A wearable multipoint ultrasonic travel aids for visually impaired

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Abstract. In 2010, the World Health Organization estimates that there were about 285 million people in the world with disabling eyesight loss (246 millions are visually impaired (VI) and 39 millions are totally blind). For such users, hits during mobility tasks are the reason of major concerns and can reduce the quality of their life. The white cane is the primary device used by the majority of blind or VI users to explore and possibly avoid obstacles; it can monitor only the ground (< 1m) and it does not provide protection for the legs, the trunk and the head. In this paper, authors propose a novel stand-alone Electronic Travel Aid (ETA) device for obstacle detection based on multi- sensing (by 4 ultrasonic transducers) and a microcontroller. Portability, simplicity, reduced dimensions and cost are among the major pros of the reported system, which can detect and localize (angular position and distance from the user) obstacles eventually present in the volume in front of him and on the ground in front of him.

1. Introduction.

In 2010, the World Health Organization estimates that there were about 285 million people in the world with disabling eyesight loss (246 millions are visually impaired (VI) and 39 millions are totally blind). In Italy, the number of VI subjects is estimated in 530.000 and about 50.000 of them are blind. During the last 30 years, with the progress of technology, there has been a growth on the research focusing on novel devices designed for the assistance of visually impaired (VI) people and blind. The first and older device used by VI subjects is a very well known (passive) device: the cane (commonly known as the white cane). The cane is light, portable and cheap and these characteristics certainly have contributed to its success and its dissemination. The most relevant drawback of this device is definitely the inspection range which is limited to a restricted part of the ground (< 1 m) in front of the user's feet; the cane cannot provide information regarding obstacles which are not located on the ground and in the area explored by the cane tip. There are a lot of obstacles located at the trunk and head level which are consequently not individuated and potentially dangerous, such as tree branches, exposed shelves or a propped-open window. Obstacle hits or even just the fear of it can consequently seriously limit blind and VI users quality of life [1-3].

Since early eighties, active devices for obstacle detection have been proposed. Such system are commonly known as Electronic Travel Aids (ETAs) and have been mainly based on use of laser and ultrasonic (US) transducers. Few of them can also be found on the market [2-4]; in the majority of the cases they detect the presence of an obstacle, but they need to be driven by the user and cannot localise the position of the obstacle.

The aim of this paper is to present a multi-sensing, obstacle detection system composed by four ultrasonic sensors; it presents the characteristics to be: portable, standalone, multi-sensing sensors. the proposed system can continuously explore the volume in front of the VI user and provide an aural feedback if one or more obstacles are found; this feature allows the VI subject to anticipate the presence of the obstacles in the explored volume.

Special attention has been dedicated to portability, use of commercially available components and costs (< 250€).

2. Materials and methods

The control of the device is based on the use of a microcontroller (PIC 18F877A) which is used to process input signals from the sensors, to control the temperature an relative humidity conditions and to provide the output information to the user by visual and audio feedbacks (fig.1). Four ultrasonic sensors realize the volume scanning and, eventually, detect the presence of a possible obstacle; their output signals are used by the microcontroller as inputs. The four ultrasonic sensors used are based on a single piezo crystal (XL-MaxSonar-EZ MB 1320) working at 42 kHz; the crystal is firstly excited in order to emit a short wave pack and then it is used as a receiver to collect eventual echoes caused by reflections from objects eventually present in the explored cone (field of measurement: 3 cm to 3 m). Two sensor are used to explore the left and right area (sensor A and B in fig. 1), while one sensor is used to explore the central area (sensor B) and one sensor is used to explore the ground in front of the subject (sensor F). The block diagram of the proposed system is shown in fig.1.

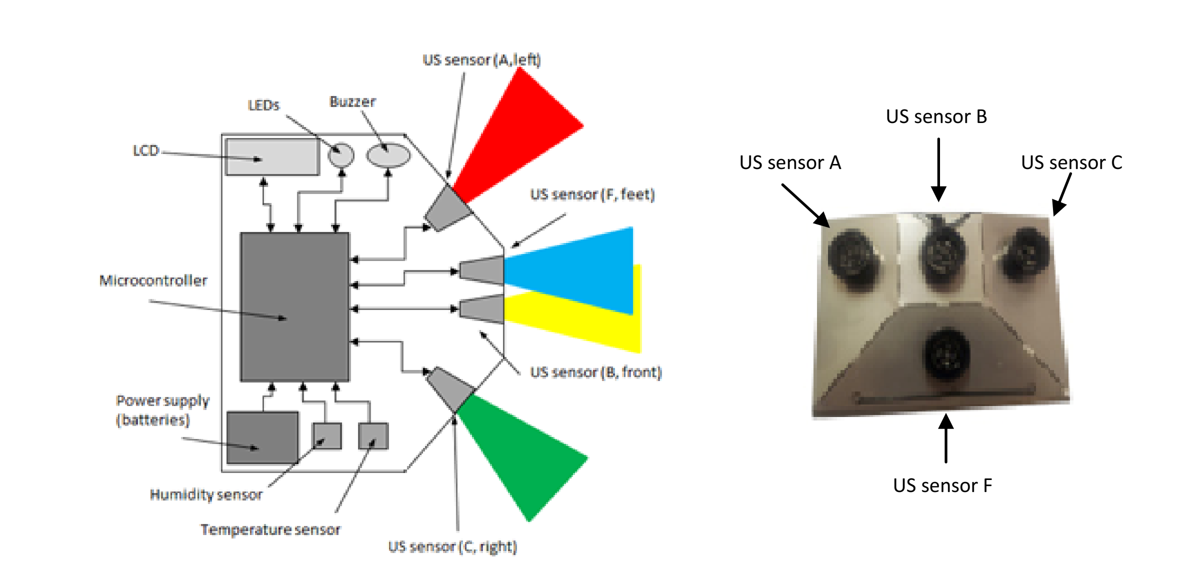

Figure 1. Block diagram of the proposed system (left); frontal view of the system with the four sensor reported (right).

The measurement of the distance between the system and the obstacle is operated by the measurement of the time interval ΔT between the launch of the wave pack and the detection of the obstacle-reflected eco (fig.2). The distance D between the obstacle and the sensor is calculated as:

$$D = \frac{\Delta T v_{air}}{2} \text{ (eq.1)}$$

where v_{air} is the velocity of sound in air.
The velocity of sound in air (v_{air}) is influenced by temperature (T) and the relative humidity (RH) of the air and these quantities can cause uncertainty on the determination of the real sensor to obstacle distance. For this reason a thermo-hygrometer sensor (1 sample/min) has been included in the proposed system in order to reduce uncertainty in the determination of the sound velocity (v_s). T and RH measured values are used to refer to tabled values of the v_{air}.

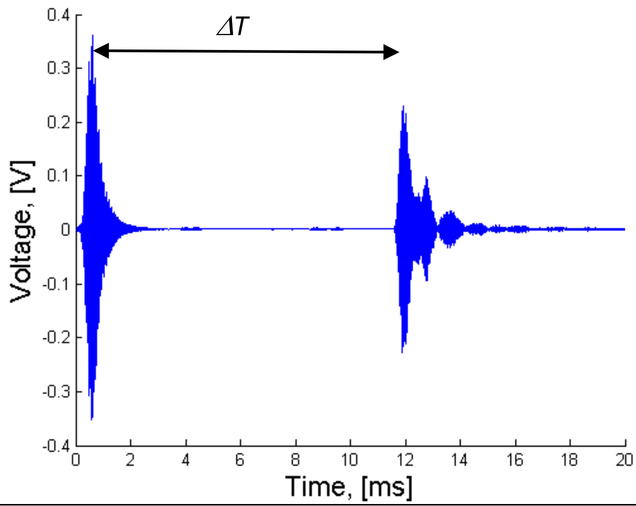

Figure 2. Example of a the signal generated by the ultrasonic sensor (in the case of an obstacle echo).

The presence of an obstacle is communicated to the user by the use of a buzzer; its intensity and frequency is related to the distance and location of the obstacle. The system is worn at the belt buckle (fig. 3) and explores 4 sectors of conical shape (A,B,C and F). Cones A and B are left and right (respect to trunk front direction), oriented respectively at -30° and +30° while cone F is inclined of 25°, toward the terrain. Each cone has an aperture of about 60°. Obstacles eventually present in region A, B or C are signaled as well as obstacles sensed by two sensors (A-B or B-C). Sensor F detects the presence of obstacles on the walking path in the range 1.75 - 2.15 m. Round Robin scheduling algorithm was chosen to extract information by the ultrasonic sensors; time slots of 300 ms are used in order to have a good data refresh. The power supply is provided by a battery (9V) which provide 5V stabilized voltage to the electronics.

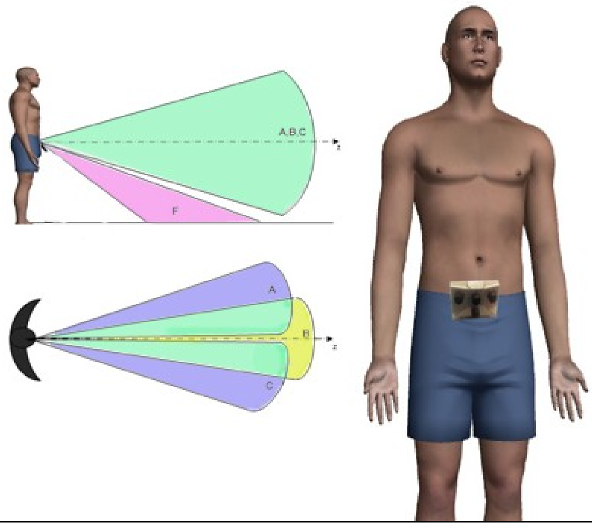

Figure 3. The four conical sectors explored by the US system.

3. Results

The four sensors were firstly calibrated using a scale as reference (resolution 1 mm). The calibration test was carried out on a object of 6X6 cm of area and on the range: 10 – 300 cm. The four sensors have similar behavior and one calibration line is reported in fig. 4 (slope: 1,004 and offset of -0.028 m). The estimated uncertainty, according GUM [5], is ± 0,004 m (k=1).

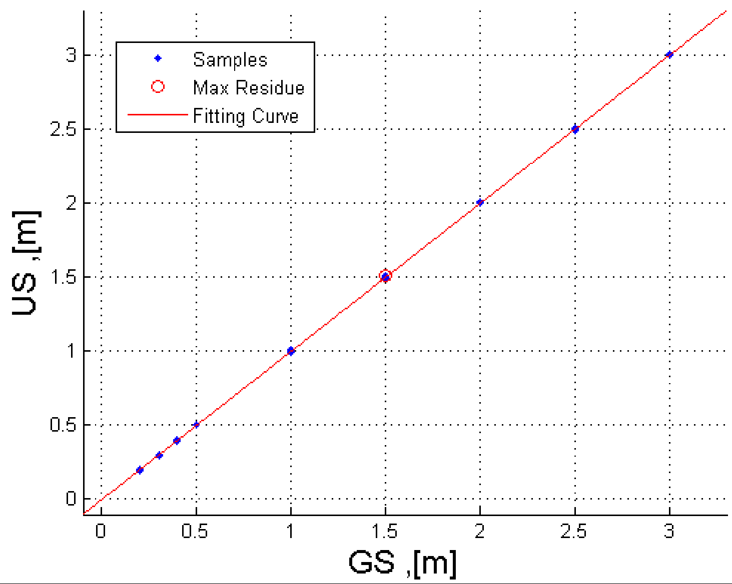

Figure 4. Calibration line for one of the US sensors.

The capability of the sensor in detecting the presence of object of different dimensions, placed at different distances, has been evaluated trough a sensitivity test. Results are reported in fig. 5, where it is possible to observe how the SNR - ratio between the amplitude of the reflected signal (mean of the 4 sensors) and the noise level measured without the obstacle - decreases with distance and with the obstacle area. In particular, it is possible to observe that the smaller obstacle tested (6X6cm) is still detected at the distance of 3m.

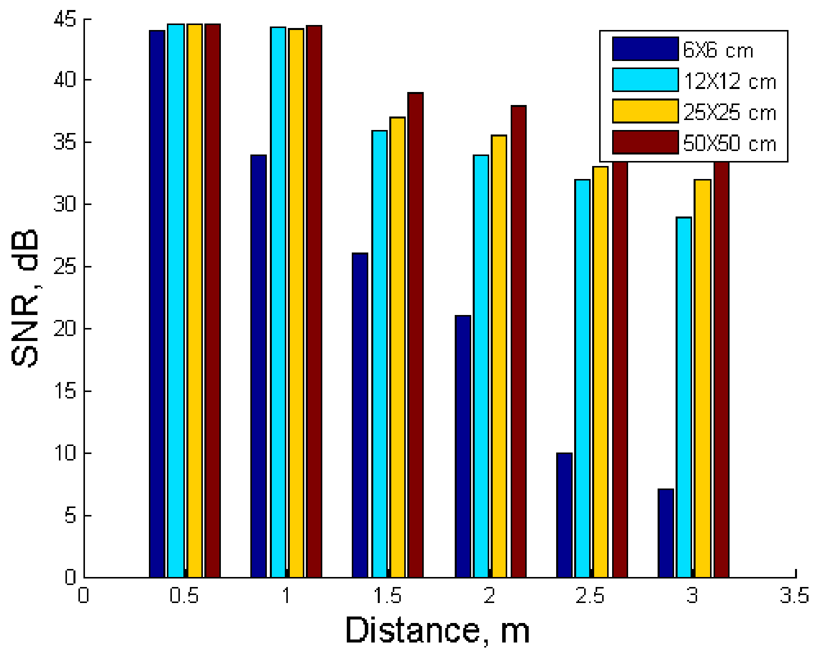

Figure 5. SNR measured for 4 objects of different dimensions.

A Bland-Altman [6] test is operated in order to operate a comparison between the proposed method and the reference. Fig. 7 shows the results of the Bland Altman test and it is possible see that there is not a dependence of the deviation between the two systems by the distance.

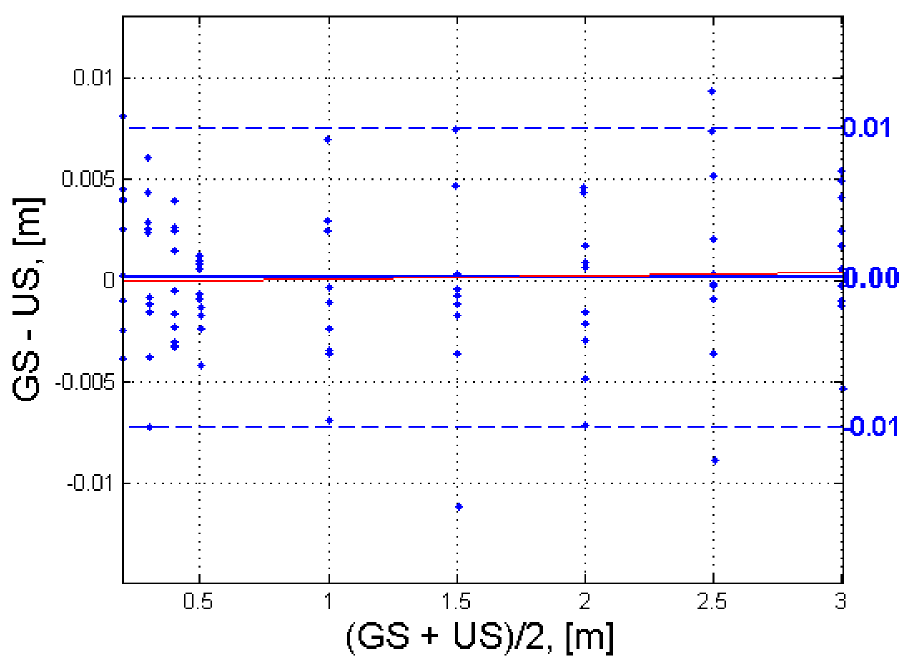

Figure 7. Bland Altman test on the proposed system.

4. Discussion

In this work a novel obstacle detection system, specially devised for blind or visually impaired, is presented. The system is aimed to explore the volume in front of the user. The main advantage respect to the state of the art for ultrasonic system for obstacle detection is the possibility to not only measure the distance from the obstacle, but to be also able to localize the position of the obstacle (left, center up, center down, right). A specific functionality has also been implemented for the exploration of the obstacle at the ground level: the sensor is able to explore the ground surface at about 2 m sending an alert signal to the subject if a ground obstacle (such as a step or a hole) is detected in the area in front of the user feet.

Specific attention has also been put on the portability of the device and on the eventual stigma effect on the VI user. For this reason, the system has been designed in order to be light and easily placed on the belt buckle, living the subjects hands free. Portability is also ensured by the reduced dimensions and the battery supply; while basic system-to-user communication protocol reduce to the minimum the training time.

Finally the use of commercially available components has allowed to reduce the costs needed for the realization of the prototype to < 250 €.

Next steps of the research will aim to:

- improve the transmission of the information to the VI user by vibro-tactile interfaces;
- carry out tests with VI users in order to collecting feedbacks for optimization of the system;
- allow the use of the proposed system in conjunction with the white can (avoiding the interference).

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