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Validation of a dynamic electronic obstacles map

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Abstract: The Intelligent Glasses System (IGS) is an electronic travel aid which gives blind people 3D environment structure information. The device assists users in obstacle avoidance by providing them a nearest environment tactile map where the obstacles are represented. This paper outlines briefly the IG system, and addresses first results on the validation of the proposed representation via psycho-physiological experiments.
Keywords: Electronic Travel Aid (ETA), Blind, Tactile Device, Obstacles, Perception, Virtual Reality, HuPer project

I. Introduction

The Intelligent Glasses System (IGS) is an electronic travel aid (ETA) that gives users a simplified representation of the 3D environment taking into account the obstacle avoidance task constraints [Mai02].

The originality of this system compared to existing devices is mainly due to an easily interpretable and user adapted representation of 3D space orthogonally projected on a 2D touch stimulating surface. This representation takes care of the most important part of user's requirements: quick interpretation, global environment dynamic representation, wearable device.

The task of an ETA is to assist blind people in obstacle avoidance. The design of the IGS is motivated by presently available aids' limitations, by technology progresses on system integration allowing new concept integration to the electronic system and by the progresses on the human perception physiology [Mai02] [Pis02] [Ber91] [Ber97] [Hat00].

Aids so far used by blind people usually permit them to travel, but many of environmental contexts are not handled by them. Indeed, these aids (white cane, dog, guide cane, [Mai02], [Her02]) provide only local and not global information on the user's closer environment. The local information may be sufficient in the simplest traveling situations, but it is not unusual to see blind people who meet an overhanging obstacle, or to spend a lot of time to exit from a dead end. Systems that provide a global information to users need a long training period, because they exploit brain plasticity to create a new sense [Bac01] [Far03] [Mei02][Len00], and the user should learn a new (huge) language.

These considerations motivate the design of a device which gives global information on nearest environment but in simple way. However, in this very first approach of the sightless 3D nearest environment representation, a task oriented representation is considered only.

The rest of the paper is organized as follows. Section II gives an analysis of an obstacle avoidance task. Section III proposes an integration of the analysis result into a real system, the Intelligent Glasses (IGS). Section IV presents first experiments in order to validate the 3D world edge representation with vibro-tactile stimulation pad, than a virtual reality benchmark experiments are defined. Section V encompasses some future works related to the IGS.

II. Obstacle avoidance task

The obstacle concept and its representation on any support, influence strongly the obstacle avoidance task. Detection of an obstacle in the environment is done by senses feedback, and brain analysis.

II.1.Human environment understanding

To extract information from the environment, it is possible to exploit independently or jointly the bio-senses' provided data.

Vision

Visual perception is based upon physiological and psychological cues.

Physiological cues, such as accommodation, convergence, binocular disparity, and movement parallax ..., directly influence the external world parameters selection and quantification by our brain.

Psychological cues, such as image size, linear perspective, surface perspective, surface gradient, objects occlusions, shading and nuances, texture gradient, …, result from a subjective perception of the observed phenomenon and are related to image photometric formation, scene photometric and geometric analysis [Gre03].

Hearing

Sound of the environment is important for the correct understanding of its structure. Sound of objects, machines, and people help to understand space structure. Sound sources properties are linked to the sound they generate. Spatial localization can be calculated using stereophony principles and their distance can be induced from sound's intensity level (the nearer the stronger: Doppler theorem).

Vestibule

Even if vision is the dominant sense for global space structure analysis, other senses are involved in the analysis task as well. Indeed, the vestibular data stabilizes the gaze and permits to integrate translation and rotation information relevant to navigation. Moreover, vestibule allows establishing the link between human being and its position in the external world by providing the reference to the gravity.

Proprioception

The fact that we have an internal (brain) representation of the structure of our body (proprioception) and their relative positions (referential) allow us to have a better understanding of our environment. Indeed, we can know how we interact with environment structure (haptic sense, motor), and we can understand the impact of the environment that forces us to adapt our body structure in order to achieve the aimed interaction [Sac98].

Touch

Physiology of the feeling (touch) sense shows that mainly Meissner's and Pacini's mechanoreceptors are involved in hand feeling [Vel03]. Meissner cells are in charge of the surface texture perception via a small pressure induced by the texture pattern, while Pacini's cells detect vibrations. It seems that Meissner's cells are mainly involved in surface gradient information registration.

Since the very first days of our life and before having a stabilized and exploitable visual perception, we have built first representations of our 3D world from world's tactile exploration.

Tactile information can be provided to human in two ways: static and dynamic, both based upon local deformation of the skin corresponding to surface gradient (if there is no purposely strong pressure). The active scanning of a tactile stimulating surface seems to be most efficient for perception and memorization (cf. Braille cell based devices).

II.2. Obstacles representation

Obstacles detection task in the real environment requires obstacles representation, and constant feedbacks to any intermediate level of brain environment analysis based upon data provided by human exteroceptive sensors when moving [Bac01][Len98][Len00][Gen03][Ber97].

Obstacle definition

Obstacle is defined as something which prevents or delays an action (© Larousse-Bordas 1998). So, an obstacle is anything which stops your progression and/or requires the modification of your current posture. From physiological and geometric points of view, an obstacle can be represented by an edge (a surface gradient) which prevents the evolution of the planned action [Ber97][Cie02].

Blind people obstacle definition

For blind people, obstacles are defined by touch (feet and hand); sounds and proprioception provide other useful cues. It should be stressed that it's often too late when a blind person has perceived an obstacle.

Obstacle internal representation: cognitive map

O'Keefe and al. [Oke96] defend the theory of a brain cognitive map which is the internal representation of our environment via place and head orientation cells. These cells permit to have a useful and efficient representation of our environment with information on obstacles' presence.

II.3. Cognitive map construction: the construction mechanism validation.

To construct a representation of a nearest environment, it is preferable to mediate the information in a relevant, but simple, structure. Hand touch sense (tactile stimulation) perception capacity suggests choosing an edge based representation. To validate the chosen representation, it is necessary to check that the brain cognitive map built without sight can be enriched by the tactile information, and if it is possible to effectively used such representation for navigation in the real world.

Figure 1 shows how the proposed Intelligent Glasses System tries to answer to this problem : touch, hear and vestibular data are fused with artificial vision and inertial data, provided by the IGS in order to get a displacements' more relevant representation of the 3D world.

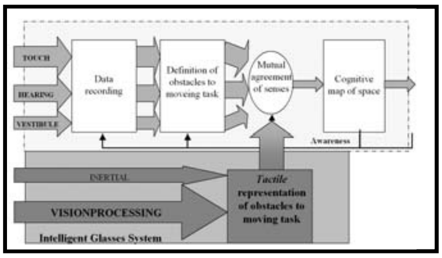


Fig.1: *Perception-Action adaptative loop with IGS.*

III. Intelligent Glasses System (IGS)

The IGS tries to provide a 3D world representation with respect to brain interpretation. Therefore, the IGS should built (dynamically) a correct cognitive map of the 3D world and coherent with this established via others senses (hearing, touch, …)

III.1. IGS principle

The IGS design tries to provide the maximum of simplicity and effectiveness to understand and exploit the information given on the environment structure to the potential users.

The IGS provides a representation of the static and dynamic peri-personal space (~4-5meters ahead of the user). It exploits recent results on physiological tactile perception [Hat00], knowledge about bio-inspired vision algorithm and new technologies for tactile interface realization.

III.2. IGS architecture overview

The IGS is composed by three sub-systems: inertial data and image acquisition system, data analysis system and tactile stimulating surface, an output device encompassing a representation of user's peri-personal space.

Inertial Data and Image acquisition system

A couple of stereoscopic epipolar cameras carried by glasses frame (Fig.2) in conjunction with an inertial station allow acquiring data on the observed scene structure. Such subsystem permits to explore the global environment with different points of view, with a free large head movement and a global feedback, on a wearable device (without forcing the user to use his hands).

Scene analyzer

A peri-personnal space obstacle can be localized via vision processing applied to stereovision epipolar rectified images. Binocular vision principle permits to extract the distance to obstacles information (in the cameras referential).

Information given by the inertial station permit to transform camera referenced data to gravity referenced information (human body usual referential). Therefore, it is possible to know the user's body movements, especially during the obstacle avoidance movement.

All obstacles are considered, in this first approach, as binary data: presence or not of an obstacle on the reference (walking) surface.

A larger classification, based on the displacement process, its leads to the following four classes of obstacles:

- Obstacles on the reference (walking) surface or overhanging obstacles
- Obstacles under the walking surface
- Dynamic obstacles
- Obstacle-free space.

Further extension of the above semantic is not excluded.

On the tactile stimulating surface, obstacles will be presented by their nearest edge from the user.

Tactile stimulating surface

To permit an easier appropriation of the interface by the blind people, a tactile transcription of user's peri-personal space, similar to Braille matrix concept, has been chosen.

Utility of static tactile map has proved their efficiency for information communication [Ung97]. Considerations about perception have shown that global scene representation allows its better understanding and safer displacement execution in it. Furthermore, an active learning, the Braille matrix hand scanning, is the most relevant way to acquire the information on environment structure.

Consequently, the Braille matrix will display obstacle edge information by activation of micro tactile actuators or taxels, tactile element (Fig.3). The device will give a projection of the environment similar – but less complex- to our city street map, on which obstacles will be indicated by a high position of the taxel. The user's position in the scene will be indicated by a hole on the interface boarder. It permits to understand the position of obstacle in the user centered referential.

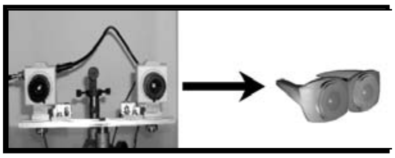


Fig.2: *Stereo cameras carried by glasses frames.*

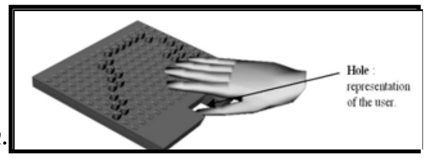


Fig.3: *Tactile interface and obstacle edge representation.*

III.3. IGS displayed data example.

Figure 4 summarizes the IGS functional principles. Left images show the observed scene (upper) and its calculated (vision processing) depth map; right images show their orthogonal top 2D projections; the bottom right image results from a data fusion of depth map and 2D top projection of the given scene. Figure 5 right picture shows the tactile representation for the observed scene; all obstacles (black points- taxels) are localized in user centered referential.

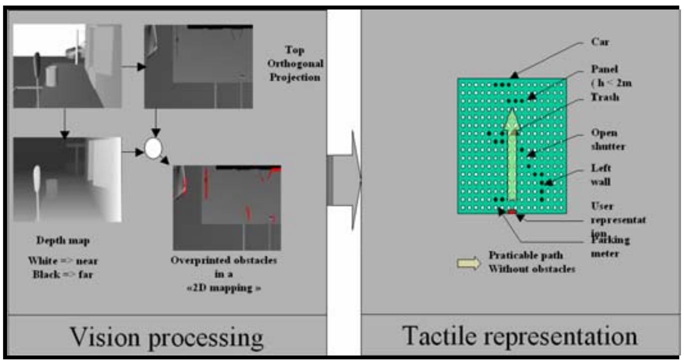


Fig.4: *An example of Vision to tactile processing .*

IV. Experimental validation of the concept of a cognitive map

IV.1. Validation of the proposed scene representation with a vibro-tactile pad.

Figure 5b shows the vibro-tactile pad, named VITAL [Haf04], used for the defined above first representation validation ; its surface encompasses 8 x 8 vibrating springs; a geometric shape is presented by the vibration of neighbouring taxels; while scene displacement is represented by activation of taxels in displacement direction. The tested participant has been sited in front of the Vital. Different geometric shapes and their displacements have been generated by program running on a PC and displayed on PC (control) screen (seen only by the experiments' leader) figure 5a.

Shape and direction have been chosen because they seem to suit for a very basic representation of dynamic scenes.

Fig.5a: *Vital system*

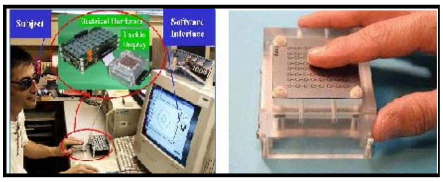


Fig.5b: *Vital vibro-tactile pad*

Two experiments on 10 people have been realised in order to get some statistical data on movement direction recognition and on static object perception via vibration stimulation. The procedure for VITAL surface exploration (scanning) has been freely chosen by the tested person.

Displacement/movement perception

A line and arrows (empty (arrow edge representation only) and full) have been used for directions' perception. Four NEWS directions have been displayed for recognition. They are: N or north (forward ahead from the user); S or south (backward: forward towards the user); E or east (right to user) and W or west (left to user)). There were two experiences, one with the line and one with the arrow. Each experience contains a series of 18 directions.

At first, the arrow chosen size has been as tall as possible according to interface size (line x column : 4*8 taxels). Partials results led us to reduce the size of this arrow (3*6).

Only the line has been effective for recognition. This is probably due to Paccini's sensor distribution.

The results gathered on direction perception with any form moving in N-S directions are quite good (well recognized by almost all participants, despite that the recognition time with arrows is slightly longer). However, they show that the moving shape (case of the empty arrow) can induce perception errors; indeed, all tested people recognized the empty arrow E-W movements as diagonal (or opposite) movements; or such movement direction were never generated.

In general, line movement perception was easier and faster to detect than this of an arrow.

It could be possible that the recognition results will improve after training.

Static object recognition

Objects to recognise are: square, circle, triangle and line. Tests on static forms perception have been preceded by oral explanation what about possible forms to recognize and their size (three different sizes: small, medium and large according to the interface size). The form user relative position's remains unchanged during the whole experiments. Forms are empty (represented just by their edge) or full.

Results obtained on empty shapes show that confusion between squares and circles are almost systematic. This is probably due to the VITAL interface week resolution. Many errors occur with small figures what is probably also due to the VITAL week resolution.

The results obtained with full figures are non conclusive: too many biosensors stimulated at the same time do not allow object recognition.

The user's favourite procedure for VITAL surface exploration has been usually the active scanning (displayed objects shape following).

The VITAL interface seems efficient for simple forms' recognition (line) and movement detection (NEWS). However, some of the tested users stopped the surface scanning during the tests; they complain about the fingers' fatigues. Two users talk about the interface's memory effect on their fingers (they have difficulties to remove the vibration effects after tests). Almost all users suggested increasing amplitude and frequency of the vibration stimuli.

The proposed representation of space should be validated via experiments that simulate its use in real conditions.

IV.2. Validation with a virtual and augmented reality theatre.

The virtual reality theatre, Figure 6, [Cea02] will be used in order to create an environment to understand and represented with IGS.

The theatre is composed by a tracking system that allow user to move in a confined environment, his head positions can be determined thanks to an ultrasonic system (data are registered by computer). A (static) scene will be realized with an augmented reality system; all obstacles present in the user's moving environment will be represented in a virtual world (Figure 7). The position of the head mounted tracking sensors will permit to create a 3D image of the environment (simulation of the information that would be captured via stereo cameras in the real system). Thanks to graphical image processing, using graphic board properties, it is easy to extract the depth map of the environment. This information will be used and processed to communicate the obstacles information to the tactile device.

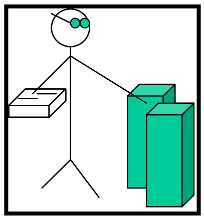
Such tests environment makes possible to display the correct information on our nearest environment, without vision processing. It allows also validating the proposed representation without a real prototype of the whole system, including vision processing (what is long to implement in a wearable device).

Therefore, it is possible to test the validity of the object frontiers representation for obstacle avoidance task and test the characteristics of the environment representation on the tactile stimulating device (resolution, scale for human representation on the tactile device, …).

Furthermore, with our experimental setting it will be possible to train better final users by association of the virtual and real world (touch of real objects (obstacles) and to associate simultaneously this perception to a tactile display).

Fig.6: *The augmented reality platform.*

Fig.7: *Tactile interface and obstacle edge representation. Learning with augmented reality possibilities.*



All experiments will be done in the framework of the CNRS HuPer ROBEA program project involving three partners CEA-LIST, LRP- University Paris 6 and LPPA-Collège de France.

V. Conclusions

The paper has addressed a problem of blind people navigation in 3D world. Objects edges closest to user and their tactile representation (according to our finger tactile discrimination ability) have been chosen as obstacles representation of a given scene.

The results of very first experiments for effective validation of this representation via VITAL vibro-tactile touch stimulating surface have been provided. They show that a line and its movement on a surface are promising for 3D dynamic scene content representation. Results with other forms could probably be improved via a longer training. The temporal results should also be precisely collected; they will determine the display time of a given scene representation.

These results show that other realization for the tactile surface should be considered. Indeed, not well identified side effects seem to exist indicating that the interface long-term usage can lead to many recognition errors.

The virtual theatre based test environment, in association with Intelligent Glasses, seem to be a promising tools for 3D world simplified representation, and provide meaningful for binary (obstacle – obstacle-free) representation for sightless displacements. The experimental results, using the IGS and the virtual reality bench, similar to those with Vital interface, will permit to obtain a better understanding of the possible utilization of the IGS device, to have a better description of the users needs before the IGS new version definition (and manufacturing).

The use of virtual and augmented reality is a new way offered by technological progress to test and validate new electronic aid system.

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