Acoustic Virtual Reality Performing Man-machine Interfacing of the Blind

VIRGIL TIPONUT, ZOLTAN HARASZY, DANIEL IANCHIS, IOAN LIE
Department of Applied Electronics
POLITEHNICA University of Timisoara
Bvd. Vasile Parvan 2, 300223 Timisoara
ROMANIA
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Abstract: - In this paper, a man-machine interface included in an integrated environment that improves the mobility of blind persons into a limited area is presented. The proposed solution relies on the Acoustic Virtual Reality (AVR) concept, which can be considered as a substitute for the lost sight of blind and visually impaired individuals. According to the AVR concept, the presence of obstacles in the surrounding environment and the path to the target will be signalized to the subject by burst of sounds, whose virtual source position suggests the position of the real obstacles and the direction of movement, respectively. After a brief presentation of the AVR concept, the paper is focused on the implementation of the proposed man-machine interface, based on this new concept and the status of the research. Finally, some conclusions and further developments are also presented.

Key-Words: - visually impaired individuals, electronic travel aid, man-machine interface, acoustic virtual reality.

1 Introduction

In the last years, many efforts have been invested in order to develop electronic travel aid (ETA) with new capabilities, used by blind and visually impaired individuals to navigate in real outdoor environments [1]-[7]. These devices, based on sensor technology and signal processing, are capable to improve the mobility of blind users (in terms of safety and speed), in unknown or dynamically changing environment.

In spite of these efforts, the traditional tools (white can and guiding dogs [1]) still remain the most used travel aid by the blind community. The main drawbacks of existing assistive devices are their limited capabilities to detect obstacles in front of the subject and the level of technical expertise required to operate these devices. Both these subjects are under development today [8], [9], [10].

This article presents a man-machine interface capable of, in a friendly way, offering the acquired information extracted from the surroundings and assisting the visually impaired individuals with hands-free navigation in their working and living environment. The man-machine interface, used for information exchange between the users (the blind or visually impaired persons) and the portable equipment that guides their movements has been developed taking into account not only 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.

The proposed solution is based on the new concept of AVR, introduced for the first time in our previous work [6]. 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 of the man-machine interface by means of the AVR has been suggested by the high sensitivity and accuracy of the hearing of blind people.

The rest of the paper is organized as follows. In section 2, the AVR concept is briefly presented. The next two sections are devoted to the implementation of a man-machine interface for blind people by means of the AVR concept and the obtained result, respectively. Some conclusions and suggestions for further research are presented in the final section.

2 Acoustic Virtual Reality Concept

The idea of using different chimes and sounds in order to guide the blind and visual impaired individuals to the desired target, with obstacle avoidance, has been already exploited in other works [1], [2], [4]. The human hearing system has remarkable abilities identifying sound source positions in 3D space [12] and allows directional positioning in space. Often, this process is aided by visual sense, knowledge and other sensory input.

In absence of seeing sense, the human hearing is not enough in guiding because of obstacles which does not generate sounds. The basic idea of the proposed man-machine interface 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.

The practical implementation of the above rules encounters some difficulties.

The most difficult task seems to be the development of 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. Since the positions of these virtual sources depend on the attitude parameters of the subject's head, these parameters have to be measured and included in the data processed for AVR generation. For example, if the subject turns around his head in the horizontal plane, the positions of the virtual sources have to be changed accordingly. A solution to the attitude parameters (heading, pitch and roll) measurement can be finding in [11].

Since the correlation between the attitude parameters of the head of subject and the position of the virtual sources that emulates the presence of obstacles and the direction of movement, the blind person looks around moving his head much similar to that of a person with normal sight that looks to detect obstacles in front of him. This behavior gives to the proposed solution the character of "bioinspired".

The solution to the above mentioned problem is even more complex. When sound waves are propagated from a vibrating source to a listener, the pressure waveform is altered by diffraction caused by the torso, shoulders, head and pinnae. In engineering terms, these propagation effects can be expressed by two transfer functions, one for the left and another for the right ear, that specify the relation between the sound pressure of the source and the sound pressures at the left and right ear drums of the listener [13]. As a result, there is a pair of filters for every position of a sound source in the space [14]. These, so-called Head Related Transfer Functions (HRTFs) are acoustic filters which not only vary both with frequency and with the heading, elevation and range to the source [15], but also vary significantly from person to person [16], [17]. Inter-subject variations may result in significant localization errors (front-back confusions, elevation errors), when one person hears the source through another person's HRTFs [17]. Thus, individualized HRTFs are needed to obtain a faithful perception of spatial location.

If a monaural sound signal representing the source is passed through these filters and heard through headphones, the listener will hear a sound that seems to come from a particular location (direction) in space. Appropriate variation of the filter characteristics will cause the sound to appear to come from any desired spatial location [18], [19].

3 Implementation of an AVR-based Man-machine Interface

In the following it will be presented the implementation of a man-machine interface for blind and visually impaired individual's guidance, base on the AVR concept discussed in the previous section. The hardware architecture of the proposed solution is depicted in Fig. 1.

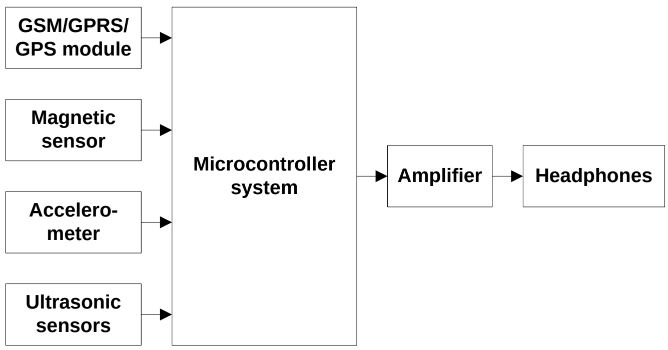

Fig. 1. The hardware architecture of the man-machine interface

The whole system is build around of a microcontroller system. The software application, running on this system, generates the AVR used as a man-machine interface, by processing the information coming from the following sources:

- Ultrasonic transducers; the received information represent the current positions of the obstacles placed in front of the subject. Base upon this information it will be generated the virtual sources of sounds that emulate the presence of these obstacles.
- Accelerometer and magnetic sensor; both these

signals are used in order to determine the attitude parameter (heading, pitch and roll [11]) of subject's head. These parameters are necessary to maintain the correlation between the movement of the head of subject and the position of virtual sources.

- GSM/GPRS/GPS module; the information coming from this module represents the actual position of the subject in his movement to the desired target. Based upon this information, the system is capable to generate the pilot signal, that guides step by step the subject the target, on a path stored in a Spatial Data Base [6], [7].

The signals that emulates the visually reality in front of the subject are then amplified and provided to the ears of the visually impaired person, via headphones (Fig. 1).

The software application, running on the microcontroller system, follows the flowchart presented in Fig.2.

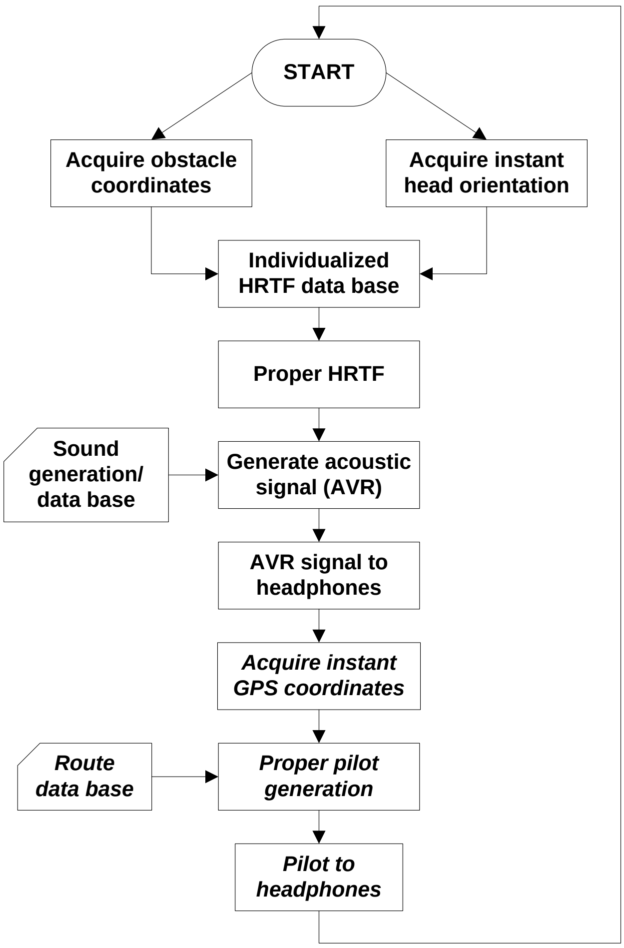

Fig. 2. AVR-based man-machine interface generation algorithm.

It can be seen that the algorithm is periodically repeated itself and includes two parts. The first one is dedicated to the generation of signals that emulates the presence of obstacles in the working space, while within the second part the pilot signal is generated.

In order to generate the signals indicating the presence of obstacles, two operations are to be performed first: the acquisition of the actual obstacles coordinates and the acquisition of the attitude parameters of the subject's head. All these information are obtained by processing in an appropriate way the date provided by the ultrasonic transducers, magnetic sensor and accelerometer, respectively.

The next step is to choose the corresponding HRTF, in accordance with the position of each detected obstacle, from the individualized HRTF data base. As we mentioned earlier, it is highly recommended to use the person's own HRTF data set for optimum results [16]. The signals that emulate the VAR can be then generated, using chimes with different parameters, stored in a Sound data base. The sounds allocated for each obstacle are filtered with the corresponding HRTF, in order to suggest to the listener the position of different obstacles by the position of virtual sources of these sounds. The signals emulating the VAR are provided then to the headphones.

The second part of the algorithm starts with the acquisition of the actual GPS coordinates from the GSM/GPRS/GPS module, which indicate the person's geographical position. Based upon this information and on the coordinates of the desired path way, extracted from the Route data base, the pilot signal can be generating. Finally, this signal is provided to the headphones.

The normal flow of the algorithm already presented can be interrupted by an incoming call. This event stops the AVR signals generation and the phone call is deserved, according to the flowchart presented in Fig. 3 (we suppose that during the phone call the subject stops his movement to the target).

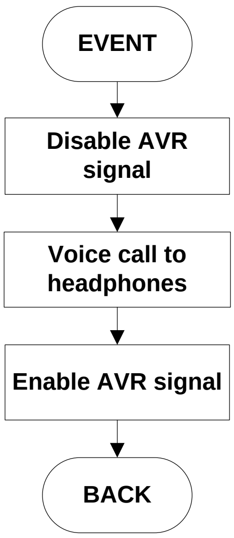

Fig. 3. The subroutine for an incomming call interrupt.

When the phone call is finished, the AVR signals generation continues from the point where it was stopped.

The algorithm for the VAR signal and pilot generation is repeated periodically, to provide a real-time operation of the system.

3 Status of the research and further developments

The man-machine interface presented in the previous section has been developed and the whole system is now in the testing phase.

The microcontroller system has been implemented using an ARM7 core-based development board (Analog Devices), capable to handle all devices included in this system and to run the software application that implements the AVR. The sensorial data, necessary to generate the AVR signals are provided by the ultrasonic system, a 2-Axis accelerometer, a 3-Axis magnetic sensor (all these devices placed on custom made printed circuit boards) and a GSM/GPRS/GPS module (Wavecom). A general view of the hardware of the experimental setup is given in the Fig. 4.

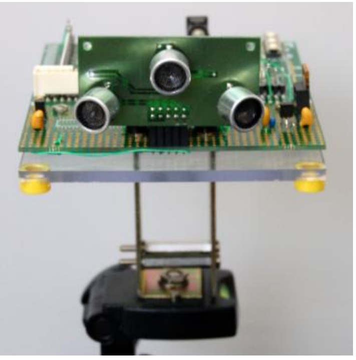

Fig. 4. A general view of the experimental setup (the hardware part).

The software application, running on the microcontroller system, includes the following modules:

- The software module that controls the ultrasonic transmitter and converts in a digital form the received echoes.
- A subroutine that determines the heading of the subject, according to the method presented in [11] (pitch and roll parameters are given directly by the accelerometer).
- The software application that implements the AVR-based man-machine interface (flowcharts presented in Fig. 2 and Fig. 3).

The software module controlling the ultrasonic transducers has been completed and successfully tested. The remaining software applications are in the testing phase and further developments are necessary in order to validate and improve their functionality.

5 Conclusion

In this paper a man-machine interface is presented, that improves the information exchange between the blind individuals and the portable equipment which guides their movement to the target, with obstacles avoidance. The proposed solution is based on the new concept of AVR and presents the following new basic features, compared to the known solution:

- The new developed man-machine interface, implemented in the form of AVR, behaves for the blind and visually impaired individuals like a substitute for their lost visual reality.
- The blind persons look for obstacles by moving their heads much similar to that of a person with normal sight is looking to detect obstacles in front of him.

We hope that this new features of the proposed equipment will speed-up the integration of this category of people with disabilities, in the economic and social life.

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