ELECTRONIC AIDS FOR BLIND PEOPLE - OVERVIEW

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Abstract. *For a very long time the advancement in technologies has had noble intentions to improve people's safety and to make their lives easier. That statement also applies to the visually impaired people. Since the common white cane does not provide the desired reliability and functionality and guide dogs are relatively expensive to train and have their own limitations, engineers in many science centers have been working on some electronic aids and complex systems for blind people. The following paper presents an overview of current status of electronic aids for blind people.*

Keywords: blind people, electronic aids, navigation assistant device

URZĄDZENIA ELEKTRONICZNE WSPOMAGAJĄCE OSOBY NIEWIDOME – PRZEGLĄD

Streszczenie. *Od dłuższego czasu osiągnięcia nauki i techniki mają na celu polepszenie bezpieczeństwa ludzi oraz ułatwienie ich życia codziennego. Dotyczy to również osób niewidomych i słabowidzących. Ponieważ zwykła biała laska dla osób niewidomych nie jest w stanie zapewnić odpowiedniej funkcjonalności i bezpieczeństwa podczas poruszania się osób niewidomych, a psy przewodniki mają pewne ograniczenia, nie wspominając o kosztach szkolenia, w wielu ośrodkach badawczych inżynierowie i naukowcy pracują nad elektronicznych urządzeniami i systemami wspomagającymi osoby niewidome. Praca przedstawia przegląd nowoczesnych rozwiązań w tematyce urządzeń dla osób niewidomych.*

Słowa kluczowe: ludzie niewidomi, urządzenia wspomagające, urządzenie do nawigacji

Introduction

Apart from simple devices which, for instance, are able to check and tell a color of some surfaces and fabrics or to index and then recognize objects by means of RFID tags [29], there are devices that help blind people safely move around in known and unknown areas. These devices could be divided into three main categories [19]:

- Electronic Travel Aids (ETAs) – these devices gather and process some partial data from the surrounding environment in order to provide a blind person with the information sufficient for a safe passage,
- Electronic Orientation Aids (EOAs) – these devices help a blind person find a direction of movement while walking from one point to another,
- Position Locator Devices (PLDs) – these devices with the help of the GPS-like, GSM and Wi-Fi technologies make it possible to locate a blind user, for example, on a digital map and to navigate to a final destination.

Although, many devices could be put into these categories, some systems for blind people due to their complexity fit into two or even all three of the mentioned descriptions. Therefore, in this chapter, another kind of categorization is being presented.

1. Categorization of electronic aids for blind people

Although, there are many ways to categorize electronic aids (EAs) for the blind, it seems appropriate to analyze them from a technical point of view, focusing mainly on elements and methods that were used and also research novel ideas implemented, rather than devices' impact on the market, commercial success or price. The overview of the devices that are being commonly used among blind people and also advanced prototypes is presented in this paper.

2. White cane substitutes and addons

Almost every blind person uses a white stick of some kind. White sticks are available in different types, endpoint shapes and sizes. They are also relatively low-priced as for assistive aids, so even small visually impaired kids are being taught how to use them. Blind people are used to white sticks and feel more comfortable and safe while getting around and traveling with them. Therefore, some EAs uses white sticks as a carrier.

Addons to white canes should not compromise the weight of white canes and restrict their movements. Usually, in this kind of a solution a white stick can work as a RFID reader [23], ultrasound obstacle detector [14, 29, 33] or as a carrier for other sensors.

Since blind people are so much used to white canes, it has been quite problematic to create such a device which would provide enough safety and high reliability to convince visually impaired persons to lay off white sticks and switch to electronic devices when getting around. Nevertheless, there are many devices that can assist blind people in order to improve their safety while walking. There are obstacle detectors based on ultrasonic transducers, infrared diodes or both [2] and simple navigation aids that employ accelerometers [10]. Engineers are currently working on complex systems for blind people navigations [8, 20, 48], which once perfected, could replace the popular white canes.

3. Single and multi-sensor devices

Electronic devices for blind people vary in terms of their basic functionality. There are devices which serve only one purpose, for instance, of obstacle detectors [57] or GPS based locator and navigations like 'Trekker GPS system' [43]. Such devices usually employ only one type of sensors. This approach is cost effective and helps to develop and produce low-price devices, which is very important especially for visually impaired people in the developing countries. However, it is hard to collect all the relevant information about the blind person's surroundings with the help of only one type of sensors. Therefore, by using more sensor types, the functionality of the EA can be extended. This multi-sensor approach compensates for the limitations of one data type. Detecting obstacles only with an ultrasonic range finder does not assure the high reliability due to the fact that ultrasonic waves reflect poorly from some types of surfaces and also the returning wave amplitude is highly dependent on the surface inclination [26]. On the other hand, the infrared range finders are fragile against transparent surfaces. Thus, for the obstacle detection it is wise to use the multi-sensor approach and use both the infrared and the ultrasonic technique [2]. This method, called sensor fusion, provides a better reliability and safety for a blind user. This is the case where different sensors types supply the same data – the distance from obstacles – but there are also devices that employ sensors which are able to provide other data from the environment. The implementation of a GPS module and POI database [45] helps to navigate blind people, especially in urban environments, and inform them about both dangerous objects and safe locations like pedestrian crossings. This type of sensor fusion increases safety in blind people navigation systems. Some solutions also uses video

Artykuł recenzowany *otrzymano: 08.07.2012r., przyjęto do druku: 05.10.2012r.*

cameras both in single mode [12, 30] and in stereoscopic mode [24]. These approaches employ image recognition to get information from an environment in a way similar to human sight and they can be used in addition to the mentioned sensors to work separately or mutually. Some complex systems for blind people often use accelerometers, gyroscopes and compass [3, 4, 11, 47] to increase GPS data precision, monitor blind person movement and position, stabilize other sensors measurements or to filter the acquired data.

4. Autonomous decision and navigation center based devices

It is safe to say that all EAs for blind people evolved from the fact that a simple white stick does not assure enough safety during walking. One way to overcome this issue is to assign to a blind person a guardian, who could guide and navigate that person. This is the perfect solution, however not every blind person can be lucky enough to have their own guardian who could take care of them 24/7. As for the navigation safety problem, guide dogs are being used. Nevertheless, guide dogs have their limitations, for instance, it is quite costly to have them trained and that special training takes several months. Another way to increase the safety level is that a blind person gets around only in familiar and well known environments. However, even on everyday road from home to work or school, some possibly dangerous scenario elements changes, like cars and road excavations occurrence or traffic lights. Yet, blind people do not want to give up the normal life and want to go through life as independently as they can. That is why various EAs – based on a guardian technique and also autonomous navigation devices – have been designed to help blind people with that.

Most of the developed EAs are based on autonomous decision operation. Multiple sensors swipe the environment to gain all the important data, for instance, visual image, blind person's position and one's movement, distance from obstacles, etc. The data is processed and used for navigation [31], walking assistance [51], human and object detection and recognition [35]. These devices are usually based on fast FPGA and MCU chips to handle real time computations, image processing, objects recognition and decision algorithms. In some cases they also have access to large databases of image samples or POI. The main advantages of these solutions are that the remote human guidance is not necessary and a blind person is relatively independent. There are also devices which employ all or some of the mentioned sensors but the decision making process and assistance are performed by some remote human operator [58, 59]. This feedback is often being done over GPRS or other radio connection [12] and its presentation is done through voice commands, sound or tactile signals. A blind person can request for help whenever one needs it. These solutions assure high level of safety and very detailed, strict and user-friendly guides. Nevertheless, a remote, human operator is necessary.

5. Self-orienting and localization based devices

People mainly use vision in everyday navigation tasks. Thanks to the sight a brain can obtain the important data from an environment, process this data and make a decision. There are also many aids to help people in navigation, for instance, regular maps, GPS devices and road signs. All these things are helpful only when a person's vision is not impaired. That is why EAs for blind people have to gather all the important data, make decisions and supply users for selective, important information, warnings and alerts.

Various EAs use only a self-orienting technique in navigation. This means that only the surrounding environment is scanned. Global positions or any maps and POI are irrelevant. Usually, these EAs are all kinds of objects detectors and obstacle avoidance. Some devices use only ultrasounds or an infrared beam to detect and inform about obstacles, like in [13]. Other EAs employ video cameras and image processing to recognize objects of interest [6, 17, 32, 50, 54, 61] or even people's faces [25, 34]. Usually, in these kinds of systems the distance from the recognized objects is important. For this reason, the stereoscopic vision [16] and infrared based ranging [9, 38, 40, 55] are being used.

The second group of EAs is based on cooperation with external systems for the localization purposes. Some solutions implement RFID tags into the environment to help to navigate blind people and avoid or inform about various objects [15, 18, 22, 25, 41, 42, 44, 53]. Although, embedding RFID tags into large size environment can be costly, it is a suitable solution for indoors and campuses. In some cases, an existing system network can be used, for instance, Wi-Fi hotspots [1, 46, 56] or GPS signal [11]. Both of these solutions usually use POI or map of some kind for guidance. Often the map created for people with normal vision is not suitable for navigating blind people and special maps with customized POI and changeable level of details are being used [62].

Some systems employ both self-orientation and external localization method to acquire more accurate data, compare detected objects image only with object database bound to the precise global location or maintain a position fix when one of the used method is unavailable, for example the lack of GPS signal in tunnel [4].

6. Autonomous and server based computation

EAs, both attached to white canes and external ones should be light weighted, relatively small and they should not meet other people eyes. They should be comfortable and safe to wear. On the other hand, EAs must be low-powered and last on batteries for at least one day without charging. Batteries capacity and weight can be a disturbing problem for mobile EAs. Due to this some devices drop power demanding computations on remote computational servers. Generally, if the functionality of the EA is large, there is lots of data from multiple sensors, the easy way to save energy on mobile device is to send data to a server and wait for the processed data or a navigation decision. Other types of devices that utilize this method are the ones that employ massive databases for navigation or image recognition, like for instance, geographic information [23], large amount of POI frequently updated [31], navigation routes [18], databases of road signs, characteristic buildings or shapes specific to a location or when EAs are using contents available online, like Google Maps, Quick Response Codes and RFID tags database [25].

The mentioned methods save energy and at the same time maintain a wide spectrum of functionality, however, sending large amount of data through Wi-Fi or cellular networks creates delays. Unfortunately, the previously mentioned methods are not the best solution for EAs which should work as real-time systems and provide reliable response in a deterministic, short period of time. That is why some electronic systems for blind people do all the computations by themselves. Usually, in these solutions autonomous work compromises for a broad functionality, yet in some EAs the real-time work is a must. Generally, they are obstacle detectors [2, 36], object recognition devices [17], simple computer vision based systems [61], navigation aids [45], etc. The quick alert about possible threats gives blind users time to react and avoid tripping over or hitting against some objects.

A flexible solution is a combination of methods mentioned in this section in one device in a way that safety-critical, real-time modules work constantly and modules which involve heavy computations can be enabled on demand.

7. Signaling methods

In most navigation systems, all the important data is presented with the help of a display of some kind, often supported with voice commands. Since this approach is futile for EAs for blind people, some other signaling methods are being implemented.

The most common way to pass information on to the blind users is by means of voice commands. There are several domains where this type of signaling can be helpful, for instance, web browsing [27, 39], banknotes, coins [49] and signage recognition [28], etc. A synthesized, pre-recorded or live speech and also other acoustic signals are often being used in some navigation systems for visually impaired [5, 22, 35, 59, 60]. Although, this type of signaling is the most natural for blind people and shortens the adaptation time for a new device and a learning period, it suppresses other acoustic signals from the environment. This could be potentially dangerous for a visually impaired user, therefore, other signaling methods are also being applied.

Blind people often recognize objects by touching them. This helps them identify shapes or read Braille signs. In [37] there is a dynamic, tactile map presented. A mechanical matrix is able to display graphical shapes, navigate by means of straight lines or arrows to indicate direction or display pre-programed characters to indicate a specific obstacle or place. Another type of signaling method for blind people is a heat based matrix [7].

There are also simple methods to indicate specific objects of interest or their distance from the user. The common approach is the use of vibrating motors [19, 21] and modulate the signal impulses number and their length. There are also prototype interfaces where signaling is done through a voltage or current stimulation of user's skin by electrodes, like in [52].

8. Conclusions

The presented EAs help to deal with general safety for blind people. Although, all the mentioned devices and systems try to compensate for the lack of vision of blind people, more extensive research and further work has to be conducted in order to achieve better functionality and a satisfying safety level for blind people.

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