TOUCHING VIRTUAL REALITY
An Effective Learning Chance for Visually Impaired People

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Abstract: This paper presents a Virtual Reality (VR) system that allows visual impaired users to explore Virtual Environments (VEs) by a haptic/acoustic interaction. The system may have many interesting educational applications: indeed visually impaired people can access and learn informative contents conveyed by opportunely designed and rendered 3D VEs. Moreover a visual 3D scene editor allows domain experts, responsible of the learning process, to design the VE even if not well grounded in VR. This tool enables an easy prototipization and a fast modification of the haptic/acoustic rendering to fit users feedback: therefore the design of the learning experience arises from the cooperation of the domain expert with the final users.

1 INTRODUCTION

Virtual Reality can help visually impaired users to learn information expressed as 3D virtual environments (VE), which can represent objects shape but also more abstract concepts.

Haptic devices such as PHANToM (Massie, Salisbury, 1994), gestures inputs such as CyberGlove (Immersion), TextToSpeech and Speech Recognition technologies enable more intuitive and natural Human-Machine interaction. Force feedback, besides traditional auditory and visual rendering, allows the tactile manipulation and exploration of interactive 3D virtual objects.

Haptics and VR have been investigated to enhance the learning of concepts involving three-dimensional spatial data by sighted students (Jones, Bokinsky, 2002). (Magnusson, Rassmus-Gron, 2005; Yu, Brewster, 2002; Jacobson, 2002) present valid educational haptic/acoustic VR applications for visual impaired users: they facilitate the comprehension of information usually conveyed by physical artefacts, less effective and more expensive.

VE can offer several views of a scene to convey the information of interest in an ordered and progressive way. Haptic and acoustic effects make easier to acquire and comprehend the characteristics of 3D view, improving their integration into a meaningful mental schema.

The proposed multimodal system (OMERO) combines the use of touch, vision and hearing for the exploration of multiple views of 3D virtual environments. Blind and seeing people can share their knowledge by experiencing (each with its own interaction modality) the same virtual scene.

The VE must be designed by domain experts to make simple and effective the cognitive process. A visual editor enables inexpert users to associate the multimodal description (MD) to a virtual scene. It also involves in the design process the final users whose feedbacks drive the customization of the MD.

OMERO has experimentally proved to be an effective learning tool in several different domains.

2 THE OMERO MULTIMODAL FEATURES

OMERO has been designed to offer an enhanced multimodal virtual experience whose aim is not to mimic the interaction with physical objects by the exploration of their approximated digital versions. Its goal is to design a digital representation of reality whose information contents and characteristics make easier and more effective (in particular for visually impaired people) the perception, the comprehension and the learning of contents that can be expressed as spatial data.

The user seats in front of the multimodal workstation (figure 1) and interacts with the virtual world via the haptic device, the keyboard and the

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audio speakers. The PHANToM desktop, a single point haptic device, allows the user to perceive the scene as if he\she were touching a physical scaled model placed on the desk with a pencil-tip. Multimodal effects (haptic and vocal) enhance the interaction. Moreover, seeing people can communicate with blind user: the model is visually rendered on the screen and a red sphere shows the current 3D position of the haptic device tip in the virtual world. The point of view of the visual rendering can be changed by suitable GUI commands (thumbwheels or a “bring me to” button) to appreciate the avatar movements but does not affect the stability of the haptic reference system.

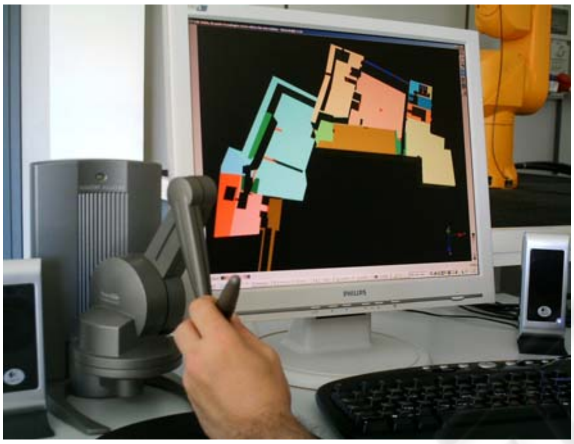

Figure 1: The exploration setup.

The MD of the scene is fundamental for an effective learning process and influences data representation and data retrieval.

Data Representation defines type and amount of information represented by the virtual scene, their mapping to 3D components of the virtual world, their organization in several semantic views.

Active Objects are parts of the scene that activate a specifically defined action when touched by the user. Haptic interface can generate tactile effects (such as vibration, viscosity, …) that can convey further information beyond shapes. Active objects can be haptic, acoustic or haptic/acoustic and can provide data (i.e. historical/ artistic descriptions, dimensions, material, etc.) by vocal messages.

Active objects can be dynamic; their dynamic behaviour can be activated either automatically whenever the user touches them or on demand by proper commands.

Scenarios try to overcome the serial nature of touch, which does not provide a quick and unitary perception of scenes as sight does. A complex virtual world, rich of details, generates long sequences of local perceptions that are hard to integrate into a coherent meaningful mental schema. Scenarios are sets of active objects representing semantically consistent and coherent views of the information content of the scene. When the user selects a scenario, he\she focuses on the information associated with its active objects, temporarily discarding all the other data.

Data Retrieval concerns how the user interacts with the virtual world: the navigation (how the user can move inside the scene) and the exploration (how 3D objects transmit their associated information).

The following features support the **navigation** task and facilitate the visit of the scene:

Containment box: a virtual box surrounding the scene to prevent blind users from moving too far from their goals. It has proved to avoid the waste of time in useless regions of the workspace. It also makes easier to find the objects of interest.

Guided path: a sort of guided visit around the virtual environment. Suitable attractive forces drive the exploration along predefined paths (De Felice, 2005). It proved to be valuable to become familiar with the scene and to build complete and effective mental schemas.

Dragging: can dynamically select which part of a large model is shown in the workspace. Inside OMERO the haptic stylus can drag the virtual scene or the containment box (by pushing on its walls).

Scaling: dynamically changes the relative size of the model with respect to the user fingertip (that being fixed in the real world can prevent the perception of small details). Increasing the size of a model makes accessible small details and reduces the dexterity required for their correct perception. Scaling, if the user is touching an object, is applied with respect to the contact point to keep a meaningful reference that prevents the user from being confused by the environment changes.

Similar dragging and scaling techniques can be found in (Magnusson, Rassmun-Grohm, 2003).

3 MULTIMODAL DESCRIPTION

Multimodal rendering can provide information through different sensory channels (redundancy) and in alternative forms (polymorphism). The MD (“how” the rendering is done) has been decoupled by the structural description of the virtual scenes (“what” is rendered). Thus the same geometrical representation can be rendered in different ways by modifying the associated multimodal rendering.

The system loads a VRML file containing all the information about the geometry of the virtual scene and an XML file, based on a schema called OMDL (OMERO Multimodal Description Language), that describes the multimodal appearance of the scene.

Creating complex virtual scenes is a difficult task (Magnusson, Rassmus-Grohm, 2004). Proper tools are required to make faster and easier this design phase. VRML models can be created using several applications (CAD system, Google SketchUp, etc.). A visual editor, providing an intuitive and straightforward authoring of rendering, has been developed (figure 2).

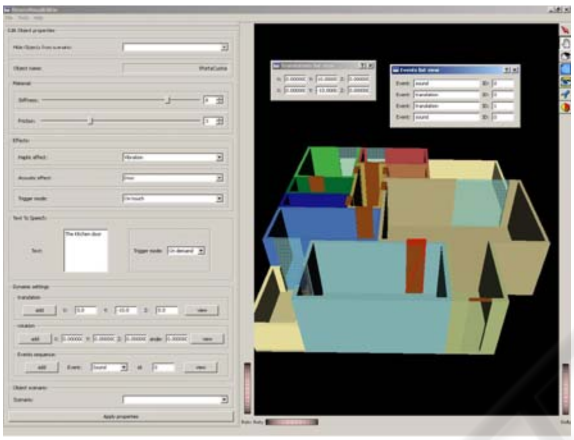

Figure 2: The look and feel Visual Editor.

Contextual menus allow the user, even not well grounded in VR, to visually edit active objects and scenarios using the mouse or the haptic tool. People responsible of the learning process and the final users cooperate in the design: the former select solutions fitting their cognitive aims, the latter provide feedback about the multimodal rendering.

4 OMERO APPLICATIONS

The previously described features of the system have been implemented and verified in different fruitful educational applications.

Svevian Castle. A VRML model of the accessible areas of the ground floor of the Norman-Svevian Castle, located in Bari (Italy), has been realized (figure 1). Its complex topology requires a huge amount of information to be transmitted to the user. The multimodal application has been tested, using different protocols, on two different groups each composed by four visually impaired people that had never visited the castle before (De Felice et al, 2007). The test sessions were followed by a real visit of the castle to check both the effectiveness of the proposed features and their best use to produce an intuitive and simple multimodal interaction.

The application has been also proposed, during the ‘International day of people with a disability’, to twenty blind visitors of the castle. They started with a basic model representing the whole plan of the castle with active objects highlighting passages between different environments and then moved to an enlarged version of the main environments and of their internal objects, with the associated historical and artistic information. More than half of them experienced a more conscious real visit of the castle due to the mental schema constructed during the virtual experience. They easily found real objects whose presence had been emphasized in the virtual model by attractive forces and vibrations. The most curiouses found really interesting and stimulating the vocal explanations on history, dimensions, buiding materials and curiosities.

A blind child with psychomotor problems was able to concentrate, to move correctly in the virtual environment and to recognize and open doors.

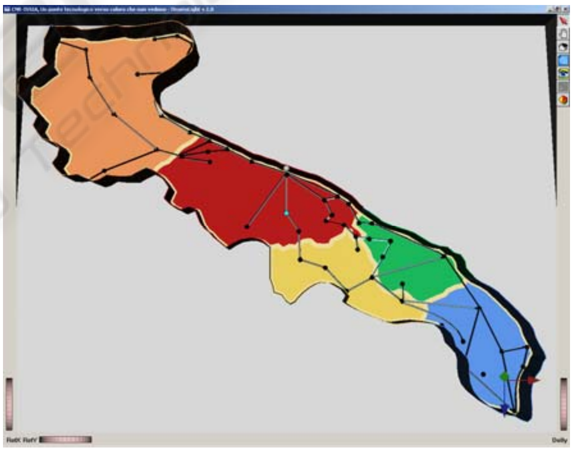

Figure 3: The streets scenario of the Apulia map model.

Geographical Map. The virtual model of the Apulia region (figure 3), constructed from GIS data, has been organized in several semantic views (provinces, rivers and lakes, towns, highways) that blind users have used to progressively build a complete mental schema of the territory.

It has been proposed to eight visually impaired users to check its potentialities (De Felice et all, 2007). Then it has been informally experienced by eleven visual impaired during a meeting of the Italian National Blind Association. Ten of them came from other Italian regions and had almost no knowledge of Apulia. The only native user, using her known contextual cues, found very easy to move through the map and judged the haptic interaction realistic and effective. Two users were unable to complete the exploration of the model: one was very tired for previous meeting activities while the other had some hands coordination problems. The other users moved through the scenarios with a growing interest, also caused by an increased familiarity with the haptic device. All the users were able to learn new information. Also the native users increased her knowledge discovering new characteristics.

This type of application received great interest from blind users, which provided many suggestions to improve the information contents and the interaction modalities of the VE.

5 CONCLUSIONS

A framework to allow visually impaired people to access virtual reality by a multimodal interaction including touch has been presented. The haptic feedback extends the visual and auditory interaction and enables the effective and efficient fruition of the information content of the virtual scenes by blind users. This multimodal interaction and the multilayered representation of the real world strongly help visually impaired people to construct a mental schema of the scenes.

The OMERO system proposes the use of virtual reality to generate an augmented experience that conveys information of different nature (shape, geometric, abstract concept) in an integrated and compact way.

The experiences made with blind users suggest that the multimodal interaction needs to be tailored to the specific user: the OMDL schema allows a quick and easy design and implementation of rendering without affecting the geometrical structure of the virtual scene. A visual editor allows this design to be made also by domain expert without specific preparation about virtual reality.

Almost all the visually impaired users have found natural the use of the system and have reached satisfactory results, providing positive feedback about this new tool. The approach represents a way to overcome some serious limitations of the direct exploration of physical objects and opens to the blind community new active and exciting learning opportunities.

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