New Achievements in Assisted Movement of Visually Impaired in Outdoor Environments

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Abstract: - In the last years, the traditional tools used by visually impaired to navigate in real outdoor environments (white cane and guiding dogs) are to be substituted with electronic travel aids (ETA). These devices are capable to improve the mobility of blind users in unknown or dynamically changing environment, but up to date no ETAs have been practically implemented. In this paper, the most important theoretical and practical results obtained in the field of ETAs are presented first. Some original results of the author's team, including new concepts in this field, like integrated environment for assisted movement, acoustical virtual reality (AVR), bioinspired solutions are then discussed in more detail. Conclusions and the further developments in this area are also presented.

Key-Words: - visually impaired individuals, electronic travel aids, integrated environment for assisted movement of visually impaired, acoustical virtual reality.

1 Introduction

There are approximately 45 million blind individuals world-wide according to the World Health Report. Vision loss limits their access to the educational opportunities, social events, public transportation and leads to a higher rate of unemployment. Many efforts have been invested in the last years in order to develop ETA tools with new capabilities, used by blind and visually impaired individuals to navigate in real outdoor environments [1]-[8].

An ETA tool includes the following main components [7]:
- An obstacles detection system,
- A path planning module,
- A man-machine interface and,
- A monitoring system.

The monitoring system is tracking the movement of the blind persons in order to be sure that they are in progress and capable to reach the target. Moreover, it is important to know in every moment the actual position of the subjects, in order to be able to help them in case of dynamic changing environments or more importantly, in case of emergency.

The path-planning module is responsible for the path to the desired target generation, with obstacles avoidance. The position of the obstacles in front of the subject is determined by a 3D obstacles detection system. The last two mentioned components should meet requirements similar to the requirements for the global path planning and obstacles detection in mobile robotics.

The man-machine interface is capable of offering in a friendly way the information extracted from the surroundings and assisting the visually impaired individuals with hands-free navigation in their working and living environment.

It should be mentioned here that the already proposed ETA tools do not include all four components mentioned in the above; each ETA proposal, presented in the literature, is focused mainly on 1-2 components, neglecting the remaining. In [7], [8], for the first time, ETA equipment with a complete four components structure is presented. This solution will briefly discuss in the next section.

2 Integrated Environment for Assisted Movement of Visually Impaired

2.1 The structure of the system

The architecture of the integrated environment is depicted in Fig. 1 [8]. It includes the necessary blocks to guide (PORTABLE EQUIPMENT) and to

supervise (MONITORING CENTER) the movement of the blind person to reach the target.

Monitoring Center (MC) 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.
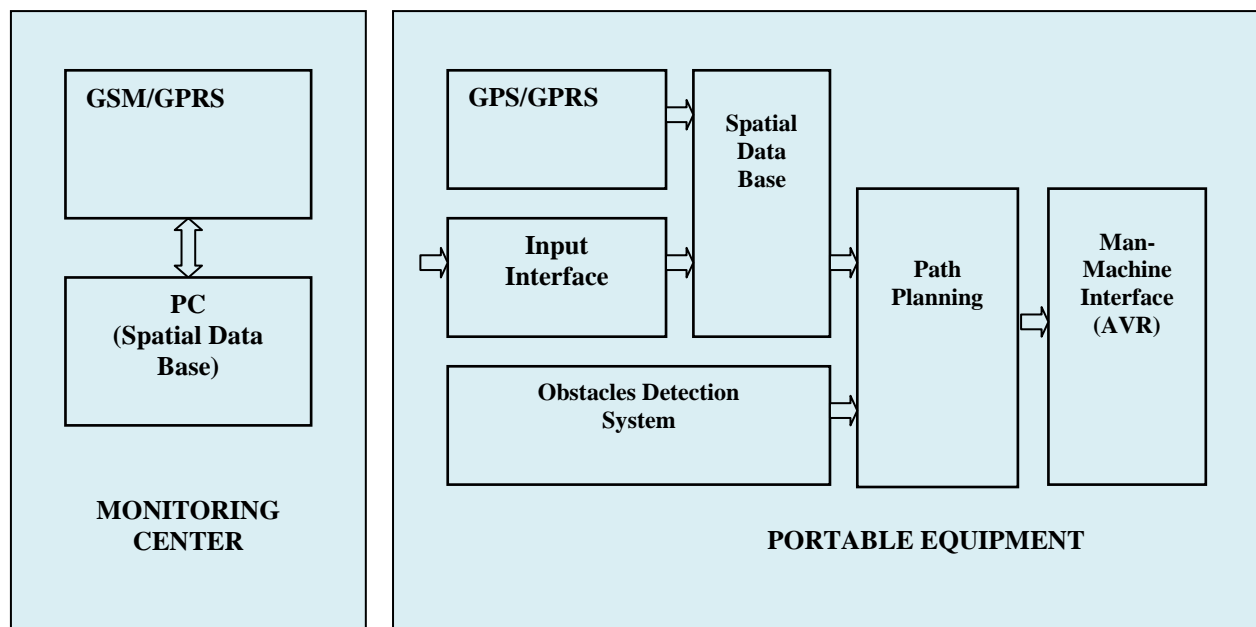
From time to time, the computer of the MC

Fig. 1. The block diagram of the integrated environment.

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. The desired pathway represents a linear piecewise approximation of the way to a specified target. Multiple desired paths for multiple subjects can be handled in the same time (a more detailed disscussion on MC is given in subsection 2.2).

It should be noted here that GSM modules, included in both MC and PE respectively, can be use like a mobile phone, for full-duplex voice communication. In this way, the subject can apply MC 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 the 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*. Actually, the desired target can be selected by the subject using an Input Interface (Fig.1).

- Data obtained from the Obstacles Detection System (ODS), implemented on the portable device; this activity represents the *Local Path Planning* (a more detailed disscussion on ODS is given in subsection 2.3).

The *Local Path Planning* prevents the collision with unexpected obstacles, occurring in a dynamically changing environment.

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 given by the ODS).
- 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 the system depicted in Fig.1, the man-machine interface has been implemented using the principles of the virtual reality. This new concept, called *Acoustic Virtual Reality* (AVR) and introduced for the first time in our paper [7], will be presented in more detail in subsection 2.3.

2.2 The Monitoring Center

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.

Two software applications, implemented on the PC of the MC and in the PE respectively, are used in order to meet the above mentioned requirements.

2.2.1 The software application resident on the PC

The block diagram of the software application running on the PC of the MC is presented in Fig. 2.

It results from Fig. 2, that after some initialization operations, the software application enters an IDLE state and waits for one of the following events to occur:

- A request to execute a voice communication or to transmit/receive a short message (SMS). No restrictions are for the partners involved in these tasks (any phone number - including the phone number of the subjects, and communication network are allowed).
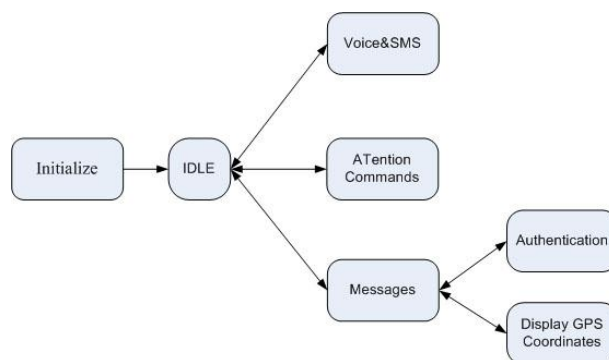

Fig. 2. The flowchart of the software application resident on the PC placed in the MC.

- A request from the operator of the PC to execute AT (ATtention) commands [9]; such commands are used in order to control the functionality of GSM/GPRS module, for debug or upgrade purposes.
- A request for message exchanges. This request may come :
  - From the PE of a visual impaired, in the form of an Authentication Message,
  - From a timer, which periodically initiates the procedure of the acquisition of the coordinates corresponding to the actual position of each subject.

The authentication process takes place in two steps. In the first step, an Authentication Message of the form: *$AUTH*, from the PE of the visual impaired will be received. As a result, it will be initiated a procedure of searching the phone number of the sender in a data base with access rights. If the sender has been included in this data base, then an acknowledge message: *$OK AUTH* will be sent to the PE. Otherwise, the message will be ignored.

In the second step, the MC is informed on the desired pathway to the target. For this purpose, a message having the form: *$PATH=XXX* is sent from PE of the visual impaired who requests services to the MC; *XXX* represents here the code associated to the desired pathway. If the map of this pathway can be find in the Spatial Data Base stored on the PC, an acknowledge message: *$OK PATH* is sent to the PE of the subject and since that time his movement to the target will be supervised.

The most frequently event that occurs is, perhaps, the acquisition process of the coordinates of each subject moving in the supervised area. Periodically, a message of the form: *$GPS REQ* is sent to the each subject and as a result, the corresponding PU responds with the message: *$RET <UTC> <Data> <Lat> <Long>*; here, the parameters *UTC, Data,*

Lat and *Long* represents time (in UTC format), date, latitude and longitude respectively. These data are used then to represent on a map the trajectory of subjects in their movement to the target and to take the necessary decision if some deviations from the imposed pathway occur.

2.2.2 The software application running on the PU
The general structure of the software application running on the PU is presented in Fig. 3.This application includes a number of software modules, each of them responsible for a well defined function:

- SMS Module, responsible for SMS messages exchanged with the MC;
- VOICE Module, capable to handle the bidirectional voice communication between the PU and the MC;
- GPS Module; this application is responsible for extracting the useful information from the data string delivered by GPS system.

It should be observed that all these software modules are implemented on the microcontroller system that controls the functionality of the GSM/GPRS and GPS systems in the PU.
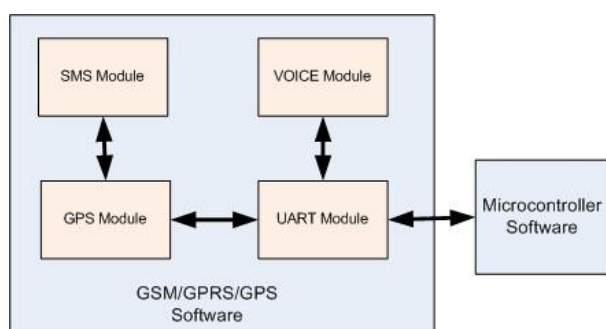

Fig. 3. The software application included in the PU.

PU includes, also, a second microcontroller system, which is responsible for other tasks (sensor system management, path planning, man-machine interface, etc.). The information exchange between these microcontroller systems is assured by the UART Module (Fig. 3).

2.2.3   Some experimental results
The software applications residing on both PU and PC of the MC have been tested and successfully implemented. The software loaded on the PC have been developed using the well known graphical programming language LabView. In Fig. 4, it can be

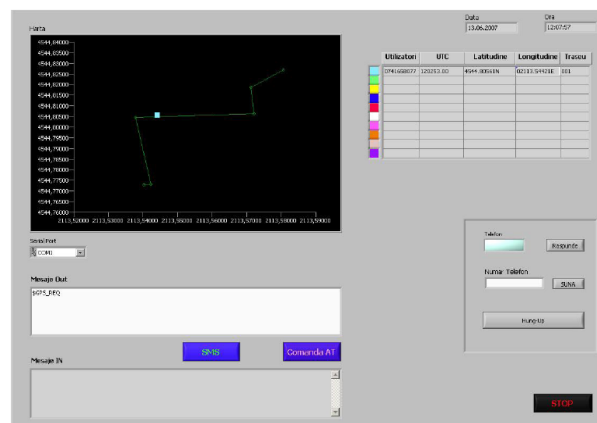seen the corresponding graphical user interface (GUI).

Fig. 4. The GUI of the software residing on the PC.

The software application meets all the requirements specified at 2.1.1. The application is capable to supervise in parallel the movement of up to ten subjects. The data received at a given moment from the PU of each subject (time, date, latitude and longitude) are visualized in a table (right-up corner); in the same time, the corresponding trajectories are marked by points of different colors on a map, along the desired pathway to the target (left-up corner).

The remaining elements are to be used for voice/SMS communication. No restrictions are regarding the partners involved in these tasks (any phone number and communication network are allowed). The cluster of controls placed in the right-down corner of the GUI are devoted to dial-up the phone number, answer to a incoming call, hang-up, etc.. Two windows (left-down corner) allow sending and receiving messages.

As we have already mentioned, the software application resident on the PU is loaded in the same microcontroller system that manages the GSM/GPRS and GPS systems (these systems are included in a single WISMO Quik Q2501 module, manufactured by Wavecom [10]). A special IDE - Integrated Development Environment, OPEN AT® [10], [11], [12], delivered by the same manufacturer, can be used for development, debugging and loading the software application without affecting the original firmware.

2.3   The obstacles detection system
2.3.1   The structure of the system
The most innovative idea in the development of the obstacles detection system is the correlation between the attitude parameters of the senzorial system (actually the orientation in horizontal and

vertical planes of the head of subject) and the position of detected obstacles in front of the subject. These parameters are known as heading, pitch and roll respectively [13]. In this way, the blind person looks for obstacles 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".

Taking into account all the above-mentioned considerations and assuming a sensorial system equiped with ultrasonic transducers, the general structure of the obstacle detection system looks like in Fig. 5.
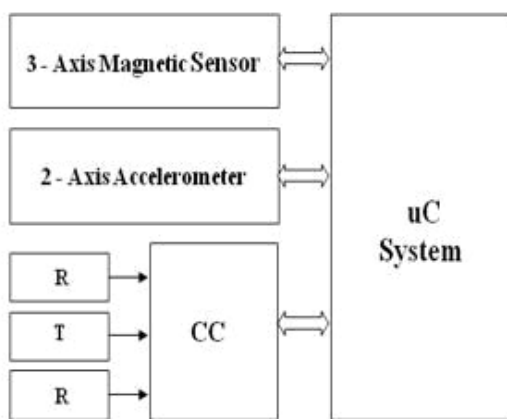

Fig. 5. The general structure of the proposed ultrasonic obstacle detection system.

The system includes three ultrasonic transducers denoted here by T and R (one transmitter T and two receivers R) controlled by a microcontroller system, through the conditioning circuits CC. These elements are responsible for obstacle detection. In the same system are included a 3 - Axis magnetic sensor and a 2 - Axis accelerometer, in order to determine the attitude parameters of the head of the subject: heading, pitch and roll. These angles are referenced to the local horizontal plane, i.e. the plane perpendicular to the earth's gravitational vector.

Heading is defined as the angle in the local horizontal local plane measured clockwise from a true North direction (earth's polar axis). Pitch and roll parameters are defined according to the Fig. 6 [13].

Pitch represents the angle between the aircraft's longitudinal axis and the local horizontal plane (positive for nose up). Roll is defined as the angle about the longitudinal axis between the local
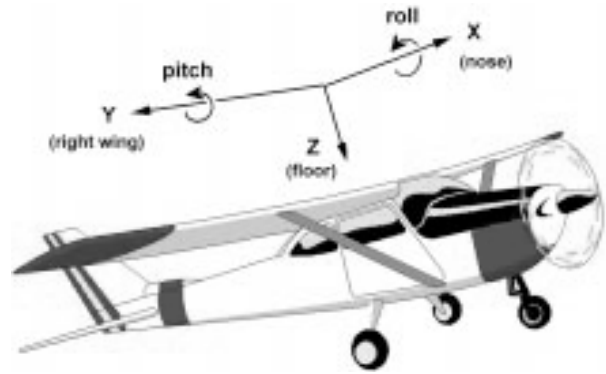

Fig. 6. Definitions for attitude orientation parameters (pitch and roll).

horizontal plane and the actual flight orientation (positive for right wing down).

22.3.2 The attitude parameters determination

There are many methods to determine the pitch and roll angles [13]. In the present research, a tilt sensor that includes a dual axis accelerometer is used. Actually, a dual axis accelerometer consists of two single axis accelerometers placed on perpendicular directions, which measure the earth's gravitational field. Based upon the results of these measurements, tilt sensor outputs directly the angle deviations from the local horizontal plane (pitch and roll angles).

The method to determine the heading parameter of the subject's head relies on all three components of the earth's magnetic field and follows a well-known procedure [13].

Let's suppose that X, Y and Z are the magnetic readings at the outputs of the 3 - axis magnetic sensor. By applying the rotation equation, shown in relations (1) and (2):

$$X_h = X\cos(\varphi) + Y\sin(\theta) - Z\cos(\theta)\sin(\varphi) \quad (1)$$

$$Y_h = Y\cos(\theta) + Z\sin(\theta) \quad\quad\quad (2)$$

the X_h and Y_h components in horizontal plane of the magnetic field can be obtained. In relations (1) and (2), φ and θ denote pitch and roll angles respectively (see Fig. 7).

Once the magnetic components X_h and Y_h are found in the horizontal plane, the heading H can be
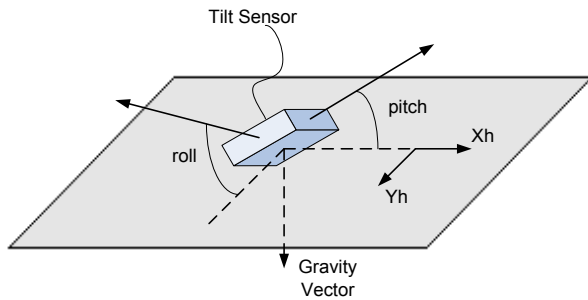
Fig.7. Pitch, roll and X_h and Y_h components referenced to the right and forward level directions

determined according to the relation (3) [11]:

$$H = arcTan \frac{Y_h}{X_h}. \qquad (3)$$

If the ultrasonic system was sitting in the local horizontal place, then the pitch and roll angles would be zero and according to the relation (1) and (2) results:

$$X_h = X \qquad (4)$$
$$Y_h = Y. \qquad (5)$$

That is, the heading can be calculated directly based only upon the readings X and Y of the magnetic sensor.

All the above calculations are software implemented on the microcontroller system. The same device is performing all the operations necessary to control the functionality of the ultrasonic transducers, magnetic sensors and accelerometer. It is important to notice that the information provided by the 2 – Axis accelerometer, i.e. pitch and roll attitude parameters, is used both for AVR generation [6], [7] and to compensate the readings of magnetic sensors (rel. (1), (2)).

2.3.3 The ultrasonic obstacles detection system

The obstacles detection system using ultrasonic transducers still represents a problem under development.

The commonly used in robotics ultrasonic systems, which are based on pulse-echo method for obstacles detection and that can include up to 32 sensors placed around the robot, are to be replaced now by biomimetic systems [14], [15]. In the present research, the proposed ultrasonic system is bioinspired from the echo locator of the bats and includes three transducers, disposed as is shown in Fig. 8 (imitating the mouth (transducer placed in the middle position) and the ears of a bat (the two
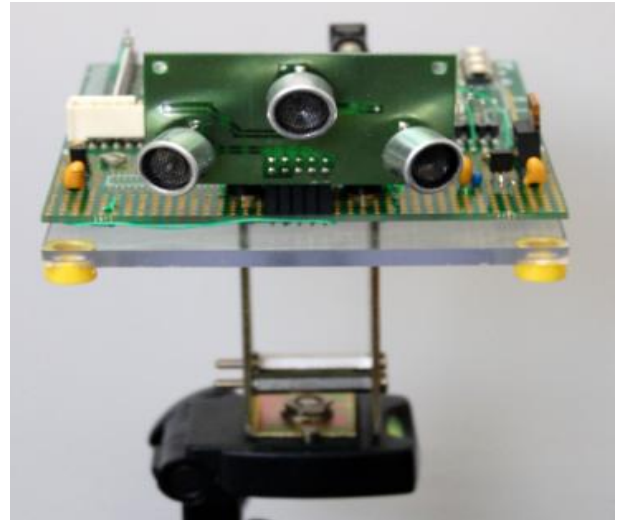

Fig.8. The placement of the transducers in the bioinspired ultrasonic system.

lower transducers). Other arrangements are also possible [14], [15], depending of the proposed method used for obstacles detection.

A single transmitted pulse and the resulting echoes are needed in order to locate all the obstacles in front of the subject. In this way, the presented method for obstacles detection is in the same time simple (only three transducers are necessary for implementation) and fast.

The investigated field in front of the subject, corresponding to this arrangement, is depicted in Fig. 9.
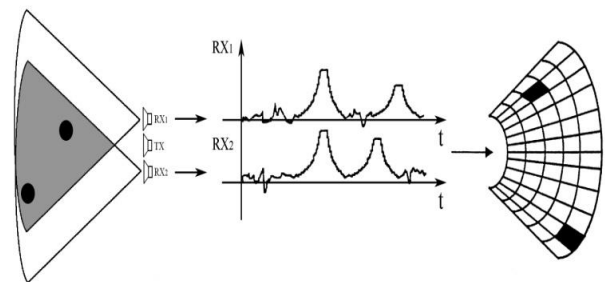

Fig. 9. The principle of obstacles detection using bioinspired ultrasonic system.

The presence of an obstacle can be detected in the area represented in grey, which is the common place of the individual fields investigated by each reception sensor. In Fig. 9, the echoes corresponding to the presence of two obstacles in the supervised area are represented. The amplitude of these pulses is a measure of the distance from the subject to the obstacles, while the time corresponding to the moment of occurrences of these pulses give the

azimuth of obstacles relative to the median axis of the sensorial system.

It should be mentioned a distinctive feature of the system presented here: the whole information, from data acquisition up to generation of the position of the detected obstacles is processed by an artificial neural network (ANN), according to the methods presented in [16] [17].

Please note that the ANN has a limited resolution, i.e. is capable to indicate the presence or absence of obstacles in a limited number of small discrete areas in front of the ultrasonic system. Actually, each output of the ANN is responsable to indicate the presence or absence of obstacles in a small discrete area. These discrete areas result by dividing the supervised area using an appropriate grid, as is illustrated in Fig. 9.

In Fig. 10, the answer of the ANN for two obstacles placed in front of the ultrasonic system is presented. It can be seen that the proposed systems is capable to detect very clearly the presence of obstacles in front of it.
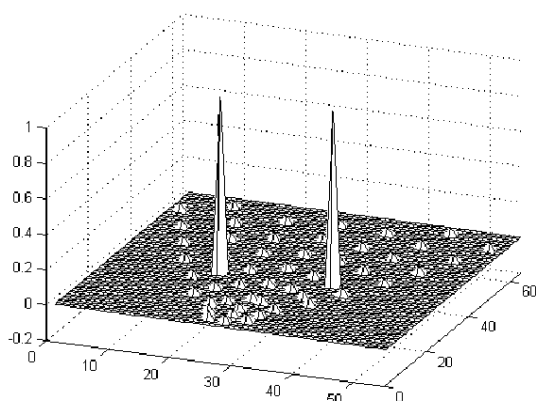

Fig. 10. The answer of the ANN for two obstacles places in front of the ultrasonic system.

2.4 The Man-machine interface
2.4.1 General presentation

The man-machine interface included in the system depicted in the Fig. 1 si based on the new concept of Acoustic Virtual Reality (AVR) [7]. According to this principle, 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 in his movement to the target.

Generation of sounds that suggest virtual sources whose positions can be placed in any point within 3D space it is not a simple task. 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 [18]. As a result, there is a pair of filters for every position of a sound source in the 3D space [19]. 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 [20], but also vary significantly from person to person [21], [22]. 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 [22]. 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 [19], [20].

The AVR concept can be software implemented in a microcontroller system, 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) 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 that emulate the obstacoles and generate the pilot signal, respectively.

 The signal comming from the Path Planning module; based upon this information, the system is capable to generate the pilot signal, that guides step by step the subject to the desired target.

The information that emulates the visually reality in front of the subject are then converted in analog form, 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. 11.
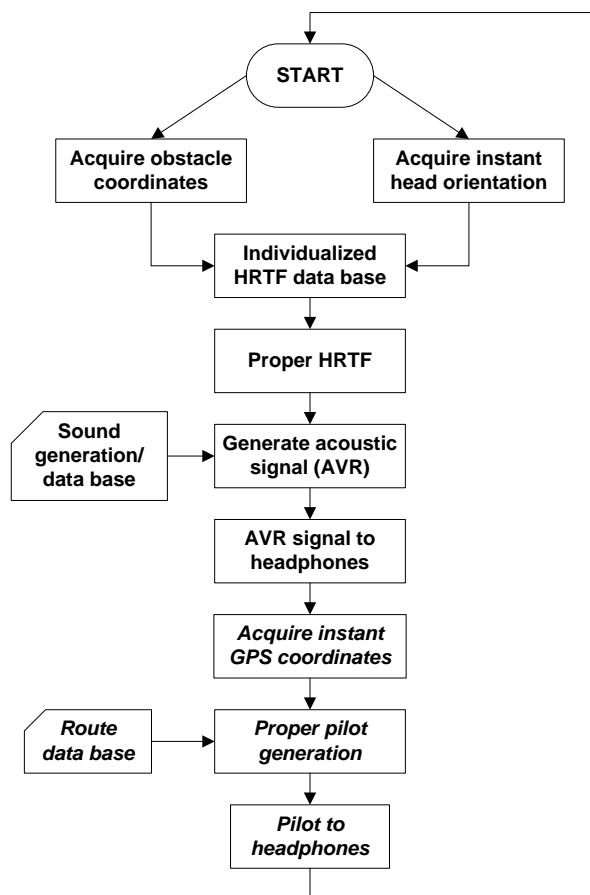

Fig.11. AVR-based man-machine interface generation algorithm

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.

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

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. 12. When the phone call is finished, the AVR signals generation continues from the point where it was stopped (it is supposed that during the phone call the subject stops his movement to the target).

2.4.2 Generation of the HRTF

The HRTF corresponding to each point in 3D space can be determined by using a quite complex procedure, which requires many measurements. Moreover, this procedure has to be repeated for each individual.

In the present paper, an Artificial Neural Network (ANN) based method is proposed in order to

determine the HRTFs for points in the 3D space [23]. Two ANNs are necessary in order to generate the HRTFs corresponding to each ear. The azimuth and elevation that define the position of a certain point in the 3D space are applied to the inputs of the ANN, while the coefficients that define the HRTF are obtained at the outputs.
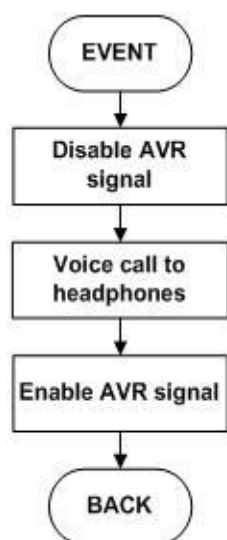

Fig.12. The subroutine for an incoming call interrupt.

The implementation of an ANN includes the structure development and the training phase. In order to train the network, there are necessary known pairs of point's coordinates (azimuth, elevation) and the corresponding values of the HRTF's coefficients, for a limited number of points in the 3D space. Such a database can be obtained only as a result of experimental measurements, but there are a few databases available for the whole scientific community.

The proposed ANN is is a multilayer perceptron (feed-forward backpropagation network) having the structure presented in Fig. 13. This type of network was selected for its simplicity and also it is considered well suited to start our experiments. In our future work, we will take into consideration other networks as well.

The network consists of three parts: an input layer of source nodes (2 inputs), a hidden layer (n neurons) and an output layer (512 neurons). Considering the fact that a pair of such ANNs are required for a single test subject, there are two inputs necessary, which will be the azimuth and the elevation of the desired virtual sound source (network inputs). Each of the two ANNs gives us a
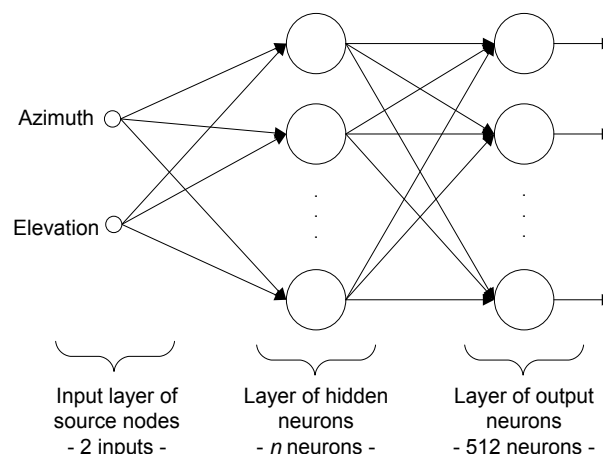

Fig. 13. The architecture of the proposed ANN.

set of 512 coefficients, which are the Head Related Impulse Responses (HRIRs) for the desired virtual sound source (network targets). These HRIRs are Fourier pairs of the above mentioned HRTFs.

The optimal number of neurons for the hidden layer is difficult to be determined. It affects the performances of the ANN and can be established by evaluating the behiavour of the networks. In this phase, we used a number of n neurons for the hidden layer, which will be chosen after careful experimentation. The obtained results suggests that n should be somewhere between 40 and 60.

In order to complete the training and testing phase of the ANNs, the Listen HRTF Database, which is a public HRIR database, has been used. The measurement process took place in the frame of the Listen project. AKG and Ircam, the two partners of the project, have both performed the HRIR/HRTF and morphological measurement sessions. The database includes measurement data of 49 test subjects. For each subject there are 187 pairs of HRIRs, each of these HRIRs corresponding to a particular point (particular azimuth-elevation pair) in the 3D space.

After careful consideration, the existing data set for a single test subject was divided in two smaller sets, as follows. Each fourth pair of HRIRs was selected and the obtained data set was used as test data for the ANNs. The remaining set of HRIRs was used as training data for the ANNs. Pre-processing of the input data or post-processing of the output data was not used. The necessity of network input and/or output data processing remains a question of future developments.

The selected transfer functions in our experiments are: the hyperbolic tangent sigmoid transfer function

for the hidden layer and the linear transfer function for the output layer.

The whole network has been trained using the *traingdx* network training function. This function updates weight and bias values according to gradient descent momentum and an adaptive learning rate. The *traingdx* function was selected due to its higher performances compared to other network training available functions.

We conducted our experiments in Neural Network Toolbox, included in MATLAB environment.

As we mentioned earlier, the existing data set was divided into training data and test data. By using this approach, we were able to evaluate the performances of the proposed ANNs. An example of the obtained training error is presented in Fig. 14. One can see that the error decreases with the increase of the number of epochs.
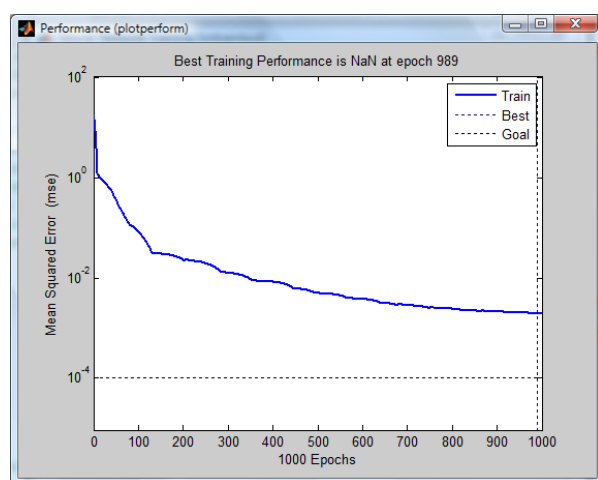

Fig. 14. An example of the obtained training error.

The experiments were conducted for a number of 56 neurons in the hidden layer. After the training phase, the next goal was to evaluate the performances of the two networks. As a performance criterion, we have chosen the mean squared error (MSE). The MSE was calculated between the resulted values on each network output and the corresponding test data values. To give a measure to the extent of this error, we compared the resulting MSE to the absolute maximum value of the network outputs. Our conclusion is that this error is commonly very small, somewhere around a 1-2%.

The error values are changing depending on the initial bias and weight values. Also, depending on the initial values there are more or less training epochs necessary to obtain the same small values of

error. The maximum number of epochs used for training was 1000, but usually a number of 500 epochs are more than sufficient. We would like to underline the powerful dependence of the error upon the initial bias and weight values after the creation of each neural network.

We would like to present shortly some results acquired for 10 neural networks, which all have the same, proposed structure. The only differences are the initial weight and bias values before the training of these neural networks. The obtained values confirm our previous statement that a number of 500 epochs are sufficient for the training of the ANNs.

Fig. 15 present the resulting MSE for 10 ANNs corresponding to the left ear of one particular subject. The training for each of these was stopped after 100, 200, 300, 500 and 1000 epochs and the MSE was calculated using the test data set. One can observe that the MSE decreases as the number of training epochs increases.
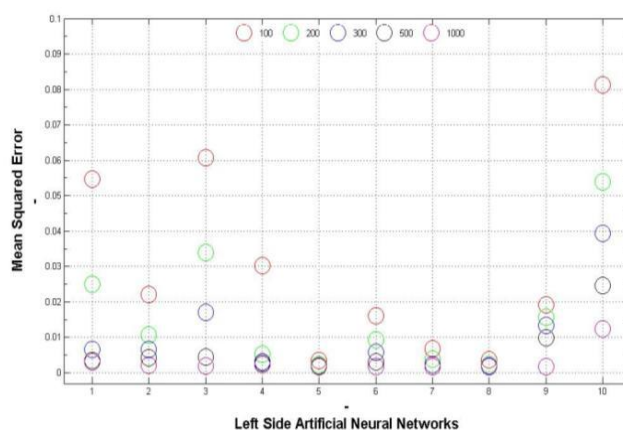

Fig. 15 – Obtained performances after the testing phase of 10 ANNs with the proposed structure. The differences appear due to the initialization of the weight and bias values after network creation.

3. Conclusion

Many efforts have been invested in the last years, based on ingenious devices and information technology, in order to develop ETA equipments as a substitute for the lost sight of blind and visually impaired individuals. As a result, there are appropriate solutions for some of the problems in this area. In our opinion, the integrated environment having the structure presented in Fig. 1 meets the most important requirements of the blind community:

- The subjects are guided step by step to the

desired target, with obstacles avoidance; in this way, they are capable of hands-free navigation in their working and living environment.

- A friendly man-machine interface, based on AVR concept is used, which exploits the high sensitivity and accuracy of the hearing of blind people.

- The integrated environment is capable to track the movement of the blind persons in order to be sure that they are in progress and capable to reach the target or to help them in case of emergency.

In spite of these results, there are still some open questions which have to be investigated in order to find appropriate solutions for them.

The obstacles detectors are usually equipped with ultrasonic transducers; this solution has the advantage of simplicity and low cost, but in the same time these types of detectors have a limited resolution and, in certain situations, encounters errors do to reflections. Much more effort should be invested in this area, in order to improve the performances. The laser-based 3D sensors are a valuable alternative solution, but they are still in the development stage [24], [25].

More promising seems to be the bio-inspired solutions. Systems imitating the characteristics of the biological neural systems had been created, making evident the advantages of these systems. From the elementary motion detector inspired from the flies, to more complex systems that imitate the human eyes, the research in the field of bio-inspired artificial vision are in continuous development. Inspired from the model of the Lobula Giant Motion Detector (LGMD) found in locusts, our research team is developing, with good results, a collision detection sensor with applicability in the field of ETA systems [26].

Research effort should be, also, invested for practical implementation of AVR concept. The HRTFs needed for this purpose, require many measurements for each individual. In a recent research, our team developed an artificial neural network (ANN) capable to generate the values of the HRTFs [23]. The proposed method, valid for only on subject, speeds up the implementation of the AVR concept after the ANN training has been completed. Now, we extend the research activity, by developing a more complex ANN in order to generate the values of ANNFs for more than one subject.

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