind people face is recognizing the amount of money and color of the objects. The blind inability to recognize the amount of money and color of the objects sets the ground for profiteering. For this reason, various tools and software have been designed and produced which recognize the objects color as well as the amount of money, and announce it to the blind vocally.

Color detection modules such as TCS3200, TCS34725, TCS230 or light-sensitive resistance (LDR) are commonly used in design of these systems.

The sensors first detect the color of the money, then convert the color to analog data; and the processor processes this analog data into digital data. Eventually, the processor converts the data into audio as an output, and the speaker broadcasts the sound according to the detected money or color, and the audio output will be detected by the blind users [6].

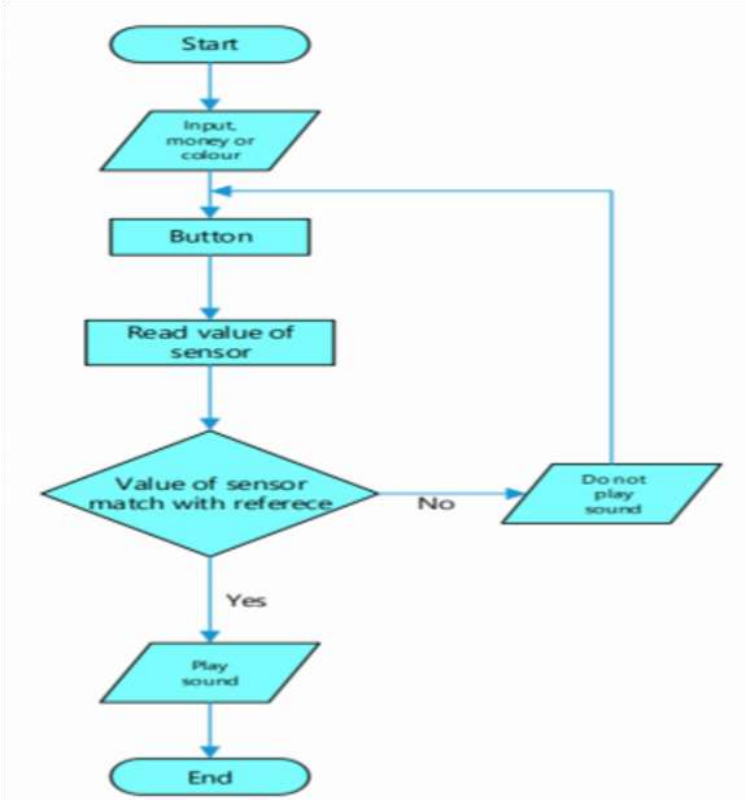

Figure 4: *The function of color and money detection tools [7].*

5. Watches Made for the Blind:

The blind has always used Braille watches to know the time. Ordinary and analog braille watches have a touch screen. In these watches, the number 12 has three prominent points, the numbers 3, 6, and 9 have two prominent points, and rest of the numbers have one prominent point. A blind person can determine time just by touching points and feeling the location of needles. With the advent of smart devices, it made sense for analog Braille watches to evolve over time and to be replaced by digital and smart watches. Therefore, big companies like Samsung and Apple started making smart watches which entered the market; but, due to undeniable role of Braille in the blind's life and their compatibility with Braille, use of Braille watches has always been more popular than speaking digital watches. It is also easier for the blind to work with Braille watches than with digital ones.

5-1. Dot watch

Due to the popularity of Braille among the blind, a company in South Korea has started to make Braille smart watches for visually impaired and blind persons, and has named it Dot watch.

This watch is not just a braille watch. This beautiful watch is a Braille smart watch that is one of the lightest watches in the world. The Dot watch weighs only 60 grams, but is structurally very strong and durable. This watch has a beautiful and qualified strap that gives it elegance and makes it to look more stylish. In addition to its appearance, Dot watch has many functions that match with a typical smart watch, and make it to be a useful companion rather than a watch. Dot watch has braille lines that are used to display numbers and letters. It also has two touch sensors that are used to read long texts. It connects to the user's mobile phone via Bluetooth and allows the user to read the messages received on social networks. Upon receiving the call, the watch displays information of the caller in Braille. By pressing the call option, the call will be accepted and by pressing the home screen it will be rejected.

The battery of this watch is very efficient and can work up to 10 days without charging.

This watch shows not only the current time, but also the date. When the watch is not in use, current hour and minute will be displayed on the Braille screen by pressing the Select button, and by re-pressing the Select button, seconds and then, date of the day will be displayed. Dot watch has a stopwatch and a timer, too. It, also has the capability of setting the alarm, and the user can set 10 alarms on this watch. Besides, the blind is able to store 10 notes in Dot watch [8].

Figure 5: *Dot watch image [9].*

6. Brain Port

Brain port is a tool that allows users to understand the world around them through their language. As shown in Figure 2, this tool consists of a camera mounted on a pair of glasses. The system receives images through this camera and, after processing, transmits the information to a tool with one square inch in size that is placed on the person's tongue.

At the beginning of producing this tool, information was transferred to a tool that was placed on the back of a blind person, but due to the fact that the tongue has a higher number of nerves than the back, it was decided to transfer the information to a tool that is placed on the tongue.

In addition to high density of tongue's nerve ending, existence of saliva in mouth leads to direction of information in a more efficient way.

Prototypes of this system included a 12×12 electrode grid that was connected to a video camera mounted on glasses. Currently, number of electrodes on the tongue and resolution of the converted images is 20×20. They also used 25×25 electrodes to increase resolution of the images, but the result was not so desirable. In the next experiment, 40×40 electrodes were used, which resulted in increasing resolution of the image, but size of the device that was placed on the tongue extended and made it more difficult to use the device. Therefore, it was finally decided that 20×20 electrodes should be used in construction of this system [10].

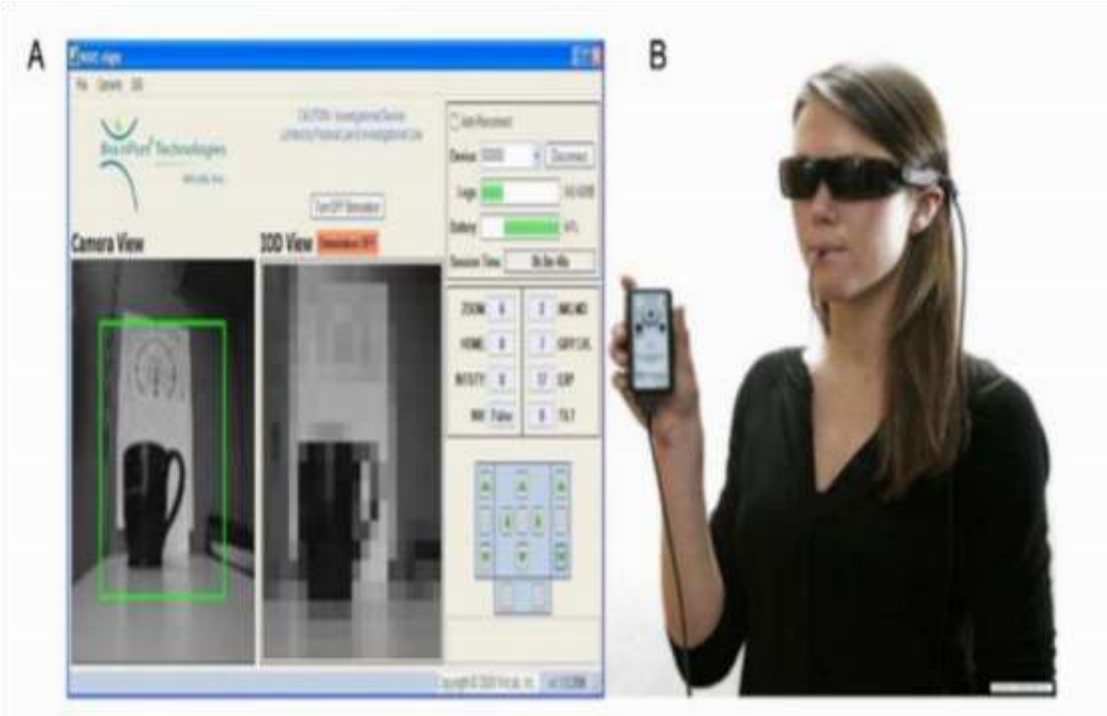

Figure 6: *Function of Brain Port, (A) Laptop screen, which is connected wirelessly to the Brain Port sight machine, (B) Shows a blind user during Brain Port training [11].*

7. Blitab Tablet:

Blitab is the brand of an Android tablet that is equipped with a Braille line. Small bubbles are used in display of the tablet in order to create a braille line.

As an Android tablet, it has Wi-Fi and Bluetooth and can run Android applications. At the top of Blitab, there is a multi-line display in Braille, with 14 rows and 23 six-point braille cell for each line. The bottom of the tablet has an Android screen.

The main screen of this tablet displays various Android applications. It can be used to read books, type emails and perform tasks, just as what you do on your Android device.

One of the powerful features of the Braille tablet is its ability of instant conversion of visual images to simple touch images. Using this feature, blind people can understand images of books.

Also, this device has provided the possibility of using Google Map for the blind. The blind can be informed of her geographical location by touching the screen and can easily move to anywhere they want [12].

Figure 7: *Blitab tablet image [13].*

8. Braille Typewriter:

Braille is a type of assistive technology for the blind and a typewriter which is specialized for the blind that has six keys corresponding to each of the six points of the Braille code. Similar to function of a manual typewriter, the paper is inserted into a machine. Typing creates braille dots on the paper that can be read with the fingers. It has six main keys for inserting braille letters and one key for creating space [14].

9. An Overview of Constructed Artificial Eyes:

Natural vision systems have encouraged scientists and engineers to emulate their intriguing features to produce advanced photon devices that can provide better solutions than conventional solutions. Among different types of natural eyes, researchers are very interested in mammalian eyes and compound eyes. The reason why researchers are interested in this type of eye is their advantages in optical properties including ability of adjusting the focal length, high resolution imaging, light intensity modulation, wide vision, high light sensitivity and efficient light management. In this review, we provide an overview of artificial eyes and photon devices inspired by natural eye functions.

The first optical prostheses were cortical implants, which were discovered in 1930s after discovery of the German ophthalmologist Karl Forrester, according to whom, direct electrical stimulation of the cortex causes blind patients to detect a light spot. In 1960s, Australian inventor, Graham Tasker invented a light-sensitive selenium cell that could stimulate the optic nerve. This invention led to development in artificial eyes researches and renewed the idea of applying optical prosthesis for returning the sight to the blind.

Until 1970s, due to the complexities of retinal surgery, placement of microelectrodes in the retina was not a suitable option, but as surgical procedures improved, it became possible to place electrodes in the eye. Since then, researchers have always sought to improve quality of artificial eyes. In this section we will explain the latest constructed artificial eyes.

Vision prostheses, known as bionic eyes, promise to provide vision for visually impaired and blind people who were able to see before. In fact, these devices are micro-electrodes that are placed along the optic nerve by eye surgery. Microelectrodes help to improve the vision process by stimulating parts of the visual system that have lost their function. They perform this action using very small electrical pulses that are exactly similar to those which are used in bionic or cochlear implants.

Through electrical stimulating of the remaining neurons, one perceives small spots of light. The spots of light that are perceived by a person are same as the lights we see when the eyes are closed. Therefore, the vision provided by a bionic eye is not like the normal vision. This is a set of flashing points and shapes that a person uses to interpret the environment around him/herself. Currently, the vision provided by a bionic eye is very fundamental and can be used for tasks such as identifying the location of an object or identifying people. Researchers hope that bionic eye would provide clearer vision in the near future.

9-1. How an artificial eye works (bionic eye):

The bionic eye receives images using a camera and then converts them to the images with higher contrast. Parts of the received images will be selected for further processing. Afterwards, high-contrast images will be transmitted to an external video processor. Finally, the images will be converted to those electrical stimulation parameters which are considered to be transferred to implanted electrodes in the eye. The bionic eye receiver receives a blurry image consisting of flashing lights.

In fact, what the user sees is a mass of light points that shows general shape of the object such as its height, width and approximate location. The scope of view that the bionic eye provides to the user is very limited, about 30 degrees; so, the user needs to have a good memory to organize the whole image in mind and to come up with a general overview of his/her surroundings.

Another complex challenge in designing these eyes is that there are different types of neurons in the retina, but the electrodes are too large for targeting the separate types. For this reason, bionic eyes cannot replicate the sense of color.

Advances in cameras and video processors can significantly improve the quality of bionic eyes. For example, remote sensing cameras can highlight obstacles such as light poles and trash cans on the sidewalk, and thermal cameras can highlight the shape of humans.

Currently, there are several ways to improve image quality. Increasing the number of implanted micro-electrodes and shrinking them empowers them to target the selected neurons for more independent pixels and greater resolution. With the remarkable advancement of nanotechnology, it is possible to produce electrodes which are small enough and have greater accuracy.

Another technique is to modify the electrical stimulation pattern to have better focus on stimulation for the purpose of activating more nerve cells. We can also artificially increase the resolution by creating electrodes that divide the electric current among two or more electrodes. These new stimulation techniques can improve image stability and reduce blur; they may even provide basic color control. Recent improvements in electrode configuration and biocompatibility of materials have improved the capabilities of these eyes. Finally, researchers seek to understand and mimic the retinal neural code for communicating with the brain [15].

Figure 8: *Prototype of a bionic eye designed for humans [16].*

9-2. Eligible People for Receiving Bionic Eyes:

Whether a bionic eye is a good option for a blind person or not, depends on the reason for which one's sight has lost.

Retinal bionic implantation is performed in the eyeball and, it is only suitable for those people who have lost their sight due to certain diseases such as inherited types of retinal degeneration and age-related macular degeneration. Currently, only people who have lost their sight due to degenerative retinal diseases are eligible to receive a bionic eye.

Quality of the vision which is provided by retinal implants is highly dependent on the health of patient's eye. Implanted electrodes are used to replicate the function of light-sensitive cells (optical receptors); but there must be surviving neurons to preserve the electrodes communication [17].

9-3. Types of Constructed Artificial Eyes:

Three bionic eyes are now approved for commercial sale:

Argus II is made in the USA, Alpha-AMS in Germany and IRIS V2 in France.

Clinical trials were performed on three blind people using artificial eyes which were made during 2012 to 2014. Prior to using artificial eyes, patients were unable to detect hand movements in front of their faces, but after surgery and use of bionic eye, they could place objects on the table and identify obstacles in their path in walking. The findings of clinical trials show that use of bionic eyes can provide useful visual information to the blind [18].

10. Audio Calculator:

Constructed calculators for the blind are composed of large buttons and an audio system. Using vocal option of Audio calculators, user can read the answers, numbers and formulas aloud. Features of these calculators include [19]:

1. They have ability of recording new sound with the user's own voice.
2. They have ability of connecting to Bluetooth.
3. They can transfer recorded sounds among other devices, using Bluetooth.
4. They Support all advanced calculations.
5. They easily access to basic calculator functions, for those who rarely use scientific operations.
6. They have high sound quality.

11. Audio Barcode Reader and Audio Books:

The audio barcode readers are available as portable devices and mobile applications such as BLaDE. Many people carry their mobile phones, and prefer not to have a dedicated barcode reader and use their cell phone to read the barcode. A variety of apps are available for reading barcodes in smartphones including Red Laser and Z Xing project for iPhone and Android, respectively. There are many published researches in this domain. However, almost all of these systems are specified for the users with normal vision and, it is necessary to insert the intended barcode in the core of mobile phone. In some designed systems, this problem has been solved and, with the help of sound alerts, it is possible for the user to put the mobile phone in front of the barcode. If the system identifies the barcode, it will be read loudly to the user [20].

In the past, the blind could not read books; but, with development of technology and advent of smartphones, it became possible for the blind to listen to their favorite books through audio files. So far, many books are converted to usable audio files for the blind and their number is increasing every day.

Further Assistive Devices for the Blind:

In addition to above-mentioned tools, other tools such as rational scales, rational thermometer, rational barometer, Braille ruler, Braille meter, etc., are manufactured for the blind, each of which helps to improve quality of the blind's life. As presented in this article, technology has taken significant steps to examine the system and vital signs of the body and to improve the quality of the human life [21-61].

Conclusion

Different types of assistive tools are produced for the blind so far, each of which helps to improve quality of life of these people; nevertheless, these tools have many drawbacks.

For example: Obstacle detection tools available for the blind are applicable only when the user is moving slowly and their efficiency and accuracy in fast-moving modes like running is low. Also, most of text reading tools are only available in English and do not support other languages. Therefore, non-English speakers cannot use these tools. Also, accuracy of color and money recognition tools is low. Besides, artificial eyes are not capable of color recognition and they just provide the user with relatively incomprehensible points of light. Working with most of the equipment available for the blind is challenging. Most of the equipment are constructed separately and the blind cannot carry several tools together. Additionally, used language in most of these tools is English which makes them applicable for limited number of users. With respect to these points, it is essential to build the tools that are more advanced, easy to use and localized in user's native language in order to improve quality of life of the blind worldwide.

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