Aided Exploration of Virtual Contents by Blind People
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ABSTRACT
This paper describes the main features of a multimodal application, based on haptic/acoustic interaction, that allows visually impaired people to access 3D virtual contents. We have realized a few applications addressing specific contexts, from the exploration of 3D spatial data to the fruition of cultural heritage. Several test sessions, involving users with different stories and different level of visual disability, have been accomplished. They have shown that the haptic/acoustic interaction supported by the definition of multimodal interactive objects, the progressive access to information and guided paths through the models are a powerful tool for blind people to catch information and to enhance their knowledge of the real world.

Keywords
Haptic, Multimodal application, Disabilities, Accessibility, Virtual Reality.

1. INTRODUCTION
Every day the visually impaired community faces the problem of experiencing the real world and of increasing the autonomy of its life style. The interaction with objects that are unsuitable for the direct tactile exploration due to their dimension, sensitivity to damages (architectural or archaeological sites, statues, etc.) or abstract nature (mathematical functions or concept, graphics, 3D models of concepts from biology, chemistry, geography, etc.) mainly relies on the use of scaled physical copies, which are expensive and sometimes ineffective to convey information in a simple and direct way. Tasks involving spatial knowledge (moving in outdoor or indoor environments, planning a route, being aware of shape and location of geographical regions) are challenging for blind people. Often they access spatial information by acoustic/testual messages, by touching tactile maps annotated with Braille or exploring directly objects or environments: these approaches do not simplify the construction of a mental schema of the world. Computer aided systems can help to overcome these drawbacks: virtual reality technology provides increasing potentialities of interaction with complex environments using several sensorial modalities. The user can experience a rich and flexible perception of the virtual world: the haptic technology [1] allows the kinaesthetic interaction with virtual object, complementing the visual and auditory channels. The sense of touch is a natural interaction modality for blind people. Virtual reality is generally more flexible than physical artefacts: it can change in size and be augmented by means of artificial kinaesthetic effects (vibration, viscosity, etc.) to help the cognition. The exploitation and integration of all the different sensory channels [2] allow sighted people a richer and more satisfactory experience and people with visual disabilities a more powerful support.

We have realized some multimodal applications using the PHANToM Desktop device by which the user, handling a stylus-like object, can explore 3D virtual models as if he were probing real geometries using a stick [3]. Two relevant tests have been the exploration of the planimetry of an ancient castle and of the map of a regional territory, both heavily involving the perception of spatial data. Also the model of a part of a historical building has been proposed to blind people, offering a sort of guided path through its principal and more interesting components. The effectiveness of these applications has been widely verified and validated by groups of visually impaired users with heterogeneous characteristics for what concerns story, culture, amount of disability, and attitude towards technological tools. These experiments have pointed out some features strongly desirable in an application devoted to visually impaired users:

- **Multimodality** (haptic/acoustic) transmits information in a more effective and natural way than verbal description.
- **Active objects** can be easily manipulated by users to change their state for a more interactive experience.
- **Progressive access to information** allows the user to focus on specific informative contents at any given time.
- **Guided paths** around the objects make easier a fast exploration of the main features of the model.
- **Normalized virtual input models** identify specific informative contents and make their access dynamically adaptable and efficient.

2. EXPLORATION FEATURES
The use of multimodal interaction extends the possibilities of experiencing virtual models allowing also particular kinds of users, such as blind, their fruition. However, presenting plain VRML models to visually impaired people does not fully exploit the power of the above features. To provide the maximum support to blind, these features must be properly associated with the specific components of the model that must be organized accordingly. The following paragraphs detail the characteristics of each fruition modality as long as its motivations and its main expected improvement to the comprehension of the model.

2.1 Active Objects
The interaction with virtual models is enhanced by active objects, that have been classified in haptic, haptic/acoustic and acoustic objects. The first ones are associated with haptic effects, such as vibration, attractive forces, etc. Haptic/acoustic objects generate complex effects that combine haptic and auditory components. Finally, acoustic objects activate auditory effects. Vocal messages
can be associated with all the active objects to describe their identity and meaning. Objects can be dynamic or static (they can or not change their state). Effects related to objects are triggered by the user that, pressing the button on the stylus, can change their state or require further vocal messages to be synthesized.

The use of these kinds of objects has been widely adopted in the castle model. In this scene, trees, hedges, pots, etc. have been modeled by simple solid shapes (acoustic objects). Doors and transit areas (associated with bumps) have been defined respectively as haptic/acoustic objects involving a light vibration and a vocal information about the environments on their two sides. Doors were dynamic (open/close) while transit areas were static.

Table 1 shows the times of the virtual and real experiences. 

Table 1. Visiting times (blue for virtual visits and red for real visits) for eight users. Users from 1 to 4 have explored only a single scale model of the svevian castle during the session 1 while users from 5 to 8 have experienced also some enlarged and more detailed models of single rooms of the castle during the session 2.

2.2 Progressive Access to Information

A large amount of information provided in a unique complex model can overburden blind users, making hard its effective exploration. To overcome this problem the informative content can be distributed among different semantic layers called scenarios. In fact, distinguishing “touchable” and “untouchable” objects, these can be grouped in different classes on the basis of their semantic meaning and several separated views of the same model can be created and offered to the users by inserting/removing details from the virtual world. This dramatically simplifies the interaction with the scene, showing only the information the user wants to receive at that moment. This facility has been extensively verified on the multilayered model of the Apulia regional territory. Blind users can simply switch between different views of the region to explore in a progressive way different semantic levels: political (region borders, province borders, towns, etc.), physical (rivers, lakes, etc.), transportation network, main cities, etc. Figure 2 shows two of these layers. In each scenario, the most significant objects are active and convey information by haptic or acoustic channels. This model has been proposed to twenty visually impaired users, some of them without any previous knowledge of the region’s features, to understand the effects of the progressive access to information on the model’s comprehension. Users started their exploration on the political map, to acquire the shape of the whole region and the shape and position of each province. After a complete and accurate exploration of all the scenarios, most of the visually impaired users were able to correctly locate rivers, lakes and towns with respect to the regional and/or provincial territories and with respect to each other and to directly reach in a fast and easy way the different features (lakes, rivers, towns, etc.) they were asked to move to. The progressive access to information can really help blind people to have a complete and effective knowledge of spatial data in an active way.
2. Guided Paths around the Objects

The complete and correct integration of huge amount of tactile data into a meaningful mental model can be strongly affected by the exploration paths followed by the blind user [4]. Haptic devices can apply forces to simulate the interaction with real solid objects but also to guide or constrain the movements of the user along more effective paths. In particular, it is possible to identify some relevant details in the virtual scene and to guide the user hand towards them by suitable forces. Moreover the navigation through each component of the model can be guided/constrained to force the visit of its most relevant features. This facility allows a more natural communication between sighted and visual impaired people that can share at each moment the experience of the same sequence of object details. This facility has been verified in the fruition of a part of a historical building (the reconstruction of a pillow with a leonine head coming out from the wall in the upper side and a seat in the lower side). Two targets were defined (the leonine head and the seat) each associated with a vocal explanation of their historical meaning and value. Clicking a button on the haptic device the guided visit brings the user towards the first target. Each new click moves the user to the next target. An attractive force helps the user to remain in the point of interest. The application has been proposed to several people during an exhibition and most of them appreciated the guided tour before a free exploration of the model.

3. CONCLUSION

Virtual reality and haptic/acoustic interaction can enable people with visual disabilities to acquire knowledge about the world in a richer and more natural way, improving the quality of their life. Different applications based on multimodal interaction have been realized to fit their particular needs and the proposed interaction modalities have been validated on large groups of visually impaired users with heterogeneous characteristics. Several features (such as interactive objects, gradual access to information and guided paths through the model) have proved to allow blind people to interact and explore complex virtual environments and objects in natural and effective way. This approach does not simply make accessible digital contents (normally explored by sight and therefore beyond the capacity of blind users): its new interaction modality strongly supports the hard task of integrating the huge amount of sensorial data serially provided by touch into a meaningful and organized mental schema that represents the final result of the cognitive process. The multimodal interaction with virtual worlds can provide an experience that avoids some serious limitations of the direct exploration of physical objects, opening to the blind community many new opportunities to know the world in an active and exciting way.

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5. REFERENCES


