

Blind people guidance system

Ljupko Šimunović

Faculty of Transport and Traffic Sciences

University of Zagreb

Vukelićeva 4, 10000 Zagreb, Croatia

ljupko.simunovic@fpz.hr

Velimir Anđelić, Ivan Pavlinušić

ESAPI

Oporovečki dol 11, 10040 Zagreb, Croatia

{velimir.andelic, ivan}@esapi.hr

Abstract. *This paper describes a guidance system for blind and partially sighted people with the aim of coping in the known and unknown internal and external spaces without the assistance of human guides. This work represents a significant step forward in the application of innovative technological solutions to increase independence and improve the quality of life for people with disabilities. This paper describes the technical and functional architecture of the system for orientation and guidance of a blind person using available modern technology. The described system consists of a digital sensor for determining the location by dead reckoning technique, infrared marks in space and handheld device that provides voice guidance instructions.*

Keywords. location system, blind navigation, dead reckoning, infrared, GPS, MEMS, PDR, GIS

1 Introduction

People with disabilities, particularly blind and partially sighted, are daily confronted with numerous problems while performing routine activities and moving through unfamiliar areas. Modern society guarantees freedom of movement and access to a desired goal under the same conditions to all the people. In order to meet the needs of persons with disabilities in the Republic of Croatia, traditional building measures such as curbs lowering, ramps building and platforms lifting, have been mostly in use. The possibilities provided by advanced information and communication technology, aiming at people's orientation in space, determining the position where a person is located (locating), tracking, leading to the goal (navigation), etc., have been under-utilized.

Finding the way [1] consists of two components: the first is detection of the immediate environment which includes finding obstacles and dangers, while the second is navigation towards a remote location that is beyond the current reach of the senses. The navigation consists of determining the current

position and determining the direction of movement along the requested route towards the goal. There are several ways of navigation. Navigation based on position relies on external signals which indicate the current position and orientation and is often connected to an external or internal map. Navigation based on speed, which is known as dead reckoning or path integration uses the known speed to determine progress and direction by integration. Navigation based on acceleration (also called inertial navigation or path integration) does not require any external signals and uses a double integration of linear and rotational acceleration to determine the progress and direction.

Blind and visually impaired are disadvantaged because they lack information about the obstacles and dangers, they have little information about the visual markings in space, they have no sense of direction and speed, essential to the people who can see for navigation through familiar, as well as through the unknown environments using maps or instructions.

The following section will describe the possible solutions that help the blind navigate independently, without a guide's help.

2 Overview of available technologies

Until recently there was no advanced technology to navigate the blind. They used mostly mechanical (usually tactile) ways to navigate in space. The first electronic solutions have been developed for the detection of obstacles and dangers on the way and they were used as a replacement for a cane which is a basic tool of the blind people. That way the variants of canes with laser or ultrasonic sensors were developed, but they have not entered into widespread use.

The goal of this project was to find a technology that would realize a navigation similar to road satellite navigation. Such navigation uses the Global Navigation Satellite System (GNSS), ie. here the Global Positioning System (GPS) to determine the user's location, and then with the help of computers

and embedded maps, the route towards the goal is calculated, and the user is navigated point by point. Today, it being used in traffic navigation daily, but it begins to be used to navigate the blind, as well. However, there is a big problem when GPS is used in the area where obstacles such as buildings, trees and bridges obstruct sky and interfere with reception of GPS signals. Then the GPS becomes less accurate, and in enclosed areas, it become unusable, because it has no signal. To counteract this, there are several technologies that are used to determine the position within an enclosed area, and for the purposes of this project all the available technologies were considered and feasibility was assessed, with regard to financial capabilities, time requirements, expandability and most importantly, applicability in practice.

The first set of technologies that could be used to locate the users within the enclosed areas are those that are already available and should not be built, such as mobile technology (GSM) and wireless networks [2] (WLAN). Public services (police, emergency services) use the mobile network to locate users, but that locating is too coarse for this application. Depending on the distribution of the transmitter, it can achieve an accuracy of about 100 m. In a similar way, one can use the existing WLAN network, so that the signal strength is read, and compared to the database in order to determine the distance from the transmitter. Using a trilateration technique, the location of the user can be determined from multiple signal sources. The problem is that WLAN should have enough points, which is not possible everywhere, and especially not in outdoor areas. The accuracy varies, as well, depending on the conditions, reflections and propagation and it can be from 1 to 3 m.

Radio-frequency identification (RFID) belongs to these radio technologies. This technology has a lot of potential and there are projects which are used for navigation and for locating. There is a whole system of guidance of the blind, developed using RFID technology. SESAMONET [3] system was installed at several points in northern Italy and it consists of a cane for the blind with an embedded RFID reader, that is connected wirelessly to a mobile device. Navigation software in a mobile device sends voice instructions to the user, and data are drawn from a central database to which it is connected via mobile network. The cane reads the RFID passive tags that are embedded in the tactile floor and on each turning point or crossing, the device signalizes in which direction one should continue in order to reach the goal. This system is efficient, but it is not easy to install it on new terrain, because it needs a lot of work and installation of expensive tactile paths with RFID tags.

There are several standard types of RFID systems, and as a major feature, we were interested in the distance at which one can detect the tag. Distances range from several millimeters to several meters for

passive tags (those that have no power inside them), but the problem at a greater distances is that for the detection of such tags, there should be a great antenna, which is impractical to carry. Otherwise, it would be a good way to make a system which there is no need to install anything in space, just set the passive tags that are inexpensive, and that way get the information about the space necessary for guidance.

The ultrasound distance and barriers sensors are often used for guidance, especially in autonomous vehicles and robots. If the entire ultrasound system is installed on the user, such user can only get information about the barriers of distance from him, but not the absolute location. For absolute locating, static transmitters system is used, reporting its location using the ultrasound, and then similar to the radio signal technology, the user's location is determined by the method of measuring the signal. Such technology is also complicated and too expensive to use in large areas.

Similarly to ultrasound signals, the infrared signals which transmit information about the area can be sent in space. They can be easily directed, and have no problem with passing through the walls, so a variant of this technology is used in this project. There are projects such as Active Badge [4] which uses infrared signals only to locate the users, but due to the impossibility of locating the correct orientation of the user in space, it is not enough to navigate the blind.

In the end, there are passive technologies using MEMS (Micro Electrical Mechanical Systems) sensors to determine the displacement and orientation of the user from the decoded values of acceleration, rotation, magnetic field and pressure. digital accelerometers, gyroscopes, magnetometers, compasses, barometers, thermometers (temperature compensation) have been used to do that. The simplest such devices as pedometers, which count steps and based on the number of steps and the average step length, they can determine the distance traveled, but they cannot determine the information about direction.

More advanced category of the system are dead reckoning systems that contain some or all of the above sensors and calculate the shift of the user based on the data measured. There are two types of such devices: The first are those in which is acceleration sensor is placed on the shoe, and in the second, the sensor is attached to the belt. In both types, it is important that the fastening device is securely connected to the body so that it transmits all its movements accurately. Then the software evaluates user's behavior from the data on the sensor (walking forward, backward, sideways, running, standing). This technique is known as Pedestrian Dead Reckoning (PDR).

Both techniques have their advantages and disadvantages, but for the purposes of this project, dead reckoning device that is placed around the waist was chosen as the only commercially available to us.

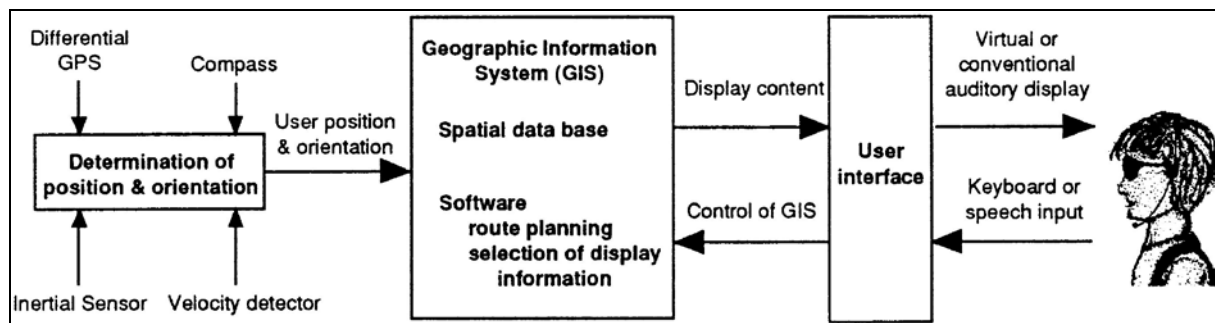


Figure 1. The functional components of any navigation system for the blind [1]

3 Navigation systems for the blind in general

For reliable navigation (of blind) pedestrians, it is necessary to determine current position of the user, using different sensors that are integrated into the system. This is called "Integrated Positioning" [2] and it consists of the following tasks:

- Tracking the movement of pedestrians in real time using the appropriate location sensors in order to optimally estimate the current position of the user
- Ability to track in three-dimensional space with the accuracy sufficient to determine the floor a user on
- Achieving the uninterrupted monitoring of the position during the transition from outdoor and indoor areas.

The integration of sensors in a modern system can be made using the Kalman filter, because that algorithm is suitable for operation in real time.

Each system for blind people navigation generally consists of three main parts shown in Figure 1:

- Module for determining the current location and orientation of the user
- A computer system that contains a Geographic Information System (GIS) with the information about the space through which the user will move
- The user interface, usually tactile and audio

Various types of performance achieve it in a variety of ways. So far, the determination of the users location technologies were described, and the following sections will describe the way the system designed for this project works.

4 System description

Our blind and partially sighted people navigation system uses several methods to determine the location of the user. The first is the use of a GPS to determine the absolute location of the user if the GPS signal is available. The second is the relative determination of the position using dead reckoning module (DRM). The third is the use of infrared tags.

The DRM being used is DRMTM4000L [5] module, made by the company Honeywell, which has already made several variants of this module and this is the last improved version. This module is a miniaturized electronic board measuring about 5x5cm which has a RS232 port for standard NMEA GPS and RS232 output for communication with the rest of the system. The module has to be tightly attached to the belt so that the body movements can be accurately read by its sensors. When the GPS signal is available, the module gives movement absolute location and direction, and the calibration of the parameters of dead reckoning system can be turned on. The basic parameters are the step length and the module angle in relation to the direction of movement. When both systems are working, GPS and dead reckoning data overlap using the Kalman filter. The module can operate without GPS receiver, and then it gives the relative position until the initialization. The declared accuracy is 2% of the distance traveled, meaning that the errors accumulate just by movement, and not over time.

DRM uses the patented classification algorithms for the analysis of movement that can detect walking forward, backward, sideways and running. For that purpose 3 commercial gyroscopes, 3 accelerometers, 3 magnetometers, a compass, a barometer and a temperature sensor are being used. The module recognizes the transient magnetic disturbance and transient accelerations that can interfere with the compass. The compass has an accuracy of 1°, and the barometer of 1.5 m.

With these specifications and using this device, navigation through the interior areas can be done, but

there remains the problem of initialization and recalibration after the error becomes too big. The solution is in the use of the infrared (IR) transmitters at key points, since they can serve to position absolutely within the enclosed spaces or spaces with

insufficient GPS signal. Both the inner and outer spaces are covered in the same way, and DRM is responsible for the integration of these systems.

IR transmitters are simple and not many of them need to be placed in the area, only at some key points

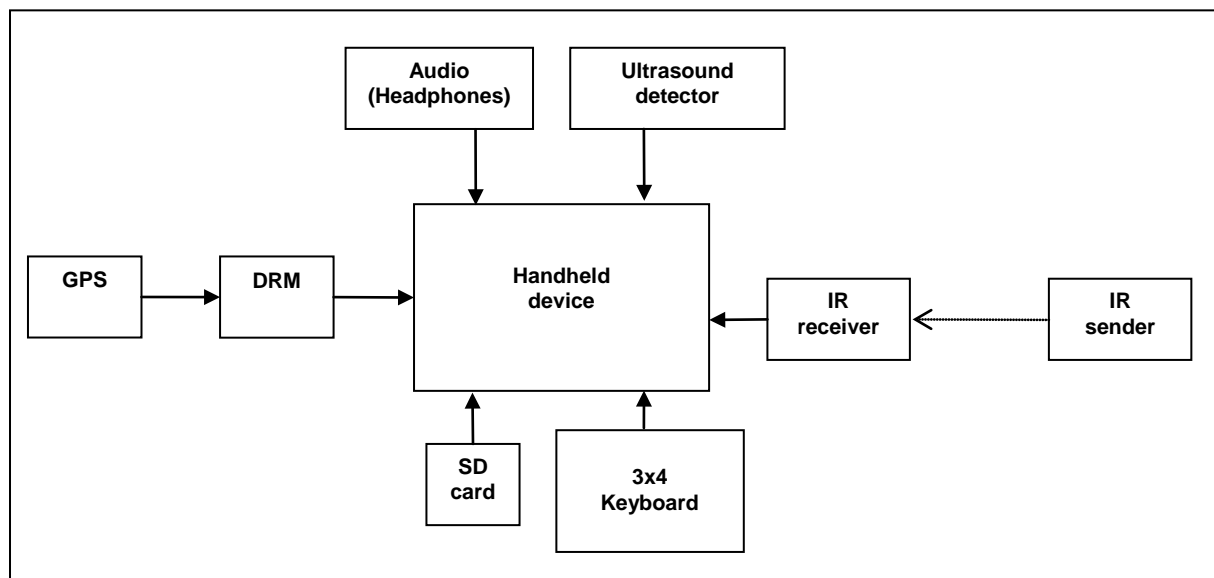


Figure 2. System description

(doors, passages), because they only serve to initialize the DRM and calibrate step length by taking a known distance between two IR transmitters and calculating step length from the read number of steps.

Figure 2 shows the schematic presentation of the entire system. Besides the aforementioned DRM and IR sensors, an ultrasound detector is used to determine the distance to the wall or barrier, but it is not used for active navigation, but only for the user who wants to find the obstacles or measure distance at his own request.

The user interface is realized using a 3x4 matrix keyboard and headphones.

5 Handheld device

Handheld device developed for this project is a battery powered device that consists of the microcontroller which is connected to the periphery. The microcontroller processes the received data from DRM and using the internal GIS data stored on the SD card and audio recordings, it navigates the user to the default target.

The DRM and handheld device are connected via Bluetooth, which transmits the user's location data. The program within the device analyzes the location using the data from the GIS system that are stored on the SD card and sends audio messages to the user. Audio messages are pre-recorded on the a PC and transferred to an SD card, as well as all the GIS data. The device has a keyboard with 4 rows and 3 columns, as on the phone, with the numbers 0-9, an asterisk (*) and hash key (#) for the easy entering of

the commands. The user sets the goal by the keyboard and seeks information about the current location. Locations are entered by entering the ordinal number of a site, which usually corresponds to the number of the room in the building. The device then provides data on the direction and distance to the first key point. The direction is obtained from the DRM, which contains a compass. The user may at any time get the current orientation in space by pressing a button, as well as the distance of the barrier read by the ultrasound sensor. The user can also, at any time, get the calculated distance by the following key point (waypoint). Key points are determined by describing every change or significant element in space on the path towards the goal. These are the doors, corridors, diversion, stairs, elevators and all of the obstacles that are on the road. At that point, there can be IR transmitters which transmit coded information about the location of the transmitter via IR light. These information are used for initialization and calibration of DRM.

6 System use

The system is intended to be used in indoor and outdoor spaces with installed IR transmitters. In order to start using it, DRM should be fitted around the waist and if a GPS is available, handheld device will get the current location using Bluetooth wireless technology. If it is initially used within a space without a GPS signal, an infrared transmitter should first be read using a handheld device, in order to determine the starting location. That is easy if the

device is given to a blind person to use it when entering the building (eg. ports) when another person helps at the beginning of use.

Using a keyboard, the user enters the desired goal, puts the headphones on and listens to the instructions and information as he moves along the route dictated by the device. The blind person continues to use his cane for the detection of the direct obstacles and people, and for the detection of the announced changes on his path. At every key point of the path, the device reports the information on terrain, where and when the person should turn, how far he should go, what he should watch out for, and what actions he should do (open the door, go around the pole, go down the stairs...). The user may require a repeated or additional information by pressing the appropriate key.

All the information about the path must be stored on the SD memory card before using them. This means that one should draw a map, mark key points, record voice directions with descriptions of the area around the key points, all in a format that will be recognized by the device. It is all done by a PC. Then the SD card is inserted into a device and the navigation may begin. The success of guidance depends on the quality of those information.

The whole system is applicable to numerous locations, such as educational institutions, administrations, hospitals, shopping centers. Such a system is not only helpful to the blind, but it might also be used by other people for easier orientation in an unknown terrain.

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