A CONTACTLESS HAPTIC CANE FOR BLIND PEOPLE

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Abstract: Mobility is a big deal for visually impaired people and many of the devices already available on the market suffer for poor degree and form of the information provided to the user. In this paper a new way of codifying the information to the blind end user is suggested.The proposed strategy is aimed to move the focus of the electronic aids from an artificial way to codify the information to a natural form. In particular, the developed contactless haptic cane exploits smart signal processing paradigms and an actuator matrix to produce on the user hand palm a stimulus miming the sensation given by a conventional white cane bumping into a obstacle in the user path.

Keywords: blind people, haptic cane, contactless.

1. INTRODUCTION

To date several aids have been developed to improve the quality of life of blind people; however, a better understanding of the needs and abilities of the Visually Impaired (VI) people must be gained to build effective aids [1].

The very first aid for blind people was the long cane (1950): it allows detection of obstacles very close to the user and requires an instantaneous reaction when an obstacle is encountered. This aid can provide the VI with a lot of useful information about their surroundings.

Subsequently a huge number of electronic devices were developed, mostly using the transmission of an energy wave (usually ultrasonic or infrared) and the reception of echoes from objects, or CCD cameras [1-10].

Electronic aids for the VI people can be classified in the following classes: Clear path indicators, Environmental sensors and Orientation devices.

Clear Path Indicators provide information about the presence and the approximate position of obstacles.

Examples are The Russell Pathsounder, which is based on ultrasonic sensors, The Mowat Sensor, The Nottingham Obstacle Detector, which provides an auditory readout of range with eight notes corresponding to the musical scale, The Laser Cane, which employs laser technology, The Talking Radar Cap, which allows for the detection of common frontal obstacles, The Polaron™, which utilizes ultrasonic technology to detect objects within sixteen feet, and The Sonic Pathfinder.

Environmental Sensors enable target identification. Examples are The Kay Sonic Torch, which is a hand-held, narrow-beam ultrasonic device which provides an auditory signal rich in information (the pitch corresponding to range and the timbre corresponding to variations in target surface texture), and The Binaural Sensory Aid, known commercially as the Sonicguide.

The Orientation Aids familiarize the VI with an area and help them navigate. Examples of such devices are the "Talking Signs" system, which uses a network of low-cost infrared transmitter modules placed on normal navigational signs in the environment to give orientation to the blind user, The Sonic Orientation Navigation Aid system, which is based on radio-activated auditory beacons to accomplish the task, The Easy Walker© System, which is based on an infra-red device to give the user right directions to their chosen destination, The MS-ST", an infra-red based information and orientation system, which gives an orientation at railway and underground stations, airports, post offices, banks, hospitals and museums, and The Pilot Light, which is an infrared portable device for urban navigation.

To date, such systems have not penetrated the market due to Information Limitations (the degree of information given by the device is not adequate for the end-user), Expense, Auditory Cues (the natural echo is masked), Training Difficulties, Limitations of Scale (expensive installation is often required), and Lack of Performance Measures. Concerning the development of systems supporting people with depressed receptors efforts must be made by both medical scientists and engineers to define the degree and redundancy of the information to be given to the end-user, on the basis of individual differences, skills and abilities, perceptual and cognitive functions which can play a strategic role in determining the device performances.

Moreover, some other points must be considered, among which:

- The specific target to meet: e.g. in the case of the visually impaired possible targets are obstacle detection, orientation and mobility, etc.

- The approach to be followed: sensory enhancement, sensory substitution, or sensory supplementation. In particular, sensory enhancement aims to partially recover the functionality of depressed receptors, while the use of devices giving supplementary information for the

accomplishment of a particular task is known as sensory supplementation.

The task confronting blind pedestrians is often independently traveling from a starting place to a destination (the mobility task). Independent travel is an important goal sought by most visually impaired and blind people. The major mobility problems that result from blindness are obstacle avoidance and navigation. It is generally accepted that in order to assist blind pedestrians the following information is needed: the presence, location, and nature of obstacles; the texture, slope, and boundaries of the path or travel surface; and spatial orientation. Clear Path Indicators and Environmental Sensors perform fundamental roles in mobility tasks [1].

Researchers at D.I.E.E.S. in Catania are actively involved in research aiming to develop multi-sensorial architectures to assist visually impaired people to accomplish Blind mobility and Domestic tasks [11-15]. In the last years great efforts have been dedicated to overcome limitations of existing technologies, which are really expensive and unsuitable for practical use, and usually give a subset of the information required (especially in complex tasks) in which redundancy is not always optimized. The technology adopted uses low-cost sensors, such as ultrasonic sensors, inertial sensors, IR sensors and CCD cameras, and suitable smart algorithms for signal processing usually running on dedicated micro-controllers. Based on the target to be reached, different smart processing techniques are adopted, which mainly define the degree and redundancy of information. Activities aiming to measure the performance of the proposed devices (by a direct and indirect methodology) are also being carried out.

2. THE DEVELOPMENT OF A CONTACTLESS HAPTIC CANE

The activity presented in this paper is oriented to the development of mobility aids for the visually impaired based on the concept of "haptic perception". Gibson (1966) defined haptics as "The sensibility of the individual to the world adjacent to his body by use of his body". The idea is to implement a contactless cane providing the user with the same sensation he would perceive by the use of traditional white cane, with the enormous advantage to perform the environment perception without physical interaction with objects and other people.

This methodology will be really valuable from a social point of view, giving autonomy to the blind people performing mobility tasks without producing inconvenient environmental interactions which could inhibit the user performance.

The strategy adopted to implement the contactless haptic cane is schematized in Figure 1. In order to develop the contactless strategy to detect obstacles a sensor head housing ultrasound sensors, SRF08, estimating the obstacle distance, D_i (i counts for the ultrasound sensors) was realized and installed on a short cane. Moreover, to sense the cane inclination the inclinometer, ADXL213, has been also adopted. Such sensors, equipped with standard communication interface, are connected with a PIC14F microcontroller acquiring and processing data.

By processing the information coming from sensors, via a multisensory data fusion strategy implemented through model M1, the location of obstacles hindering the user path can be estimated. The operating range of the device was set to a couple of meters which is the same working range of a traditional white cane.

Once the obstacle position has been detected, such information must be delivered to the user by imprinting on his/her hand palm a sensation similar to the sensation he/she can perceive by using a conventional white cane. To such aim a set of actuators was positioned into the cane handle in a matrix configuration covering the contact interface between the cane handle and the hand palm.

In order to properly operate the actuator matrix, when a specific event (obstacle bumping) occurs, an activation model M2 is required. The definition of such model requires a preliminary analysis of human/environment interaction. To this aim a sophisticated tool has been implemented which allows for monitoring the stimulations produced by a white cane bumping into obstacles on the hand palm.

It must be stressed that bumping into obstacles positioned in different locations of the space neighboring the user will cause different hand palm stimulations.

The idea is to monitor the solicitation zones of the hand palm by using an array of Strain Gauges sensors mounted on a standard white cane and covering the interface between the user hand palm and the cane handle. Such devices have been conditioned by suitable electronic devices connected to a data acquisition board to collect signals. A dedicated user interface has been developed in LabVIEW to record and to manipulate acquired data.
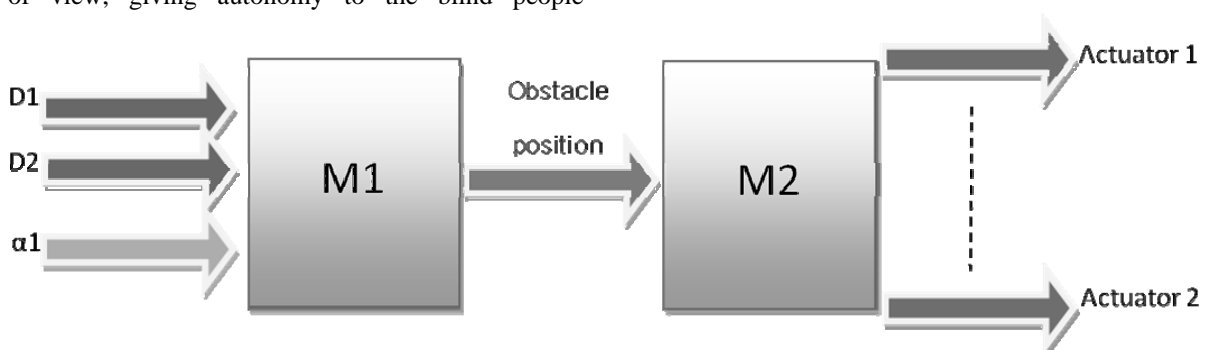Figure 2 gives a real view of the tool developed in this work.

Fig. 1: relationship between obstacle location parameters and activation zones.

In particular, Figure 2a) shows the implementation of the cane with the Strain Gauge matrix on the cane handle, while Figure 2b shows the user interface developed in LabVIEW to acquire and process signals coming from the multi-sensor architecture.

Figure 3 shows the realization of two boards dedicated to the conditioning of signals coming from the Strain Gauge and to the acquisition of such signals, respectively. A serial communication protocol has been adopted to transfer data to the PC where the LabVIEW application is running.

A typical set of signals acquired by one of the Strain Gauge is given in Figure 4.

The signals are related to a set of acquisitions referred to different observations of the same experiments, consisting of bumping the cane against an obstacle positioned in a fixed position.

In order to synchronize signals coming from different experiments a synchronization architecture has been implemented by a mechanical switch mounted on the cane which reveals the collision with an obstacle and activates a flag in the acquisition system. This synchronization system allows for a validation of the device reliability on the basis of successive replications of the same experiment.
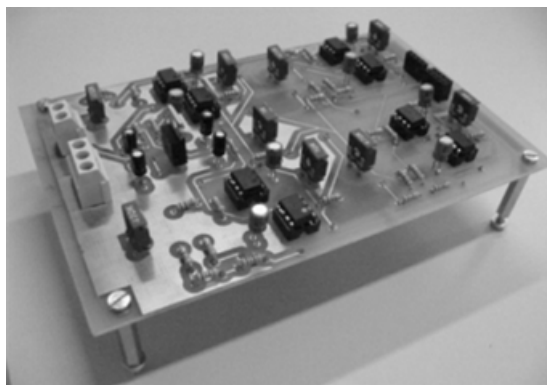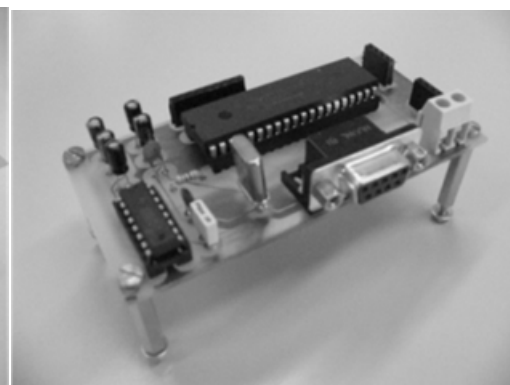

(a)
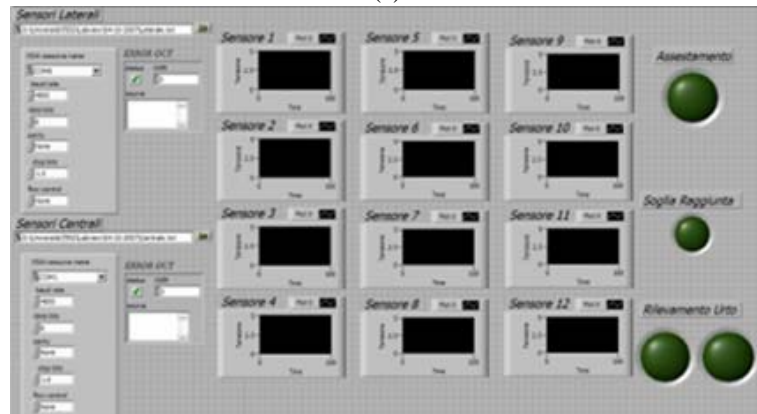
(b)

Fig. 2. a) A real view of the white cane housing the Strain Gauge matrix. b) The front panel of the user interface to record and process signals coming from the sensor matrix.

a

b

Fig. 3. Electronics developed to process signals coming from the multi-sensor architecture implemented in the Cane handle: a) conditioning board, b) acquisition board.

Figure 5 gives the reconstructed hand palm stimulation when the cane bumps against an obstacle in the front-central position. In this first realization of the system, signals coming from the sensor matrix have been manipulated by using suitable filters aimed to produce a binary information (ON-OFF) of the hand palm zones activated for each kind of bump due to obstacles positioned in different locations.

Some preliminary results of the hand palm zones stimulated as a consequence of obstacles-cane interactions for specific obstacle locations are given in Figure 6.
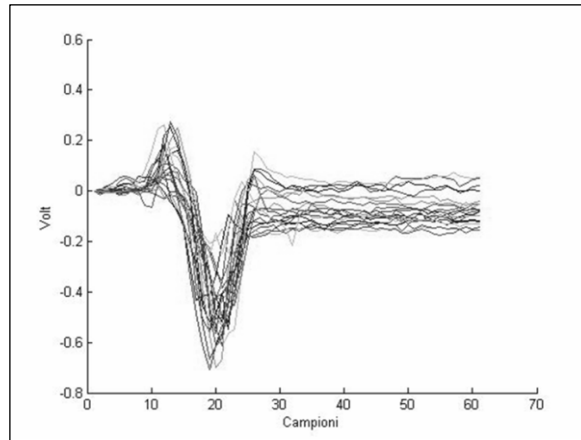

Fig. 4. Typical signals recorded by one Strain Gauge in different observations of the same experiment: the white cane bumps against an obstacle located in the same position.
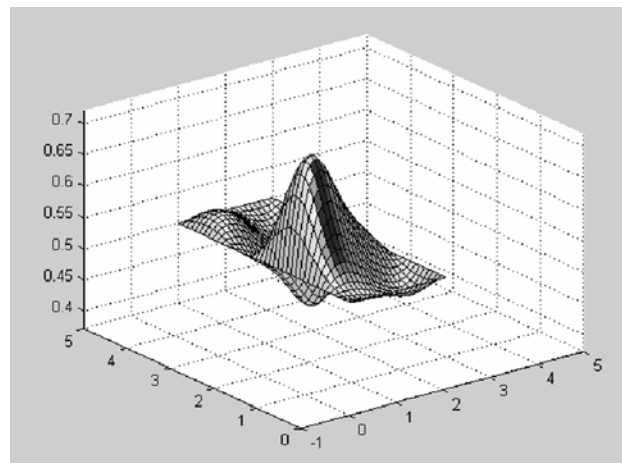

Fig. 5. Reconstruction of hand palm stimulation for a front side bumps.

Model M2

Fig. 6. Results of the characterization surveys oriented to estimate the relationship between obstacle locations and stimulated hand palm zones. A matrix (4X3) of Strain Gauges has been used. Dark cells states for the stimulated zones of the hand palm.

As can be observed discriminating combinations of solicitation zones have been recorded for different bumps. The solicitation maps estimated for each kind of analyzed bump will then be used to control the actuators in the cane handle in order to reproduce into the hand palm of the user adopting the haptic cane sensation similar to those perceived by the use of the white cane. Actually the correspondence between obstacle locations and the stimulated zones of the hand palm was implemented by a set of crisp rules (model M2).

In order to design the multi-sensor head a simulation of the interaction between ultrasound sensors and a typical environment with obstacles has been performed in the 3D studio environment (Figure 7a). This analysis along with considerations on the operating range of the transducers adopted (Figure 7b) has been valuable to define the layout of the sensor probe. Figure 8a illustrates a real view of the sensor head while Figure 8b is a real view of the inner section of the cane handle housing the actuators. The final prototype was equipped with a soft cover improving the device handling without compromising the actuator operation.

The architecture adopted to manage signals coming from sensors and to implement models M1 and M2 in order to control the actuator on the basis of the obstacle location is based on a PIC14F microcontroller and suitable electronics for signal conditioning.

The smart core of the Haptic Cane is hence represented by a set of rules implemented into the microcontroller which reproduce the mapping between the information collected through the multi-sensor probe and the zones of the hand palm to be solicited. Actually, the algorithm implemented exploits information obtained from the distance sensors to advice the user for the presence of incoming obstacles (on the user path) also in the case they would be slightly out of the nominal operation range of a typical white cane. This solution, which someway would violate the similitude between the white cane and the contactless haptic cane, has been implemented in order to enrich the information available to the user. A schematization of information typically provided to the user on the basis of obstacle location is given in Figure 9. Actually, the user can perceive two different feedbacks from the device operation. When an obstacle is detected on the user path he is notified by a stimulation corresponding to the obstacle position: in Figure 9 this events are marked as "User driven detection". In case an obstacle is detected in the close proximity of the user path the user will be also notified for its presence and in this case the events have been marked as "System driven detection".
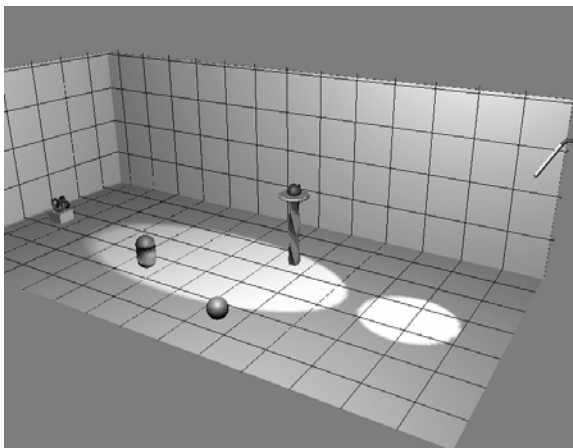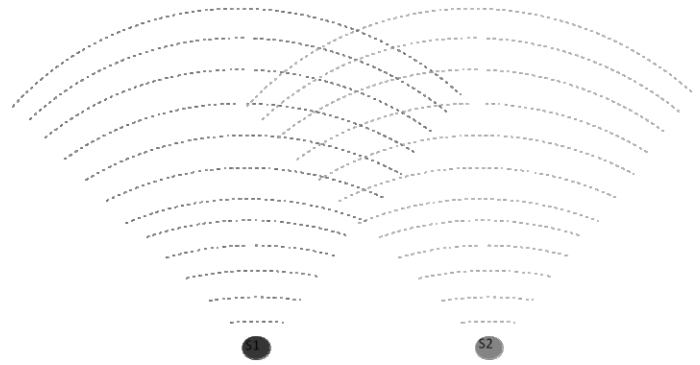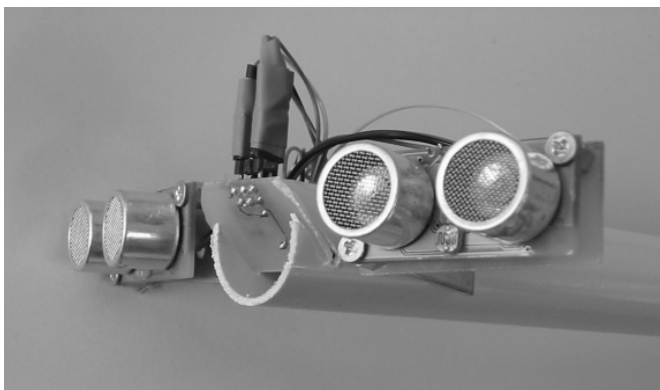

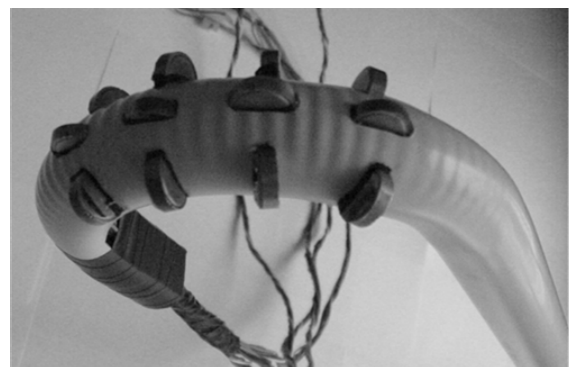(a)   (b)

Fig. 7. a) The 3D studio environment dedicated to the simulation of the interaction between Ultrasound sensors and a typical environment with obstacles; b) Schematization of the operating range of the Ultrasound sensor probe.

(a)   (b)

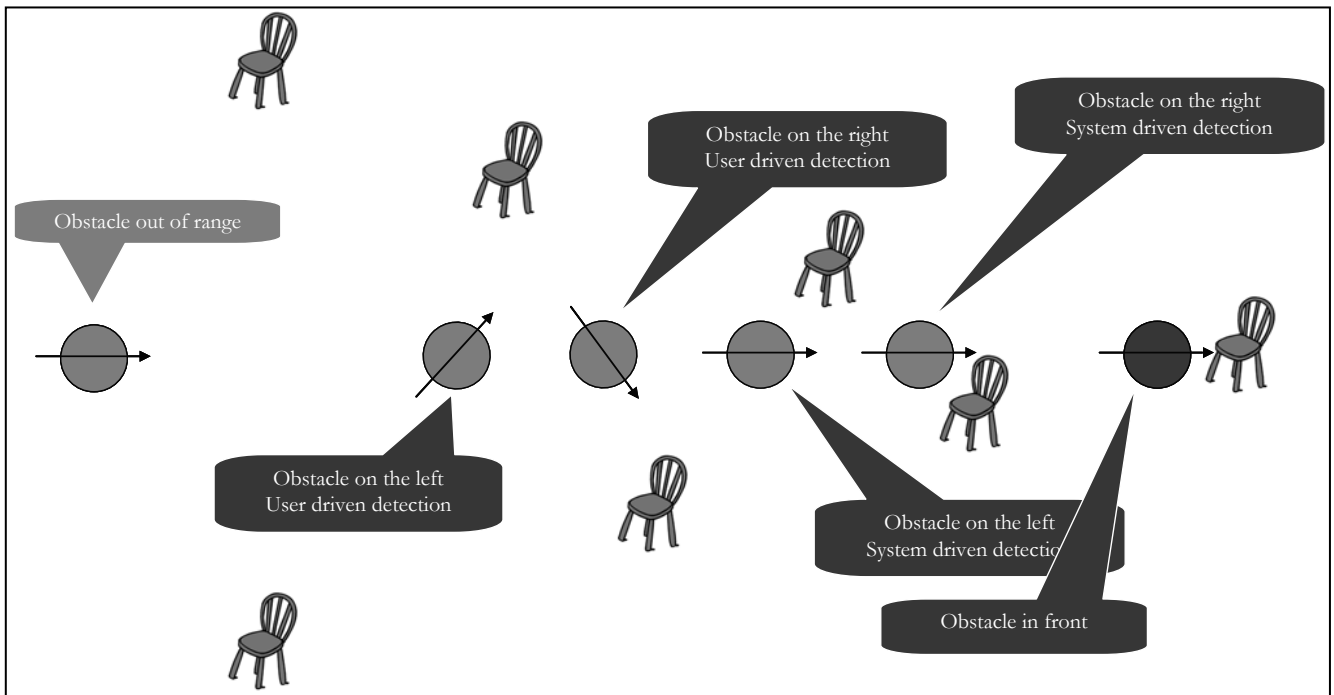**Fig. 8. Real views of (a) the sensor head and (b) the cane handle with actuators.**

Fig. 9. Description of the system response in case of obstacles located in different position as respect to the user path.

4. RESULTS AND CONCLUSIONS

Preliminary tests on the device were performed in order to estimate the performances of the proposed methodology in terms of capability to properly codify the information on the obstacle position. Considering risks associated with this kind of activity such tests were performed by sighted people with banded eyes and 80% of successes in correctly recognizing the obstacle location was obtained. Future efforts will be dedicated to improve the reliability of the prototype and to test the device with blind people.

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