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Technologies supporting independent moving inside buildings for people with visual impairment

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Abstract. Sustainable Development Goals (SDGs) include disability and persons with disabilities for example partially sighted or blind. Disability is referenced in multiple parts of the SDGs, specifically in the parts related to education, growth and employment, inequality, accessibility of human settlements and buildings. The paper presents selected technologies that support independent movement blind people inside huge buildings. The paper will refer to two SDGs: No 9 and No 11. There needs to be a future in which cities provide opportunities for all with access to basic services, housing, friendly public buildings, transportation and more, even to people with eye disabilities. This paper presents selected systems for finding objects or places, recognizing objects inside rooms and navigation inside buildings based on non-radio and wireless technologies. The following technologies and solutions were presented and compared: physical items, smartphone cameras, laser rangefinders, pedestrian dead-reckoning, intelligent lighting, Wi-Fi, BLE beacons, magnetic fields and barometric pressure sensors.

Keywords. Sustainable Development Goals, independent movement, people with visual impairment, navigation inside buildings, indoor positioning systems.

1. Introduction

The Sustainable Development Goals (DSGs) [12] are a set of 17 interlinked goals that are designed as a blueprint for achieving a better and more sustainable future for all people around the world. The DSGs were defined in 2015 by the United Nations General Assembly and planned to be achieved by the year 2030. Among the many goals, United Nations identifies two goals to improve urban life, in the particular case of the use of indoor services by people with visual impairments. The article will refer to two SDGs: No 9: Industry, Innovation and Infrastructure. Investments in infrastructure are crucial to achieving sustainable development; No 11: Sustainable Cities and Communities.

According to the research results presented in [3] globally, of the 7,33 billion people alive in 2015, an estimated 36,0 million were totally blind, 216,6 million people had moderate to severe visual impairment and 188,5 million had mild visual impairment. Statistically, the share of females 55%. Functional presbyopia affected an estimated 1094,7 million people aged 35 years and older, with 666,7 million being aged 50 years or older. The estimated number of blind people increased from 30,6 million in 1990 to 36,0 million in 2015. This change was attributable to follows factors: increase of population growth, population ageing and reduction in age-specific prevalence.

The latest WHO reports [13] say that at present at least 2.2 billion people around the world have a vision impairment, of whom at least 1 billion have a vision impairment that could have been prevented or is yet to be addressed. Globally, the leading causes of vision impairment are: uncorrected refractive errors, cataract, age-related, macular degeneration, glaucoma, diabetic retinopathy, corneal opacity, trachoma.

In Polish National Organization for the Blind (pol. PZN) is registered about 58000 members (adults and children) disabled due to the moderate or severe dysfunction of the eye including 31 000 totally blind.

It is a number of people who encounters great difficulties with independent movement, both in outdoor environment and also in closed area of public buildings.

The aim of this article is to show the direction of research and technology enabling the blind people to move inside buildings without the assistance of some guide. At the beginning, the most popular applications for navigation in open space will be indicated. These applications are installed on smartphones and only use the GPS signal to locate the user. Then, the physical elements for orientation inside buildings are shown. The main part of the article presents the classification of research directions in the field of Indoor Navigation. Three directions were discussed: find an object or place, recognize indoor objects and navigation inside buildings. Selected systems, technologies or devices are shown for each research direction. At the end, the properties of the presented technologies were summarized and compared.

2. Moving in an open space

Navigation based on GPS (Global Positioning System) makes it easier to move around in an open space. It turns out that blind people are perfectly capable of operating mobile devices. The people may use GPS navigation devices/applications to determine the path to the destination. There are many useful and accessible applications on smartphones, e.g. Maps – the popular GPS-based navigation system (see Figure 1). The new feature introduced in 2019 is of course about walking around the city, its main novelty are detailed instructions and additional messages.

In addition, there are dedicated devices such as NaviEye. The NaviEye has a GPS receiver that provides accurate position readings. The device announces the messages with the natural voice of the IVONA speech synthesizer. The user can control this device by voice or physical buttons. It offers a friendly interface, so it is easy to use. The "my assistant" function is an innovative solution. It is a help that can be used on every menu level.

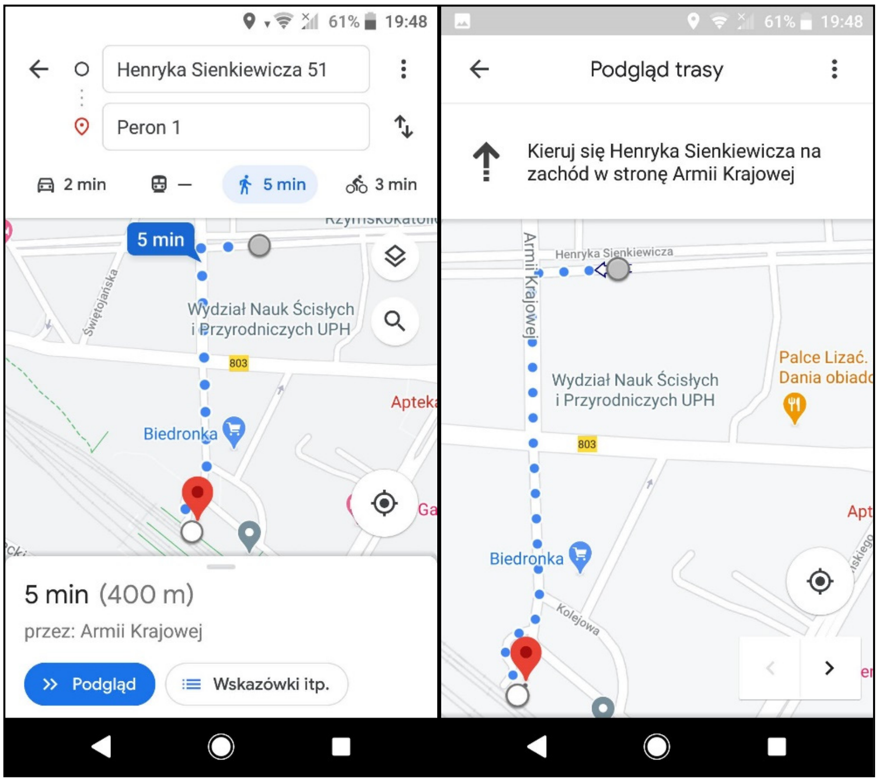

Figure 1. Maps – a popular navigation systems for open spaces. Screenshot from Sony Xperia XA1 Ultra G3212 4. Own elaboration.

Blinds are able to move around an open environment a little easier, due to ability to hear sounds reflected from obstacles (echolocation), sounds of passing cars, etc. (see Figure 2). Blinds are doing well on well-known routes, for example from home to work.

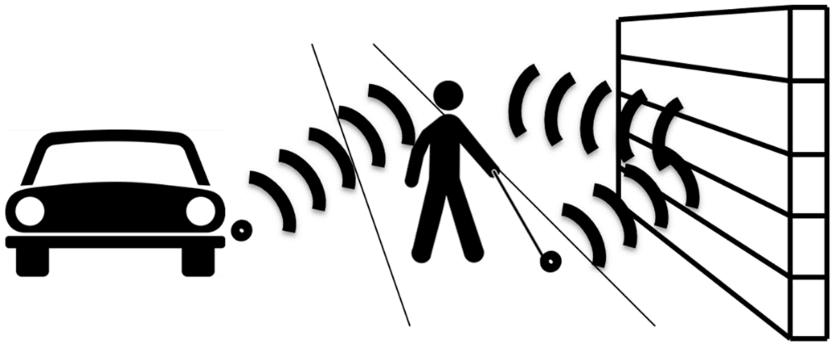

Figure 2. Sounds generated by an objects and sounds reflected from an obstacles (echolocation). Own elaboration.

3. Independent moving inside buildings

However, a problem arises when the blind wants to move independently inside huge buildings. Examples of these buildings can be hospitals, airports, shopping centres or museums. It turns out that independent movement in open areas of public buildings is even more complex for them because it has not certain streets, pavements, passing cars, which they could hear. What's more, the GPS signal indoor is blocked by the roof and walls of the building.

To help, inside buildings a physical items, such as the metal paths (see Figure 3) leading to important places or round protrusions, informing, for example, on the stairs beginning are applied. Most often, this type of solution can be found in tunnels, railway stations and airports. However, very few buildings are set such services, and in addition, their installation is usually too expensive. Although there are a few commercial solutions, but there is no clear standard for building such navigation systems.

Figure 3. A physical components installed on the ground. The photo was taken with a smartphone Sony Xperia XA1 Ultra G3212 4 at the Warsaw Chopin Airport station. Own elaboration.

Taking it into account worth notice that there is a great need of electronic supporting of navigation of blind people in public buildings. The solution should be possibly easy accessible to blind user, popular mobile devices such as smartphones and tags on various objects in the building in such system, should be used. The navigation steering mechanism should be smart enough, for example, to allow making definition of safe routes between any two points in the building using voice commands.

There are already many solutions for helping in navigation inside a building. They use some e.g.: GPS replicators, radio waves, tags, acoustic or magnetic sensors, gyroscopes, compasses, strength signal meters, motion detectors or other. Also distance data provided by the sensors and e.g. building plans are used with a software associated with this equipment.

Blind people face a number of challenges when interacting with their environment because so much information is encoded visually e.g. by pictograms (see Figure 4). In the area of blind help, it is natural that attention is paid to compensating for the lack of sight.

Figure 4. Examples of pictograms and boards not available to the blind. Free ClipArt. Own elaboration.

As one of the basic senses, sight is used every day for many activities e.g. recognizing objects, people and above all to movement in the real space. There are many interesting researches in this area. But each path or direction has a common feature – the blind help system uses different devices coming to the: Internet Of Things [11]. Internet Of Things is the network of physical devices, vehicles, and other items containing electronics, software, sensors which are connected to network and exchange data with each other.

4. Indoor navigation - direction of research and technology

In the area of Indoor Navigation, worth indicate three main directions of development: (1) find an object or place, (2) recognize indoor objects and (3) navigation inside buildings. The last branch can be further divided into: non-radio technologies and wireless technologies.

4.1. Find an object or places

A system that directly supports this type of interaction is presented by Bigham and Jayant [2] and called VizWiz. The system based on a three steps algorithm that uses information to guide users to the appropriate object interactively from their phone. The blind users must only sent a photo of a object and ask for assistance in finding the object or place. The request is sent to remote workers who are watching the photo and give an answer to the question.

The system works as follows (see Figure 5). In the first step (Step 1), the user takes a photo of the object or place. The photo is sent (message 1) to the application server. The second step (Step 2) is to record the question e.g. “Which can is the corn?”, which is also sent (message 2) to the server. Next a remote worker watches the photo (message 3) and reads the question, makes a response and sends it to the user (messages 4 and 5). At the last step (Step 3), the user listens to the answer, e.g. “It’s not corn”.

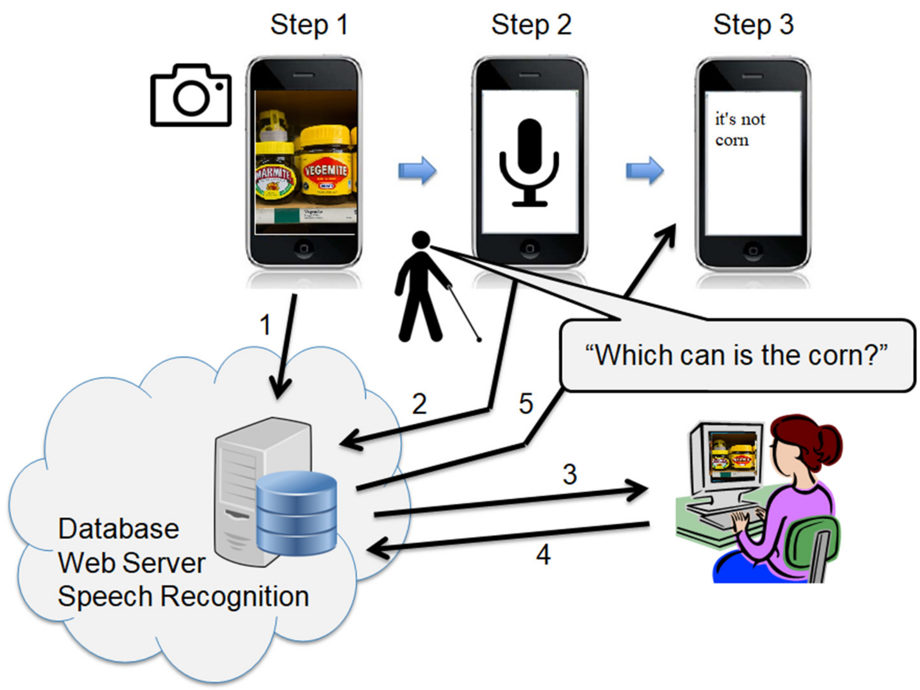

Figure 5. VizWiz– three steps algorithm that uses information to guide users to the appropriate object interactively from their phone. Own elaboration based on the sequence of messages and the architecture of the system presented in [2].

4.2. Recognize indoor objects

The next approach present the prototype of system, which offered to recognize multiple objects in public indoor environments [10]. The system focuses on aspects: navigation and recognition. The system uses hardware components (such as: camera, laser sensors) that the blind person wears on his chest (see Figure 6).

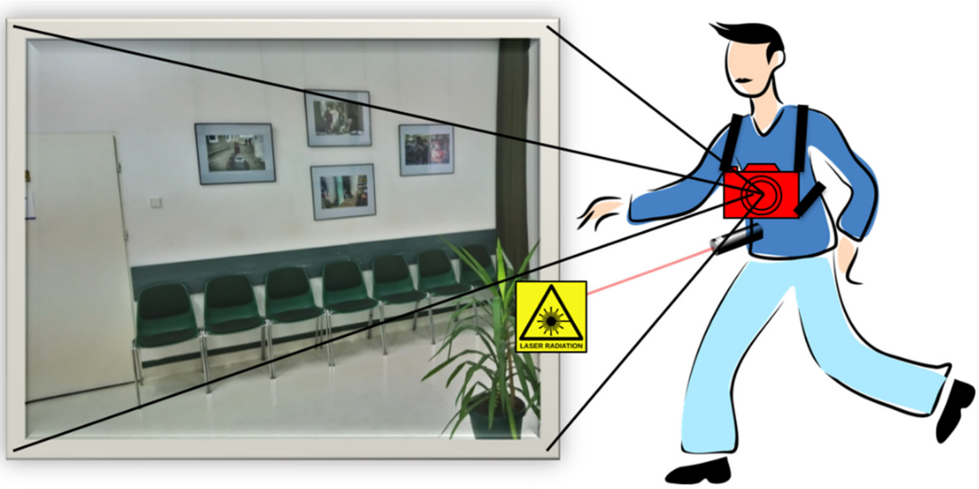

Figure 6. Recognize indoor objects. Own elaboration based on the idea of the system presented in [10].

Its algorithms to recognize objects are mainly based on advanced computer vision and machine learning approaches. The interaction between the user and the system is performed through speech recognition and voice synthesis. The prototype offers to the user the possibility to navigating to the target and detecting mobile obstacles and ask the system through vocal interaction to list the visible objects in the user's field of view. The system returns a list of objects captured by camera at the time of the user's request. User request: “Give objects”. Answer from the system: “Predicted objects are: internal door, chairs, paintings, plant”.

4.3. Navigation inside buildings

The indoor navigation is more specific then outside one and it requires use much more diverse technologies, because there is no GPS signal and the path to the destination can follow many floors of the building. For this kind of navigation Indoor Positioning Systems (IPS) [4] can be used. IPS uses two main technologies: non-radio technologies and wireless technologies.

Non-radio technologies – magnetic fields

The first presented non-radio technologies is based on magnetic fields. The technology is partly inspired by evidence that animals (e.g. spiny lobsters) use the Earth’s magnetic field not only for orientation detection but also for navigation. Modern buildings have a unique magnetic field (see Figure 7) produced by the Earth’s magnetic field that interacts with steel and other materials found in structures of buildings. One of the available solutions is IndoorAtlas [1]. The

IndoorAtlas is a complete software toolbox for adding and managing buildings plans, collecting and create magnetic field maps, and an API to use data location service based on magnetic field for mobile applications.

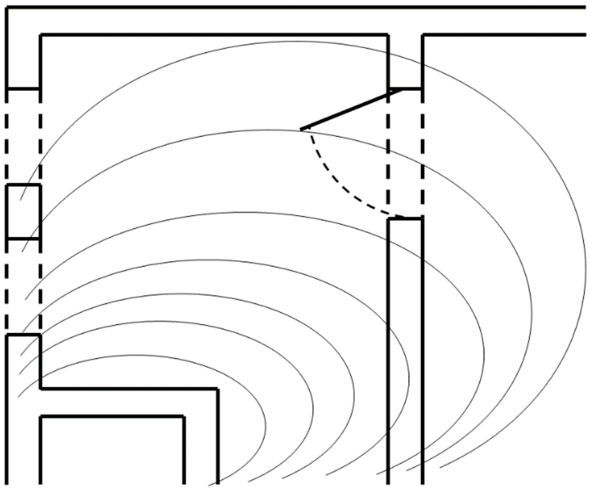

Figure 7. An example of the spectrum of the magnetic field inside a building. Own elaboration.

Non-radio technologies – pedestrian dead-reckoning

The technique uses a sensor which has some modules in one: accelerometer, gyroscope and sometime magnetometer. The sensor and additional technology tracks the movement of the user (see Figure 8). Simpler solutions [8] are based on devices like a mobile devices, which tracks pedestrians through typical dead-reckoning approach using data from inertial sensors embedded in smartphones and do not require any additional infrastructure. The disadvantage of this solution is that with increasing distance of the user from the established position, the accuracy of the position decreases.

Figure 8. Pedestrian dead-reckoning. Own elaboration.

Non-radio technologies – barometric pressure

Next one non-radio technologies technology based on the barometric pressure is useful for recording vertical movement [9]. The smartphone or a watch barometric sensor can detect even the smallest changes in atmospheric pressure. Typically, this happens when the user moves in vertical direction such as walks up or down a flight of stairs or uses escalators or elevators. Disadvantage is, that the pressure inside a building changes from hour to hour, it is also related to temperature.

Non-radio technologies – intelligent lighting

The last presented non-radio technology is intelligent lighting [5]. The basis of the system is the transmission of location data through special light bulbs by modulation of light, which it is invisible by the human eye, but it's readable for the smartphone's camera. User witch smartphone (see Figure 9) can enjoy location-based services, e.g. searching for specific position inside building or products that he have on the shopping list with an accuracy of 30 cm.

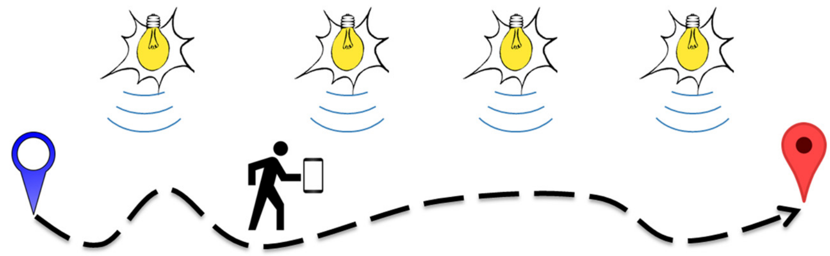

Figure 9. Visible Light Communication technology (VLC). Own elaboration.

Wireless technologies – Wi-Fi, triangulation, signal strength, delay

It turns out that Wi-Fi triangulation [6] is one of the oldest technologies used in indoor positioning. And for a good reason – rich Wi-Fi environments exist inside shopping malls, offices, and residential buildings (see Figure 10). Also, all smartphones today have a Wi-Fi chip. This freely available information can provide a room level accuracy under good conditions.

Figure 10. Technologies based on Wi-Fi triangulation. Own elaboration.

Wireless technologies – Bluetooth Low Energy beacons

Bluetooth Low Energy (BLE) beacon it is small device. The transmitter can sent identifier and several bytes data on small range, which are used to determine the device's physical location. BLE beacons are becoming increasingly common in most commercial environments. They provide a quick and cost-efficient way to create small to midsize indoor positioning deployments [7]. In addition to its applications in navigation, BLE is also used to send information about store promotions (see Figure 11) or repertoire in cinemas.

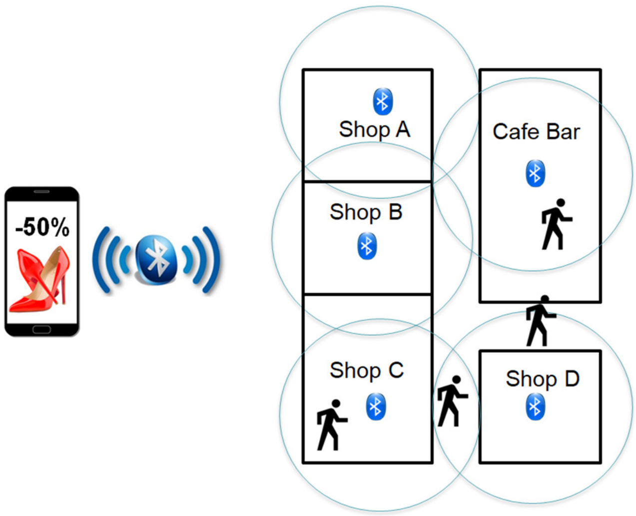

Figure 11. Bluetooth Low Energy (BLE) beacons. Own elaboration.

5. Technology comparison

As venue owners evaluate which indoor technologies deploy there are a number of questions they need to ask. Are we interested in location and/or navigation? What level of accuracy is required? What is the total cost of regarding the deployment and maintenance of the chosen technology? E.t.c. The table 1 shows a comparison of the technologies presented in this article that can be used for indoor navigation and positioning techniques.

Table 3. Comparing technologies for indoor navigation and positioning techniques. Own elaboration.

Technology	***Accuracy***	***Infrastructure***	***Set-Up /Costs***	***Power Source***	***Developer Environment***
physical items	2-3 centimetres	physical items	pin / 1$, 1m metal path/10$	none	n/a
smartphone camera	variable	hardware, software	Smartphone / 100-1000$	battery (degrades)	iOS / Android

laser rangefinder	1 centimetre	hardware	rangefinder / 100-200$	battery (degrades)	n/a
magnetic fields	1-2 meters	software, cloud	API, remap / minimal	none	iOS / Android
pedestrian dead-reckoning	n/a (complementary)	software, cloud	API / minimal	battery (degrades)	iOS / Android
barometric pressure	variable (complementary)	hardware, software	sensor / 10-50$	none or battery (degrades)	iOS / Android
intelligent lighting	30 centimetres	hardware, software	LED / 25-80$ (mesh coverage)	electricity	iOS / Android
Wi-Fi	10-100 meters, room level accuracy (under good conditions)	hardware, software	remap (finger printing)	electricity	iOS / Android
BLE beacons	1-30 meters	hardware, software	BLE / 1-3$,	battery (degrades)	iOS / Android

Commercial solutions and implementations most often use BLE beacons. The reason is sufficient accuracy when using dense coverage of building space, small dimensions of the device and a fairly long life of battery operation.

6. Conclusion

There are many people with eye disabilities live around us. They also need the ability to move independently. It seems such a possibility should be provided to everyone. In turn out that technologies are developing in the right direction and has a great potential. There is potential and many possibilities to help blind people to move independently inside buildings. Positioning accuracy is usually depending on the amount of infrastructure equipment and their cost. The architectures of these systems usually use: Bluetooth, BLE beacons, Wi-Fi-based positioning system, building plans and software. Sometimes hybrid solutions connecting mentioned earlier technologies are applied.

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