Multi-sensory virtual environment for supporting blind persons' acquisition of spatial cognitive mapping, orientation, and mobility skills

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ABSTRACT

Mental mapping of spaces, and of the possible paths for navigating through these spaces, is essential for the development of efficient orientation and mobility skills. The work reported here is based on the assumption that the supply of appropriate spatial information through compensatory channels (conceptual and perceptual), may contribute to the blind people's spatial performance. We developed a multi-sensory virtual environment simulating real-life spaces. This virtual environment comprises developer / teacher mode and learning mode.

1. RATIONALE

The ability to navigate space independently, safely and efficiently is a combined product of motor, sensory and cognitive skills. This ability has direct influence in the individuals' quality of life.

Mental mapping of spaces, and of the possible paths for navigating through these spaces, is essential for the development of efficient orientation and mobility skills. Most of the information required for this mental mapping is visual information (Lynch, 1960). Blind people lack this crucial information, thus facing great difficulties (a) in generating efficient mental maps of spaces, and therefore (b) in navigating efficiently within these spaces. A result of this deficit in navigational capability is that many blind people become passive persons, depending on others for continuous aid (Foulke, 1971). More then 30% of the blind do not mobilize independently outdoors (Clark-Carter, Heyes & Howarth, 1986).

The work reported here is based on the assumption that the supply of appropriate spatial information through compensatory sensorial channels, as an alternative to the (impaired) visual channel, may contribute to the mental mapping of spaces and consequently, to blind people's spatial performance.

Research on blind people's mobility in known and unknown spaces (Dodds, Armstrong & Shingledecker, 1981; Golledge, Klatzky & Loomis, 1996; Ungar, Blades & Spencer, 1996), indicates that support for the acquisition of spatial mapping and orientation skills should be supplied at two main levels: perceptual and conceptual levels.

At the perceptual level, the deficiency in the visual channel should be compensated with information perceived via other senses. Touch and hearing become powerful information suppliers about known as well as unknown environments. In addition, haptic information appears to be essential for appropriate spatial performance. Haptics is defined in the Webster dictionary (1993), as "of, or relating to the sense of touch". Fritz, Way & Barner (1996) define haptics as " tactile refers to the sense of touch, while the broader haptics encompasses touch as well as kinaesthetic information, or a sense of position, motion and force." Haptic information is commonly supplied by the cane for low-resolution scanning of the immediate surroundings, by palms and fingers for fine recognition of objects' form, textures, and location, and by the legs regarding surface information. The auditory channel supplies complementary information about events, the presence of other people (or machines or animals) in the environment, materials which objects are made of, or estimates of distances within a space (Hill, Rieser, Hill, Halpin & Halpin, 1993).

At the conceptual level, the focus is on appropriate strategies for an efficient mapping of the space and the generation of navigation paths. Research indicates two main scanning strategies used by people: route and map strategies. Route strategies are based in linear (therefore sequential) recognition of spatial features. Map strategies, considered to be more efficient than the former, are holistic in nature, comprising multiple perspectives of the target space (Fletcher, 1980; Kitchin & Jacobson, 1997). Research shows that blind people use mainly route strategies while recognizing and navigating new spaces (Fletcher, 1980).

2. THE PROPOSED STUDY

Advanced computer technology offers new possibilities for supporting visually impaired people's acquisition of orientation and mobility skills, by compensating the deficiencies of the impaired channel.

Research on the implementation of haptic technologies within virtual navigation environments reports on its potential for initial training as well as for support and rehabilitation training with sighted people (Giess, Evers & Meinzer, 1998; Gorman, Lieser, Murray, Haluck & Krummel, 1998), as well as with blind people (Jansson, Fanger, Konig & Billberger, 1998; Colwell, Petrie & Kornbrot, 1998).

In light of these promising results, the main goals of this study are:

(a) The development of a multi-sensory virtual environment enabling blind people to learn about different (real life) spaces which they are required to navigate (e.g., school, work place, public buildings).

(b) The systematic study of blind people's acquisition of spatial navigation skills by means of the virtual environment.

In the following sections a brief description of the learning environment will be presented, as well as preliminary results of the pre-pilot evaluation of it.

3. THE ENVIRONMENT

For the research project reported here, we developed a multi-sensory virtual environment simulating real-life spaces. This virtual environment comprises two modes of operation:

(a) Developer / Teacher mode.

(b) Learning mode.

3.1 Developer / Teacher mode

The core component of the developer mode is the virtual environment editor. This module includes three tools: (a) 3D environment builder; (b) Force feedback output editor; (c) Audio feedback editor.

3.1.1 3D environment builder. By using the 3D-environment editor, the developer can define the environment characteristics. These characteristics are:

- Determine the size and the form of the room.
- Determine the ground texture.
- Selected the objects in the environment (doors, windows, walls, rectangle, cylinder etc.)

3.1.2 Force feedback output editor. By this editor the developer is able to attach Force-Feedback effects (FFE) to all objects in the environment. Examples of FFE's are vibrations produced by ground textures (e.g., stones, parquet, grass etc); force fields surrounding objects; friction sensation.

3.1.3 Audio feedback editor. This editor allows the attachment of appropriate audio-feedback to the objects, for example: "facing a window", "turn right" etc.

Figure 1 shows the environment-building editor screen. The interface allows the developer to determine the different features of the target space, e.g., size, objects, FFE's and audio effects attached to the objects, ground texture.

By using the developer mode, the environment developer can built new navigation environments, accordingly to the need of the users, and to progressive levels of complexity.

3.2 Learning mode

The learning mode includes two interfaces: User interface and Teacher interface.

3.2.1 The user interface. The user interface consists of a 3D virtual environment, which simulates real rooms and objects. The user navigates this environment using the Microsoft Force Feedback Joystick (F.F.J). During this navigation varied interactions occur between the user and the environment components. As a result of this interactions the user get haptic feedback through the F.F.J. This feedback includes sensations such as friction, force fields and vibrations.

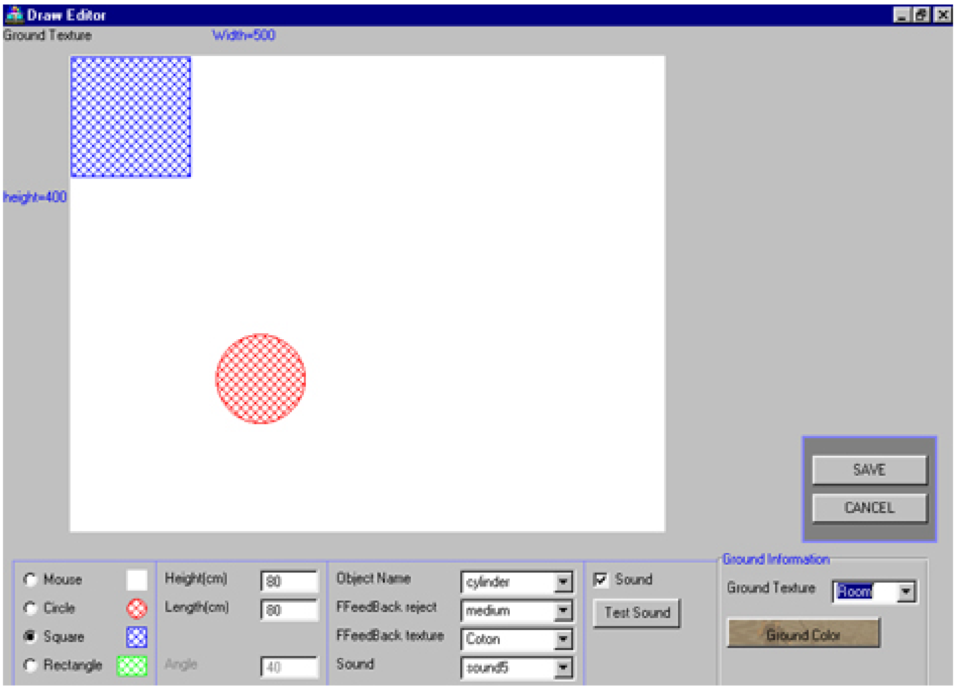

Figure 1. *3D environment builder*

By using the F.F.J the user can get information at two levels:

- Foot level – this mode provides information that is equivalent to the information that the user gets by his feet, as he walks in the real space.
- Hand level – this mode provide information that is parallel to the information that the user gets by his hand in the real space.

In addition the user receives auditory information generated by a “guiding computer agent”, contextualized for the particular simulated environment. This audio feedback aims to provide appropriate references whenever the user gets lost in the virtual space. Figure 2 shows the user-interface screen.

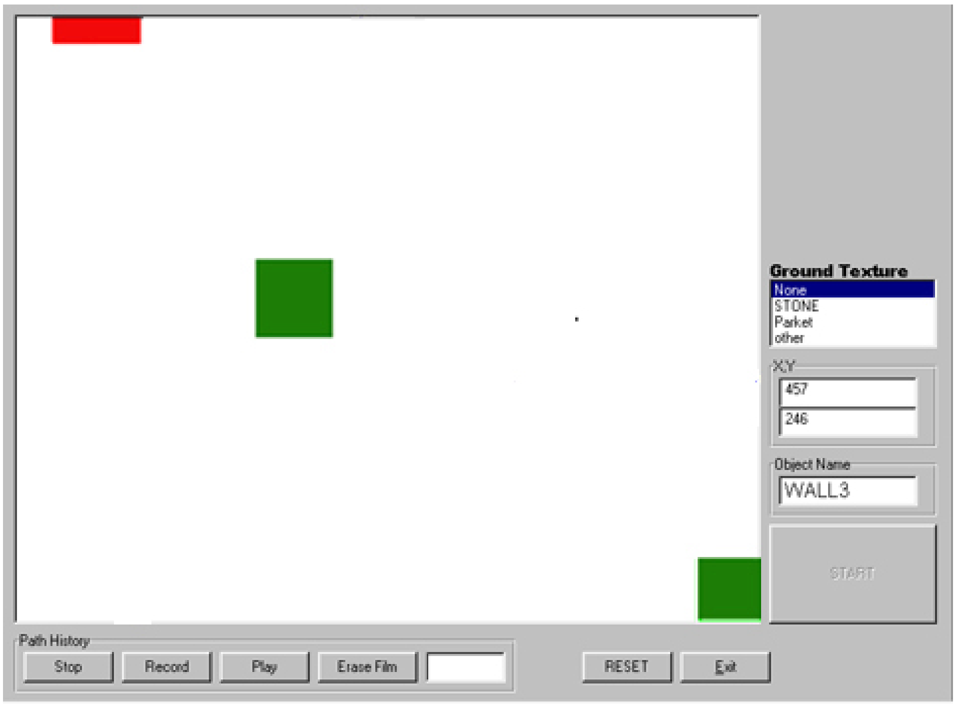

Figure 2. *The user interface*

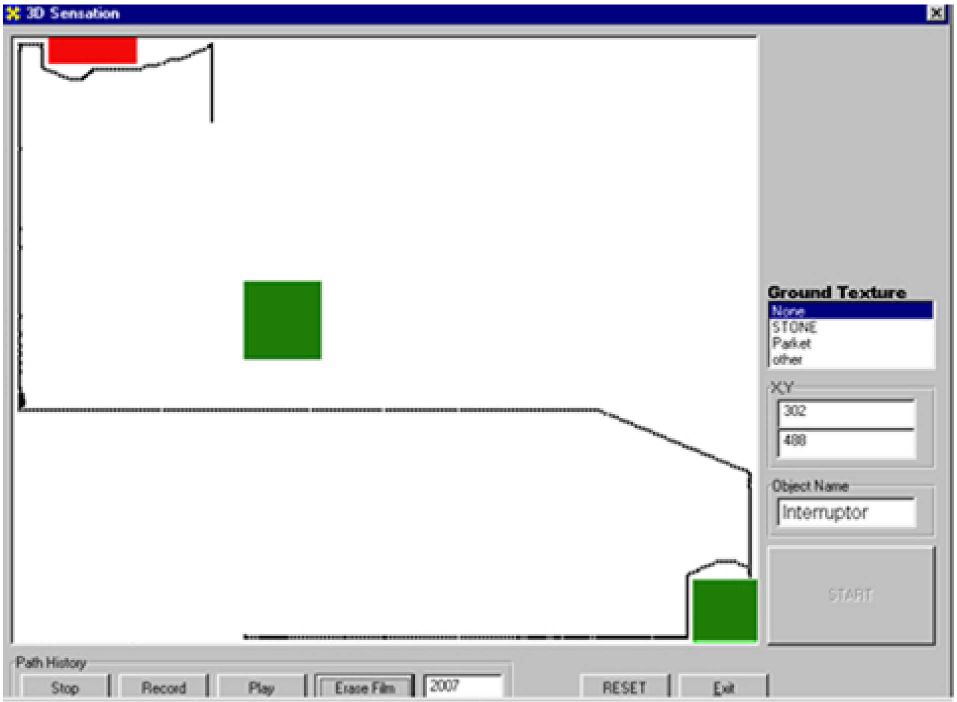

Figure 3. *The teacher interface*

3.2.2 The teacher interface. This interface comprises series of features serving teachers during and after the learning session. Several monitors on the screen present updated information on the user's navigation, e.g., position, objects reached. In addition, other functions allow the teacher to record the user's navigation path and replay it aftermath to analyze and evaluate the user's performance (Figure 3).

4. PRE-PILOT FORMATIVE EVALUATION OF THE FORCE FEEDBACK VIRTUAL ENVIRONMENT

The pre-pilot formative evaluation stage aimed to analyze the user's performance within the environment regarding three main aspects:

(a) User's response to F.F.J, and the type of FFE's that were of high effect on the user.

(b) Users ability to identify the environment's components. Two issues were addressed:

- User identification or recognition of the space and the objects.
- User's difficulties in the identification of the objects' shape and size.

(c) User navigation within the environment. Two issues were addressed:

- Environment characteristics that lead the user to high immersion-feeling.
- User's movement in the environment.

5. METHOD

5.1 Subject

The subject, A., is a forty nine years old, a congenital blind. He is a computer user for more than eleven years. A. using a cane for mobility in outdoor.

5.2 Procedure

The study consisted of two stages: F.F. evaluation stage, and navigation in virtual environment stage.

5.2.1 Force feedback evaluation stage. A series of probes were administered, at which different FFE's were tested by the subject. Data on the subject's reports was collected by direct observation of his performance, and by interview questions. As a result of this stage, a characterization of the potential value of the different

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effects for the builders of navigational environment was obtained. The F.F. evaluation stage lasted about half an hour.

5.2.2 Navigation in virtual environment stage. At the beginning of the stage the subject received a short explanation about the features of the environment and how to operate the F.F.J. The series of tasks included: (a) free navigation; (b) directed navigation; (c) tasks focussing on emerging difficulties; and (d) task aimed to probe auditory support (human feedback in this preliminary version), referring to direction, turns, and proximity to objects. As a result of this stage, a characterisation of appropriate and required features of the environment and the navigation tools was generated. This stage lasted about forty-five minutes. At the end of this session an open interview was conducted.

5.2.3 Data collection. Three data-collection instruments were used in this study. The first was a log mechanism built-in in the computer system which stored the subject's movements within the environment. In addition the whole session was video recorded. The third data collector instrument was an open interview.

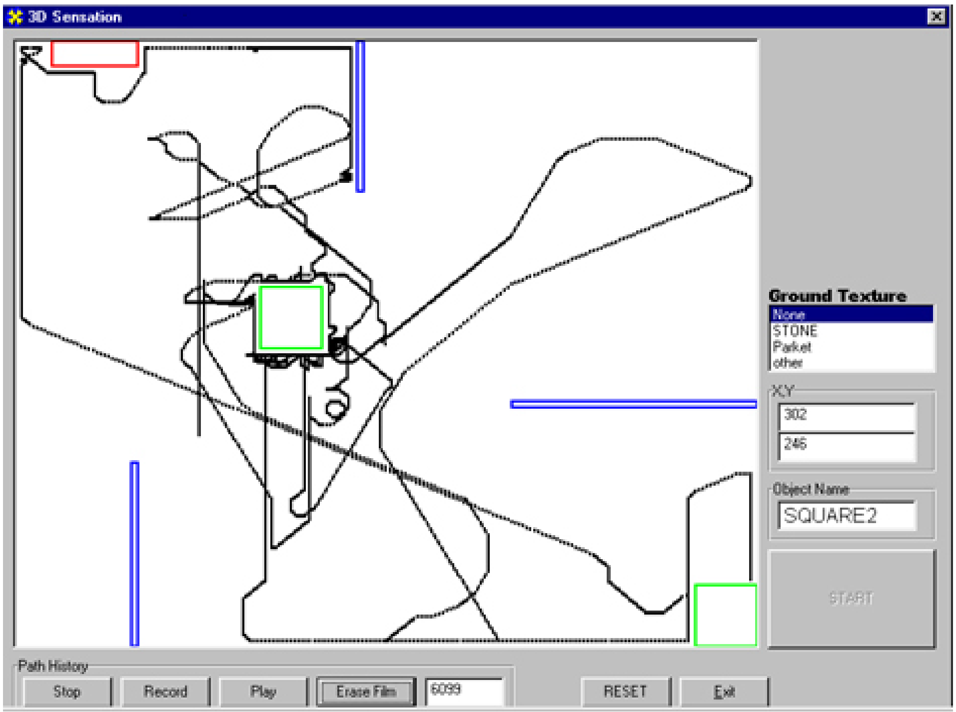

Figure 4. *Subject's navigation in the environment*

6. RESULTS

6.1 Force feedback joystick features

A. Learned to work freely with the force feedback joystick within a short period of time. During the first session A. recommended to define a magnetic force field around the objects and in front of the walls. By this magnetic force field the user can feel an attraction or repulsion whenever he approaches an object or an obstacle. The force feedback characterizations that were effective to the user were high resistance force, bumps vibrations and high frictions.

6.2 Identification of environmental components

A. could identify when he bumped into an object, or arrived to one of the room's corners. The subject could not identify the objects. As a result of the size of the objects and without a magnetic force, the subject was lost in the space.

6.3 Navigation

A. moved within the environment in a rapid response, the rapid walking cause him to get lost in the haptic space. Another reason that made him to lose is way in the space, was the walking at the environment without references.

Figure 4 shows the intricate paths in one navigation task. The paths unveils situations at which the user got trapped in corners, lost referential landmarks in the space, or in contrast, his attempts to grasp the object from all angles.

The pre-pilot probes resulted in the devise of several required improvements:

- Enlargement of the objects.
- Improvement of the resolution of correspondence between the movement and the force feedback.
- Introduction of friction effects for walking along the walls.
- Reduction of allowed navigation velocity in the environment.

At the time of the conference, detailed results from the actual study as well as preliminary conclusions will be presented.

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