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Walking Using Touch: Design and Preliminary Prototype of a Non-Invasive ETA for the Visually Impaired

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Abstract—**This paper presents the design and preliminary prototype of the *Intelligent Glasses*, a novel non-invasive electronic travel aid (ETA) designed to assist the blind/visually impaired to navigate easily, safely and quickly among obstacles in indoor/outdoor 3D environments. The Intelligent Glasses, a joint project between the Robotics Laboratory of Paris (LRP) and the French Atomic Energy Commission (CEA), is based on a visuo-tactile system. Two mini-cameras mounted on the user's eyeglasses frame detect the obstacles ahead the walking course and translate this information to a tactile display as a map representing where the obstacles are located in the scene. The user freely explores the tactile map and is able to follow it easily, demonstrating initial feasibility of the system.**

Keywords: Electronic Travel Aid (ETA), visuo-tactile system, 3D environment, obstacle detection, tactile map.

I. INTRODUCTION

Over the last four decades, several electronic travel aids (ETAs) [1]-[8] have been proposed to improve mobility and safety navigation independence of the visually impaired. However none of these devices is widely used and user acceptance is quite low.

Four fundamental shortcomings are identified in all ETAs:

1) They obtain a 3D world perception via complex and time-consuming operations: environment scanning using sonar-wave or laser-beam requires the user to actively scan the environment, to memorize the gathered information, to analyze it and to take a decision: constant activity and conscious effort that reduces walking speed and quickly fatigues the user.

2) They provide an acoustic feedback that interferes with the blind person's ability to pick up environmental cues through hearing. Another problem is degradation and overload of the hearing sense. Recent studies [9] have shown that a 20-30 minute usage of acoustic feedback devices causes serious problems to human sensors information registration, reduces human capacity to perform usual tasks and affects the individual's posture and equilibrium.

3) They are invasive. They are intrusive and disturb the environment with their scanning and feedback technologies.

4) They are still burdensome and conspicuous to be portable devices, which are essential needs for people with visual impairments.

The Intelligent Glasses proposes a vision-like 3D world "quite" global perception concept that overcomes the drawbacks of sequential, time-consuming and environmental intrusive scanning. As feedback, touch, a not usually involved sense, could provide a significant improvement: quick interpretation and non-aggressive feedback using lightweight highly portable devices.

The rest of the paper is organized as follows: Section 2 introduces the Intelligent Glasses concept and operation principle. Section 3 describes the current prototype and its main modules, while section 4 presents some preliminary results obtained with this system. Finally, section 5 concludes summarizing the main concepts and contributions.

II. THE NAVIGATION CONCEPT

The Intelligent Glasses is a new ETA which provides a simplified representation of the obstacles present in a 3D environment. This system is basically composed of 2 main modules: vision system and tactile display [10]. Figure 1 shows the concept of navigation proposed by the Intelligent Glasses.

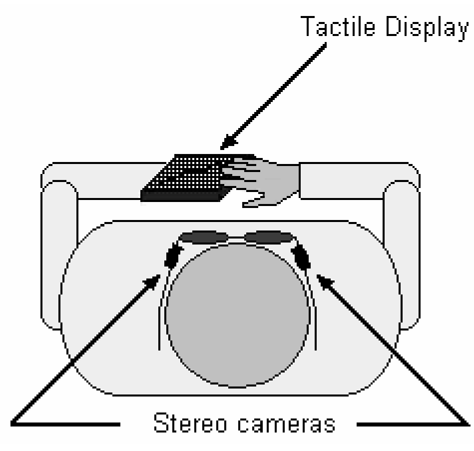
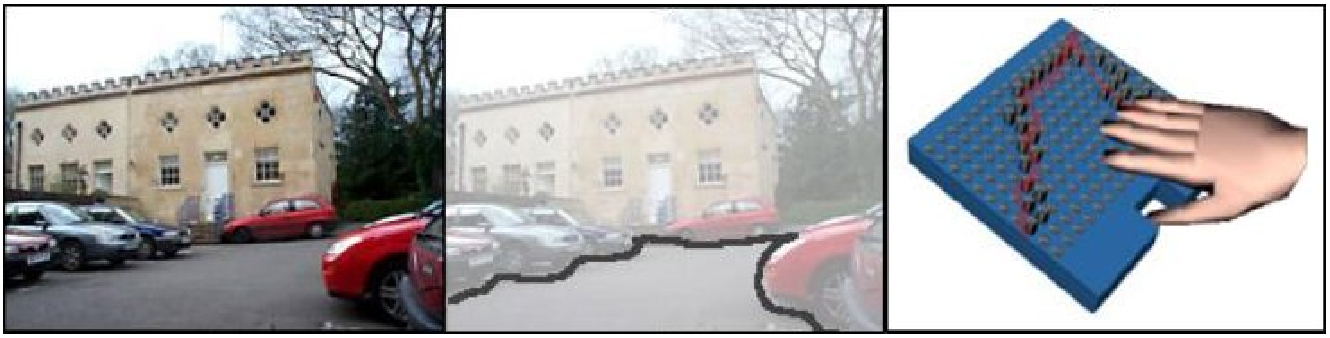


Fig. 1: Navigation using the Intelligent Glasses System.



(a) (b) (c)

Fig. 2: The Intelligent Glasses operation principle: Translation of visual data onto a tactile representation.

Figure 2 shows its operation principle: (a) the stereo cameras acquire the environment's representation. (b) Vision algorithms are then applied in order to identify the obstacles in the scene and their user-related position. (c) Finally, this information is displayed on a tactile display for fast exploration by the user. Note that the resulting tactile map is an edge-like representation of the obstacles' location in the scene.

III. PROTOTYPE

A) Vision System

1) Data/Image Acquisition

It is widely known that orthogonal mapping of a 3D scene onto an image plane produces a 2D scene in which depth information is missing. The choice of a binocular or stereo vision system seems then to be mandatory for obstacle detection as depth is directly related to the object's location in the scene.

Using two cameras, it is possible to obtain two separate and different image views of a point in a scene. Once homologous points in both images are found, the third dimension of a point (its depth) can be recovered via triangulation, for example (figure 3). An original biologically inspired method for this purpose has been proposed in [11].

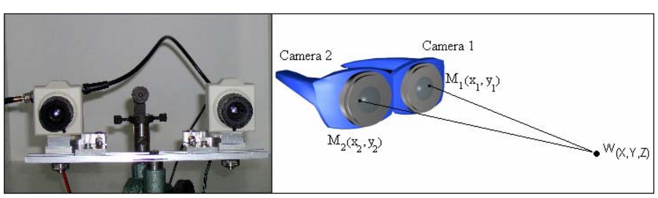


Fig. 3: Stereo cameras carried by the user.

The fact that the cameras are mounted on the glasses frame permits the user to explore comfortably the environment with different view points and with a wide freedom as the cameras move with the head.

2) Scene Analyzer

As aforementioned, binocular vision permits to extract the distance to an obstacle. However, this information is obtained according to the cameras referential. If an inertial sensor is added to the system, the camera referenced data can be transformed to gravity referenced data and thus, the information will be referenced to the user's body.

A virtual reality based platform which integrates the inertial sensor and the camera system was implemented to track the user during the obstacle avoidance task and to establish a correspondence between the user and the 3D environment [12].

This solution permits to extract the 3D environment's map from the user's view (figure 4(a)) and to use it to establish the corresponding tactile obstacles map (figure 4(b)).

As seen in figures 4(a) and 4(b), this first approach considers obstacles located on the walking surface and overhanging obstacles. A further extension is not excluded (obstacles located under the walking surface like holes, dynamic obstacles, obstacle-free zones, etc).

Note that all obstacles are considered and displayed in tactile domain as binary data: presence or absence of an obstacle.

B) Tactile Display

To ensure an easier adoption and a higher user acceptance of the Intelligent Glasses ETA, a tactile transcription similar to Braille has been chosen. Moreover, Braille is by far the most successful tactile tool for displaying text information among the deaf/blind and it is a standard worldwide.

A Braille-like tactile display involves arrays of upward/downward moveable pins as skin indentation mechanisms. Typical Braille devices are piezoelectric refreshable displays that start at 3,800 USD and might cost up to 20,000 USD with the most popular displays costing between 7,500 and 15,000 USD [13].

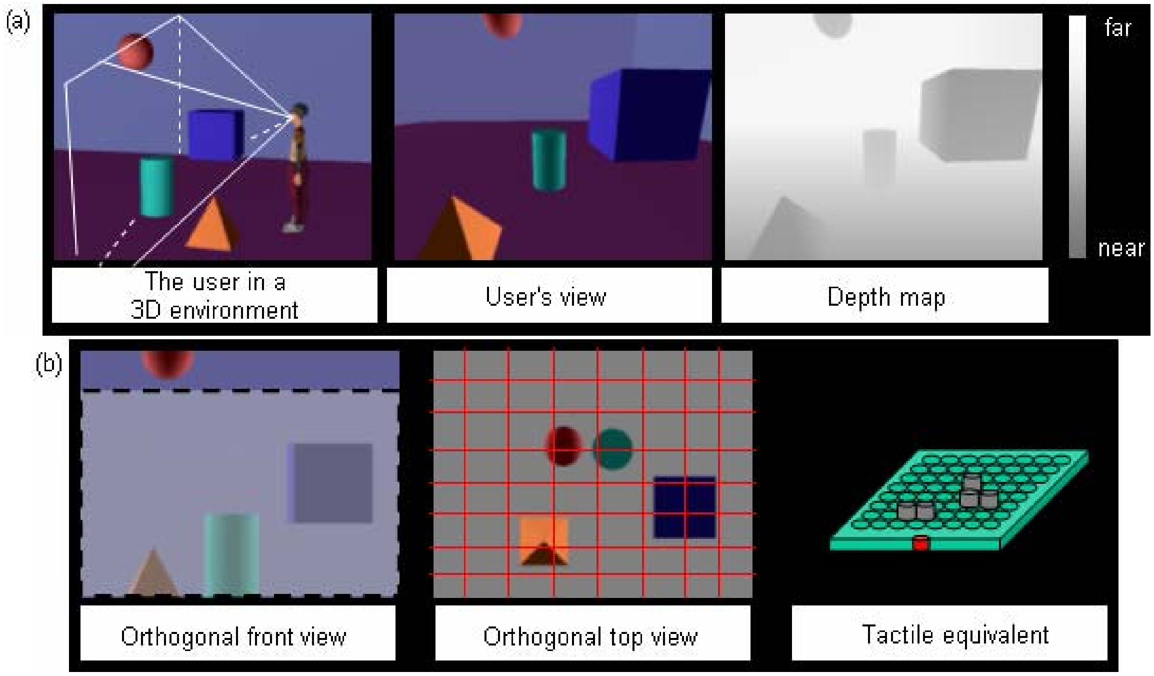


Fig. 4: (a) Depth map of a 3D scene and (b) its tactile representation.

Cost is not the only drawback when further applications of Braille displays are considered:

1) Displaying 2D graphical information is practically impossible due to the burdensome piezo-actuator module that drives the pin. Devices for 2D tactile graphics are commercially available like Metec's 159 x 59 array display for 70,000 USD [14].

2) Portability in Braille text displays is quite relative. Nowadays it is defined by 1 kg weight devices of dimensions: 12 x 32 x 4 cm.

A tactile display based on Shape Memory Alloy (SMA) actuation technology has been developed seeking a more efficient implementation in terms of cost, performance and flexibility.

The prototype consists of an array of 64 SMA miniature actuators featuring a 60 g weight device of compact dimensions (4.5 x 4.5 x 4.5 cm), which can be easily carried in the user's hand (figure 5).

Pin spacing is 2.6 mm (Braille standard) and each actuator is capable of developing a 320 mN pull force at 1.5 Hz refresh rate [15].

This concept has also introduced the possibility of making possible truly lightweight, highly-portable text-graphic Braille-like displays for 200 USD or less.

IV. PRELIMINARY RESULTS ON TACTILE MAPS

Figure 6 shows two examples of tactile maps displayed on the tactile display according to the Intelligent Glasses obstacle detection principle.

Note that the obstacles are displayed as a Braille-like tactile contour letting know their location in the scene and thus, the available walking way.

Current work concerns tactile map, shape and pattern recognition tests.

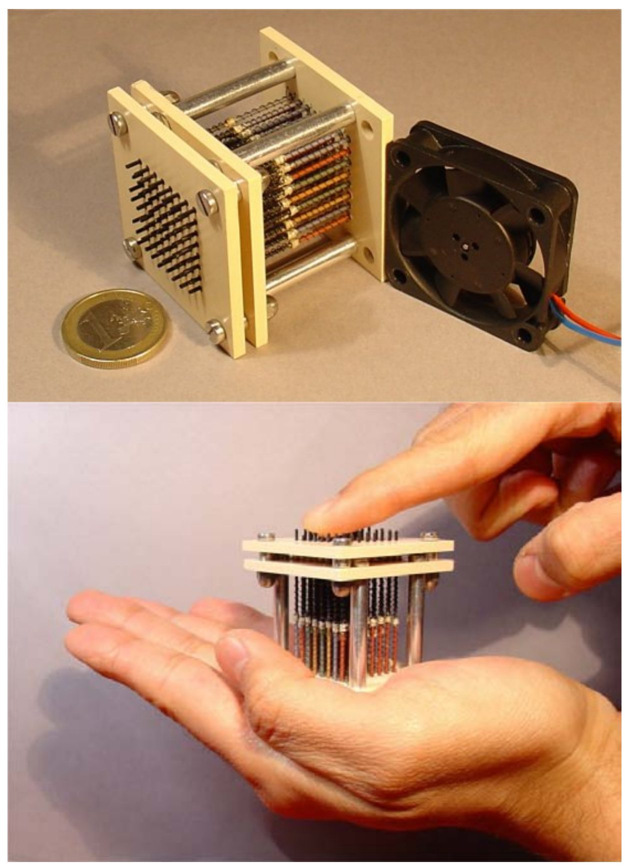


Fig. 5: SMA based tactile display.

Fig. 6: The Intelligent Glasses tactile maps representing obstacles in 3D environments.

V. CONCLUSION

This paper has presented the design, preliminary prototype and first results of the *Intelligent Glasses*, a new portable ETA for the visually impaired.

The novelty of this ETA is based on its concept of real-time representation of the 3D visual world. Using a visuo-tactile principle, it is able to scan the global environment in a non-intrusive fast way. On the other hand, its tactile feedback provides a quick, easy and almost intuitive interpretation.

Dedicated experiments involving healthy blindfolded sighted and blind subjects which will validate the Intelligent Glasses ETA are currently under design.

REFERENCES

[1] J. Benjamin and N. Ali, "A Laser Cane for the Blind", *Proc. of the San Diego Biomedical Symposium*, Vol. 12, pp 53-57, 1973.

[2] L. Kay, "A Sonar Aid to Enhance Spatial Perception of the Blind: Engineering Design and Evaluation", *Radio and Electronic Engineer*, 44(11), pp 605-627, 1974.

[3] D. Bissit and D. Heyes, "Application of Biofeedback in the Rehabilitation of the Blind", *Ergonomics*, 11(1), pp 31-33, 1980.

[4] Wormald International Sensory Aids, 6140 Horseshoe Bar Rd., Loomis, CA 95650, USA.

[5] J. Borenstein, "The NavBelt – A Computerized Multi-Sensor Travel Aid for Active Guidance of the Blind", *Proc. of CSUN's 5th Annual Conference on Technology and Persons with Visual Disabilities*, Los Angeles, USA, pp 107-116, 1990.

[6] P. Meijer, "Cross-Modal Sensory Streams", *Proc. of Conference on Computer Graphics and Interactive Technologies*, Orlando, USA, pp 184-192, 1998.

[7] I. Ulrich and J. Borenstein, "The Guide Cane – Applying Mobile Robot Technologies to Assist the Visually Impaired", *IEEE Transactions on System, Man and Cybernetics*, 31(2), pp 131-136, 2001.

[8] R. Farcy, R. Damaschini and R. Leroux, *Autonomic - Workshop & Exhibition*, Paris, France, 2002.

[9] J. Hakkinen, "Postural Stability and Sickness Symptoms After hmd Use", *Proc. of IEEE International Conference on Systems, Man and Cybernetics*, Hammamet, Tunisia, 2002.

[10] E. Pissaloux, "A Vision System Design for Blind Mobility Assistance", *Proc. of 24th Annual Int. Conf. of IEEE-EMBS*, Houston, USA, pp. 2349-2350, 2002.

[11] F. Maingreaud and E. Pissaloux, "Biologically inspired 3D scene depth recovery from stereo images", *Proc. of IEEE International Symposium on Industrial Electronics*, Ajaccio, France, 2004.

[12] F. Maingreaud, E. Pissaloux and R. Velazquez, "Understanding Environment Structure with Tactile Map", *Proc. of 8th International Conference on Information Visualisation*, London, England, 2004.

[13] Royal National Institute of the Blind, updated information available at http://www.rnib.org.uk

[14] Metec AG, Stuttgart, Germany, updated information available at: http://www.metec-ag.de

[15] R. Velazquez, E. Pissaloux, M. Hafez and J. Szewczyk, "Miniature Shape Memory Alloy Actuator for Tactile Binary Information Display", *Proc. of IEEE International Conference on Robotics and Automation*, Barcelona, Spain, pp 1356-1361, 2005.