Improved Version of an Integrated Environment for Assisted Movement of Visually Impaired

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Abstract: In this paper an improved version of an integrated environment that improves the mobility of blind persons into a limited area is presented. For the first time, the concept of the audio virtual realty is introduced here, as a man-machine interface between the subject and the wearable equipment that guides the movement. Other improvements are regarding the sensors used to acquire data from the surrounding environment: the 2D visual sensor has been replaced with a newer 3D visual sensor, while other types of sensors have been removed (an infrared sensor and a laser range finder). The obtained results and the further developments are also presented.

Key-Words: visually impaired persons, autonomous navigation, supervising system, audio virtual reality, artificial neural network, GPS/GPRS

1 Introduction

There are many types of devices capable to guide the movement of visually impaired or blind persons in real outdoor environments with obstacles [1]-[8].

The white can is still the most successful and widely used aid to detect obstacles in front of the subject, on the ground, uneven surfaces, and other hazards. There are some advantages of this device: small dimensions, light weight, low cost, etc., but the user must to be trained in it use for more 100 hours. Furthermore, the white can require the user to actively scan the area in front of him in order to find possible obstacles; then, the white can is not capable to detect potentially dangerous obstacles at the head level.

The guiding dogs seem to be another solution. They are capable to guide the blind persons in outdoor environments, with obstacles avoidance, but require extensive training and the cost of trained dogs is high enough. Furthermore, the blind and impaired people are, in general, elderly, and find difficult to care appropriately for another living being.

In the last years, several devices based on sensor technology and signal processing has been developed. Such devices, named electronic travel aid (ETA), are capable to improve the mobility of blind users (in terms of safety and speed) in unknown or dynamically changing environment.

The principle of functionality of the most of these devices is quite simple: a laser or more frequently an ultrasonic fascicle is sent in the investigated area and the received echoes, generated by obstacles, are detected. The time of the flight but also other principles are used in order to determine the distance from the subject to the different obstacles. The relevant information is then transmitted to the blind person, using different kind of methods: chimes, vocal messages, tactile sensation, etc. In general, obstacles not far than five meters ahead the subject are detected.

It is not in our intention to present in detail the already known ETA solution in the literature, but we will mention here the most important of them:

- The laser C5 cane [2], whose functionality relies on the principle of triangulation. This device is capable to detect obstacles at head level, ahead of the subject and on the ground.
- A hand-held device, Mowat sensor [2], is capable to inform the user upon the distance to the obstacles in front of him. The relevant information is transmitted to the blind person like tactile vibrations.
- Sonicguide [2], a more complex device, have been developed as a pair of eyeglasses. Three ultrasonic transducers: a transmitter - placed in the center of the device and two receivers, located on both sides of the transmitter, detects the obstacle positions in front of the user. The system is capable to acquire not only the distance to the different obstacles, but using the difference in time of the flight of the two echoes, the direction of obstacles can also be determined.

- The most performed solution seems to be the Integrated Environment for Assisted Movement of Visually Impaired [8], developed by author's team. This solution not only avoids the main drawbacks of the previously proposals (the necessity to actively explore the neighborhood in front of the subject, a low performance man-machine interface, additional measurements are needed to determine the shape and the dimensions of the detected obstacles), but has some improved capabilities:
  - A supervising system to track the movement of the visually impaired to the target position has been added,
  - The system includes in the same unit different types of sensors and the data fusion has been used then, in order to improve the consistency and the reliability of the decisions,
  - The acquired data are processed using mainly algorithms based on artificial neural networks (ANN) and cellular neural networks (CNN); in this way, a true real time behavior of the system have been achieved.

Actually, the principles of the above mentioned device are very similar to the methods and techniques well known in robotics. It has been a good opportunity for the author's team, which have a valuable experience in mobile robotics [9] – [12], to apply all these knowledge in the field of rehabilitation robotics.

2 The Structure of the Proposed Device

The architecture of the improved integrated environment is depicted in Fig. 1. It includes the necessary blocks to guide (PORTABLE EQUIPMENT) and to supervise (SERVICE CENTER) the movement of the blind person to reach the target.

There are at least two reasons to track the subjects as they are moving in the supervised area:

- The first one, to be sure that the movement of all subjects is in progress and they are capable to reach the target,
- The second one, it is important to know in every moment the actual positions of subjects, in order to be able to help them in case of dynamically changing environments or even in case of emergency.

The above mentioned requirements are assured by the first component included in the Integrated Environment, called SERVICE CENTER (SC) (Fig. 1). SC includes a GSM/GPRS module (Global System for Mobile Communications/General Packet Services), connected to the serial port of a personal computer (PC). A similar module equips the PORTABLE EQUIPMENT (PE), placed on the head of each subject which navigates in the supervised area.

From time to time, the computer of the SC interrogates the portable equipment in order to receive the actual position of the subject. The geographical location in the form of Cartesian coordinates X and Y, are provided by a GPS (Global Positioning System) module (included in the same psychical unit with GSM/GPRS module – see Fig. 1). The received coordinates are then placed onto a map of the path that should be followed by the blind person, in order to reach the target.

The desired paths to the different targets are stored in a Spatial Data Base (SDB), resident on the PC. Any significantly deviation from the imposed path is detected and a warning message is sent to the subject, to correct his movement accordingly.

It should be noted here that GSM modules, included in both SC and PE respectively, can be use like a mobile phone, for full-duplex voice communication.

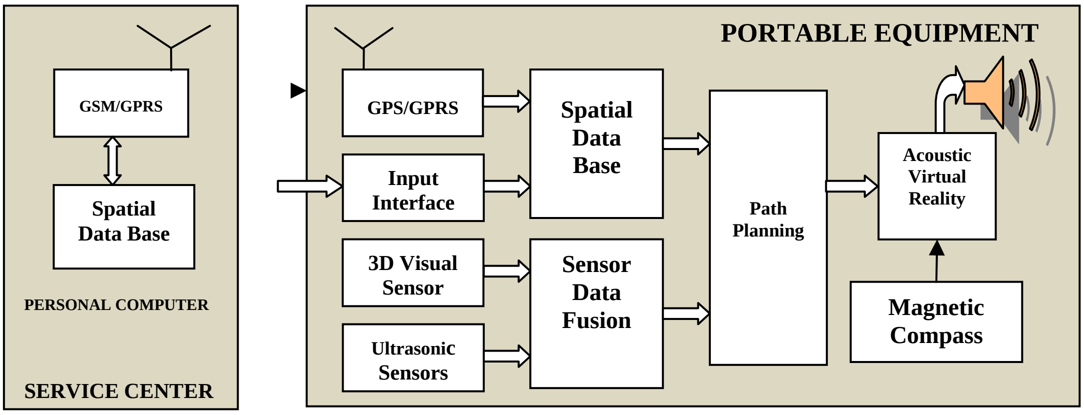

Fig. 1. The block diagram of the integrated environment

In this way, the subject can apply SC at any moment, for additional information, for help, etc.

The portable equipment PE is a quite complex device, that has been developed inspired from the well proved techniques specific to autonomous mobile robots. It is responsible for the following main task:

- To generate the path to the desired target with obstacles avoidance, and
- To provide to the user on the fly all this information, in order to manage his movement.

The trajectory generation is performed by Path Planning block, based upon the following information:

- The path to the desired target, obtained from the Spatial Data Base stored on the portable device (which is the same to the data base resident on the PC); in robotics, that means so called *Global Path Planning*.
- Data obtained from the sensorial system implemented on the portable device; this activity represents the *Local Path Planning.*

The hardware components that implement the above mentioned planning methods are the *Hierarchical Controller* and *Reactive Controller,* respectively. The Hierarchical Controller includes the Spatial Data Base and the Input Interface. The last item can be used by the subject to select, from the SDB, the desired target (SDB contains data of the paths to different and well defined targets).

On the other hand, the Reactive Controller prevents the collision with unexpected obstacles, occurring in a dynamically changing environment. It includes the sensorial system (Ultrasonic Sensors and 3D Visual Sensor) followed by a Sensor Data Fusion block.

Ultrasonic sensors equip constantly mobile robots, while the 3D visual sensors are a valuable alternative solution for the near future [13], [14].

The data fusion is a common used procedure applied to the sensorial data, in order to improve the consistency and the reliability of the acquired information. An appropriate data fusion will cumulate the advantages and eliminate the disadvantages of different type of sensors.

The Path Planning block is implemented according to the following simple rules:

- As long as no obstacles are in front of the subject, the trajectory is generated according to the Global Path Planning, i.e. using data obtained from the SDB;
- Otherwise, the path to the target is generated using the Local Path Planning (based upon the sensorial data).
- As the obstacle has been passed, again the Global Path Planning procedure is taken into account.

The most difficult task in the development of the proposed equipment is the communication between the user (the impaired or blind person) and the portable equipment. We had to take into account not only the technical problems but also some other aspects, specific to this category of people (people with disabilities). Otherwise, a technical good solution can be rejected by the blind people community.

In our proposal, the man-machine interface has been implemented using the principles of the virtual reality. We called this new concept, for the first time introduced in our paper [8], *Acoustic Virtual Reality.*

According to this concept, the position of obstacles and the direction of the trajectory to be followed are suggested to the subject by generating different chimes and sounds. Actually, the visual reality is substituted by an appropriate acoustic virtual reality.

The implementation in the presented solution of the above mentioned concept has been suggested by the high sensitivity and accuracy of the hearing of blind people.

3 Acoustical Virtual Reality Design

The implementation of the new concept of *Acoustical Virtual Reality* (AVR) is a difficult task [15], [16], [17] and is beyond of our purpose to present here this problem in more detail. Moreover, our research activity in this area is in progress, and new results are on the way.

Instead, we will summarize in the following the basic principles we have in mind in order to implement the man- machine interface for the proposed integrated environment, using AVR.

The basic idea is to substitute the visual reality for an acoustical virtual reality, according to the following rules:

- The presence of different obstacles in the surrounding environment will be signalized to the subject by burst of sounds, whose virtual source position will suggest the position of real obstacles.
- Different obstacles will be individualized by different frequencies of the sound generated by the virtual sources that suggest their presence in the supervised area.
- The intensity and the repetition frequency of the burst are depending by the distance between the subject and obstacles: the intensity and the repetition frequency increases when the distance decreases.
- A pilot signal, having a constant amplitude and frequency is generated, to indicate the direction of the movement to the target; the subject should follow step by step the position of this virtual source.
- Since the position of the virtual source that generates the pilot signal depends on the azimuth in horizontal plane of head of the

subject, this parameter have to be measured and included in the data processed for AVR generation. For this purpose, a magnetic compass has been provided in the proposed architecture (Fig. 1).

The implementation of the above rules is in progress. The most difficult task seems to be to find a simple and efficient algorithm for generation of appropriate sounds whose virtual source is perceived by an individual in a certain point of the working place.

The results of our research in this area and other similar experiments already reported in the literature [15], [16], [17], prove the idea that a satisfactory solution will be available soon.

4 Practical Implementation and Experimental Results

The architecture represented in Fig. 1, for both SC and PE devices, has been implemented according to the detailed description presented in the previous sections. Two WISMO Q2501B modules, developed and manufactured by WAVECOM [18], are used for GPRS data exchange. The already mentioned type of module includes in the same unit a GPS system, which is used in the PE to acquire coordinates of the geographical location of subjects.

The experimental set-up of the SC includes a WISMO Quik Q2501 Starter Kit, connected to the serial port of the personal computer. This arrangement gives the flexibility required for software development. The dedicated server for GPRS communication is implemented directly on the WISMO Q2501B module.

The portable unit includes three microcontroller systems.

The first microsystem, build around an ARM based LPC 2104 microcontroller chip [19], manages the activity of the WISMO Q2501B module included in the portable equipment. A second microsystem, containing an ARM based ADuC 7024 microconverter chip [20], controls and process the information related to the ultrasonic sensors.

The third microsystem is totally devoted to the acoustic virtual reality implementation and is build using a small 8052 compatible core ADuC 814 microconvertor chip [20].

All these microcontroller systems are interconnected for information exchange using an on chip SPI (Serial Peripheral Interface) interface.

A general view of the portable unit and a partial view inside the same unit are presented in Fig. 5 and Fig. 6 respectively.

The challenge of the integrated environment seems to be the software development.

In order to minimize the programming effort, two small fotprint, real-time operating system (RTOS) have been developed: the TinyOS-A for 8052 compatibile core and TinyOS-C, for ARM core compatibile. These RTOS allow the integration in a simple manner the application software. The software has been developed using uVision 3 IDE development tools [21].

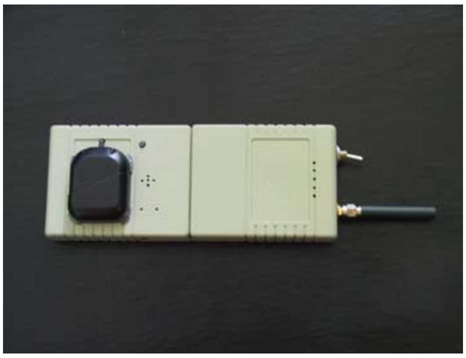

Fig. 5. A general view of the portable equipment.

Fig. 6. A partial view inside the portable equipment.

Up to date, the superviseing system and the software application which processes the data acquired by ultrasonic sensors are already done. The application software that implements the acoustic virtual reality is the most difficult task and needs much more effort in order to be completed.

3 Conclusion

In this paper, an integrated environment that improves the mobility of visually impaired and blind people, in terms of safety and speed in an unknown or dynamically changing environment is presented. The solution discussed here represents an improvement of an earlier version of similar equipment, developed by the same team, and presented in [8].

The most important idea of the present research is the concept of acoustic virtual reality, implemented for the first time in the proposed device. According to the literature, this new concept is the most complex and complete man-machine interface applied up to date to equipments that aid the movement of impaired or blind people.

Other improvements are related to the sensors used to implement the reactive controller.

Having in mind our experience in mobile robotics, we considered that ultrasonic sensors are the most appropriate in this application, in terms of cost and performance, for data acquisition from the surrounding environment. Recently results on VLSI implementation of the bat echo locator in a neuromorphic chip [22] confirm our idea and open new challenges in this area.

The applications of the 3D visual sensors are in an incipient phase to day [11], [12]. However, we introduced this type of sensor in the proposed architecture taking into account their huge potential for 3D visual data acquisition in the near future.

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