

# Design Criteria for Usable Web-Accessible Virtual Environments

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## ABSTRACT

We have conducted a study revealing how even important Museums in various countries have implemented virtual environments that engender a number of usability problems for Web navigators. In our paper, we discuss a set of criteria that should be taken into consideration to obtain usable virtual environments, discuss how we have implemented them in a specific case study (the Marble Museum), and show how the tools provided can help users.

**KEYWORDS:** Desktop Virtual Environment, Usability, Interactive Museum, User Tasks.

## INTRODUCTION

Usability [10] is an important dimension when developing applications for many users as is the case of museum applications. In recent years, we have seen the increasing availability of environments that allow designers to easily develop desktop virtual reality applications. Such environments have also been applied in museum web sites but usually provide results characterised by rather poor usability. This demonstrates that little attention has been paid to the introduction of this type

of technique. Also previous studies of usability in museum applications [5] have not considered it.

In particular, we have conducted a study revealing how even important Museums in various countries have implemented virtual environments that engender a number of problems for Web navigators: huge files with long download times, useless introduction of graphical elements, unintuitive interaction with the 3D environment, just to mention a few of the problems identified. In our paper, we present a set of criteria that should be taken into consideration to obtain usable virtual environments and discuss how we have implemented them in a specific case study (the Marble Museum). Thus, we show how the tools provided can help users to: orient themselves, recognise the interactive parts of the application, choose from a number of flexible options for movement, receive clues about the possible information content, completely visualise the environments, and select elements to extract them from their context for further analysis. The design proposed consists of two parts, one dedicated to the virtual environment and the other one providing additional tools for

navigation and the possibility of analysing selected works of art in depth. We also report on a first usability evaluation exercise that evidenced how users like the possibilities offered by virtual environments when these have been designed following such criteria and gave suggestions for further minor improvements.

A virtual environment (VE) is a simulated, three-dimensional computer-generated environment that is rendered in real-time depending on the user behaviour [9]. Virtual reality systems can be classified depending on the level of user involvement that they support. In [1] they are classified as: non-immersive (desktop) VR, semi-immersive (projected) VR and fully immersive VR. In this work we focus on desktop VR. A desktop VR system is a virtual environment provided through a desktop personal computer. A user interacting with keyboard and mouse can manipulate representations of objects and navigate through three-dimensional environments obtained using tools such as QTVR or VRML. This type of technique is becoming easier and easier to develop, and this is facilitating its adoption in many applications, thus allowing users to ignore the physical distance and navigate in realistic representations. It also becomes important to identify a set of design criteria in order to guarantee usability in this type of application. Otherwise the introduction of such techniques would be just an additional decoration with low usability [6].

More precisely, in this paper we discuss a set of design criteria for usable Desktop VR with particular attention to museum applications. We also show examples of application of such criteria to the virtual visit of the Marble

Museum. This set of criteria can be applied to any desktop VR applications that are used by a single user at any given time. Independent of the software used for the implementation, such applications are composed of multiple environments with a number of objects located inside each of them and support multiple viewpoints, with the possibility of navigating across them.

The paper is structured in the following manner: we first discuss the limitations of current approaches to using desktop VR in museum applications; next, we propose a set of design criteria for usable desktop VR applications and then show how we have applied them in our case study. Lastly, some concluding remarks are given.

#### **EXAMPLES OF LIMITATIONS OF CURRENT APPROACHES**

If we analyse museum web sites that provide virtual environments we can notice that these 3D environments often have a marginal function because their possible use does not improve the access to works of art; they do not give a precise idea of how the museum is structured or what can be gained by a physical visit. An example of these limitations can be found by visiting the web site of the Museo della Scienza in Firenze ([http://www.unifi.it/unifi/msn/geopa/qtv\\_r\\_ita.htm](http://www.unifi.it/unifi/msn/geopa/qtv_r_ita.htm)). Here, a web page attracts the user by offering the possibility of performing a virtual visit through a QTVR representation. However, users start the visit after having downloaded all the plug-in required, they find a page such as that in Figure 1, where they realise that the virtual visit is just a 3D representation of a room where it is possible to change the viewpoint but that does not improve access to the related information. Moreover, it is not possible

to perform such simple tasks as selecting an object and receiving a related description, receiving information regarding the room, or exploring the room in a satisfactory manner (there is no indication on how to change the viewpoint or zoom in and out).

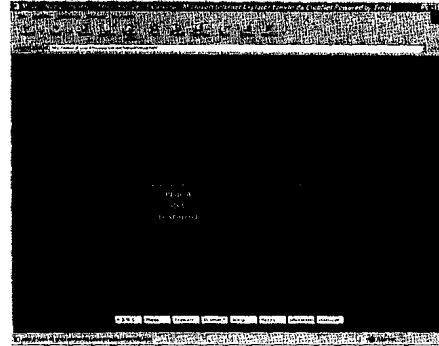


**Figure 1: Museo della Scienza web site**

This type of 3D environment, which we have also found elsewhere (see for example <http://geoweb.berkeley.edu/Geoimages/QTVR/ThematicLists> and [http://www.vps.it/home/web/horne\\_credits.html](http://www.vps.it/home/web/horne_credits.html)) is useless.

Other types of problems can be found if we consider sites such as that of Museo Nazionale degli Strumenti di Calcolo, where virtual environments obtained by QTVR aim to show the rooms before and after the restoration. As can be seen in Figure 2, first the user is asked whether he wants to access the museum as it appears before or after the restoration. At this point, we can notice that there is no indication about the use of three-dimensional movies or the plug-in required to render them or the links where it is possible to download them. Once users perform the initial choice,

the application presents a 3D environment representing the outside of the museum and below a list of links corresponding to the environments that can be visited.

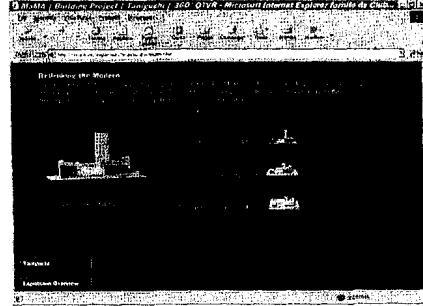


**Figure 2: Museo Nazionale degli Strumenti di Calcolo web site**

Once an element of the list has been selected, a new virtual environment appears but, as Figure 3 reveals, there is no indication of what the available environments are (where they are located, what they contain, ...), nor is there even a meaningful name to help the user to get oriented and understand what may happen if they select one link. Another problem is the inability to move directly from one environment to another instead of referring to the list of links. This example shows again how the basic principles of usability (efficiency, easy of learning and satisfaction) are often ignored when virtual environments are provided.

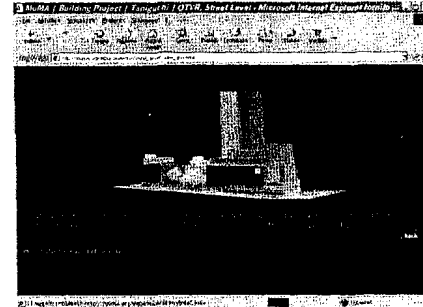


**Figure 3: Museo Nazionale degli Strumenti di Calcolo web site**



**Figure 4: Museum of Modern Art web site**

Another usability problem is highlighted by the site of the Museum of Modern Art in New York. As can be seen in Figure 4, they provide virtual environments whose QTVR files are about 500 Kbytes, whereas it is possible to reduce them to about 100 Kbytes still providing acceptable quality. A non expert user or one not interested in a perfect quality or with a slow connection can be frustrated by the long wait to obtain a representation that could be rendered by a smaller file using a more careful compression. The size of the files and the possibility of offering various sizes is something that is rarely considered when virtual environments are made publicly available. In addition, as in this example, the quality of the resulting environment does not reward the long wait. As we can see from Figure 5 the graphic does not provide the level of detail to justify the 500K bytes.



**Figure 5: Museum of Modern Art web site**

There are sites where the problems that we have just mentioned do not occur. An example is the Louvre Museum that provides a pleasant visit supported by an accurate map with the possibility of downloading movies of various sizes (see Figure 6), however it does not support the possibility of moving from one environment to another one but still requires referring back to the map. This can create problems for users: suppose that users while accessing an environment can see some parts of another one through an open door. It would be better to allow them to directly select the door and activate the representation of the next environment, whereas the solution offered by the Louvre Museum requires them to select



rarely supported and usually it is necessary to use a map or a list of links for this purpose;

- Such environments rarely support the ability to select a work of art and analyse it in a detailed and exclusive manner without interferences with the surrounding environment.

**DESIGN CRITERIA FOR USABLE DESKTOP ENVIRONMENTS**

In order to introduce our design criteria we start with a set of task types that are particularly relevant in Desktop VR applications: navigation and orientation, object selection and object manipulation. We have considered the Esposito classification of task spaces for virtual reality [3] and have focused our analysis on those that are more relevant to the class of applications that we consider.

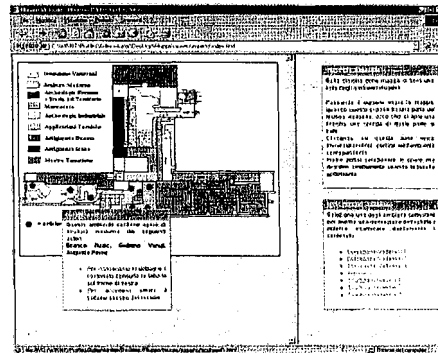
**Navigation**

From childhood, humans like exploring environments. In virtual environments it is particularly important to make navigation and orientation easy. Mice and keyboards were not designed for these types of activities. Thus it becomes important to design user interfaces that facilitate them. First, we need to improve our understanding of what navigational tasks are in this context. They can be classified into:

- Navigation without knowledge, the user has a goal but does not know the location;
- Navigation with knowledge, the user has a goal and knows the location;
- Exploration, the user has no precise goal.

Users in a VE often find themselves in unfamiliar surroundings and so the

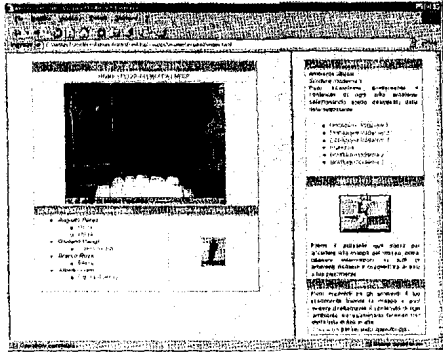
efficiency of their performance depends on how well they can understand the spatial structure [4]. It becomes important to give support to orientation and navigation. As a consequence of the above distinction, it is important to guarantee various navigation modalities. Indeed, if users know what work of art they are looking for, then it is important to have interaction techniques that allow them to easily orient themselves, rather than exploring systematically all the possible environments. Vice versa, if users are exploring without a precise goal then they prefer the ability of freely moving from one environment to another one.



**Figure 8: A map with related information**

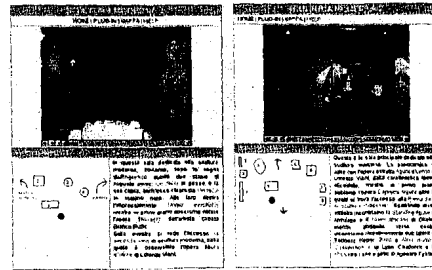
In the first case, users need some orientation tool supporting the search. Figure 8 shows an example where a map can be activated from the user interface, composed of active sections that display a window showing the works of art located in the related room when the cursor moves over them. Thus, once users have identified the room they just have to select it in order to access the part of interest. Such orientation tools should always be available, because at any time users may want to change the

task, for example from exploration to search. In the second case, we can suppose, for example, that the user is in a room and sees the access to another room. It would be frustrating to have to select the map to access it. Figure 9 shows an example solution to this problem.



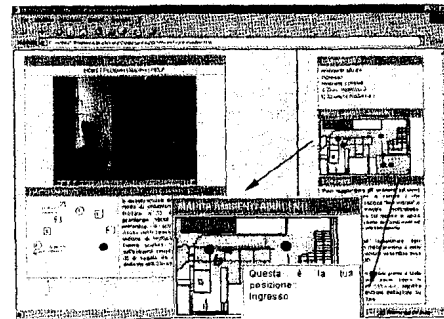
**Figure 9: Access to another room by direct selection.**

As we have seen understanding spatial relationships is an important aspect in designing desktop VR. Sometimes there are rooms (or more generally environments) that contain several objects and connected to other rooms, whose relationships are not easy to understand. To overcome this problem, it is important to support carefully chosen multiple viewpoints in order to guarantee a complete view and enhance understanding of the relationships. To this end, it is important to be able to arrive at complementary views and have some reference points supporting navigational tasks.



**Figure 10: Example of complementary views**

More generally, it is important to provide frequent directional suggestions. For example, in our application (see Figure 11) the user has always available a small map indicating the current position and adjacent environments. Annotating the virtual environments with meaningful labels is also useful to support them in understanding the environment.



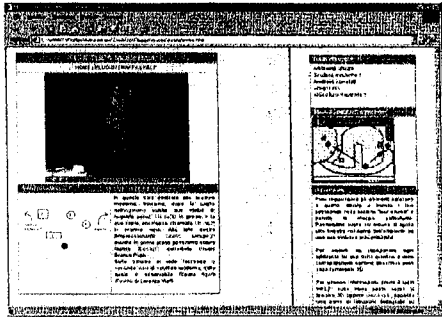
**Figure 11: Example of interactive small map indicating current position**

**Object selection**

Object selection is another type of task that can often be performed during interaction with a VE. This is particularly important in a museum visit where people like to select works of art and interact with them. To support object selection they should be easily

distinguishable, their representation should be clear and the objects selectable should be clearly highlighted. A possible implementation of these criteria is to have lists of selectable objects with a related map and when one element is selected then the related position is highlighted (see Figure 12).

Thus, we support another useful design criteria: supporting multiple techniques to select an object (direct selection in the virtual environment, selection from the list, selection from the map). This multiple possible ways to perform selection is useful because each technique is more appropriate in a specific context. For example, there are cases where users do not want to inspect all the room but just want to access one specific work of art contained in it, thus it is better to enable them to access immediately it without having to explore all the room.



**Figure 12: Representation of objects and related positions**

Another important aspect is to provide information regarding the selected objects, before the user interacts with them. Thus the user can better understand what object is considering and plan how to interact with it [7]. For example, our museum application allows users to check if the work of art selected is really the desired object. Some short

related information at selection time allows users to immediately deselect it in case of wrong selection. Figure 13 shows an example of implementation: when moving the cursor on the icon then a window with title, author and its location in the 3D environment appears.

Users of Desktop VR usually select objects in order to manipulate, modify or receive information about it. In museum applications people do not want to modify the objects of interest, however the possibility of interacting with them and receiving related information should be carefully introduced in order to improve their usability. In these applications one important aspect in the interaction is the possibility of extracting an object from its context and manipulate it to better analyse some details. Wickens and Baker [12] propose other criteria for the interaction with objects of interest (accurate reconstruction, multi-modal interaction, and pertinent viewpoint). In our case these criteria mean possibility of manipulating an object allowing the user to focus on interesting details and support of viewpoints that enable a clear and complete analysis of the works of arts. Another important aspect is to minimise the downloading time.



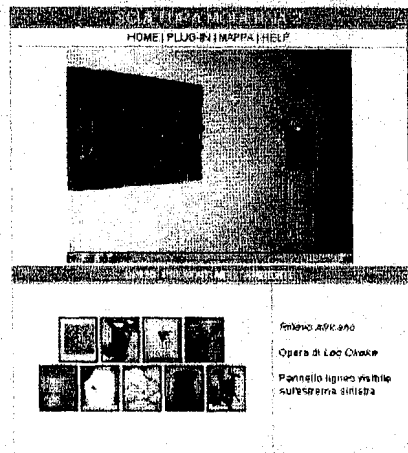


Figure 13: Dynamic presentation of information related to a work of art

**EXAMPLES OF APPLICATION OF THE DESIGN CRITERIA**

In our application we have implemented a design that takes into consideration the main types of tasks that people want to perform in Desktop VR: navigation, object selection, object manipulation. We can notice that the first two tasks regard the interaction with the context where the last one refers to interaction with the content. Thus, considering also the need for supporting an analysis of an object of interest abstracted from the visual environment we have implemented this logical structure into the user interface.

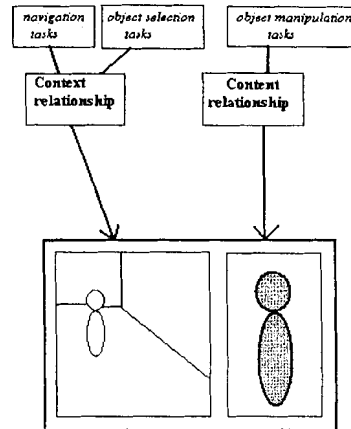


Figure 14: The logical structure of the user interface layout

Thus we have a working area on the left side with the virtual environment for the visit and on the right side the selected works of art follow each other with a tool bar supporting users in their manipulation. This solution allows users to concurrently perform the virtual visit and manipulate specific objects (see Figure 15).

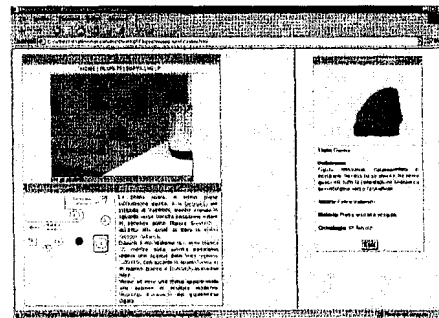


Figure 15: The implementation of the design proposed

Another design choice was to support profiles of different user that can navigate [11] in the virtual museum and interact with the work of art selected differently. The user profile can change dynamically during the user session. The application supports three types of stereotypes (tourist, student and expert) whose definition was developed after a study of museum visitors performed

with questionnaires and interviews. The differences in supporting the user profiles are in: the navigation among the rooms of the museum, the presentation of information related to works of arts, the presentation of the content of each room, and the modalities of access to the work. The diagram below summarizes the differences among user models.

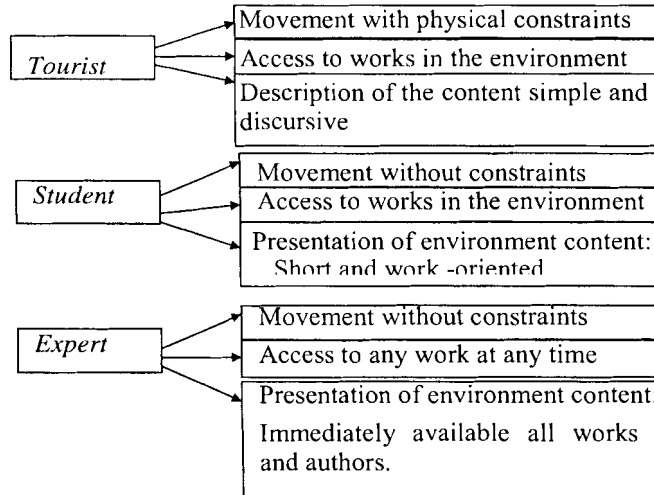


Figure 16: User models considered

The navigational style depends on the current user model. In particular, the movements of the tourist user are limited by constraints reflecting the topological structure of the real museum. Thus they cannot access rooms that are not adjacent to the current one. At any time, the application provides the tourist user with a map indicating the current position, the next environments, and the description of the current environment (see Figure 17).

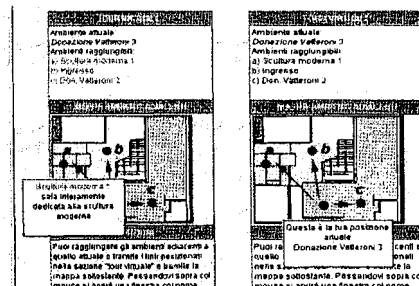


Figure 17: Representation for the tourist user

In the case of student or expert students these constraints are not provided. They are able to request the complete map of the museum and select and access immediately the place of interest. Also the tourist user can access the complete map but in this case its purpose is to support orientation and not navigation.

Another substantial difference between the expert user model and the others is in how access to works of art. In the case of an expert whose main purpose is the study of works of art, it is more important the content of the environments rather than a visit through them. To better support this, we give the possibility of accessing all the works in an environment independently from where an expert user is located. Thus, they always have available on the right side the list of environments (see Figure 18). When an environment is selected then the list of works of art contained in it appears for an easy access to them.

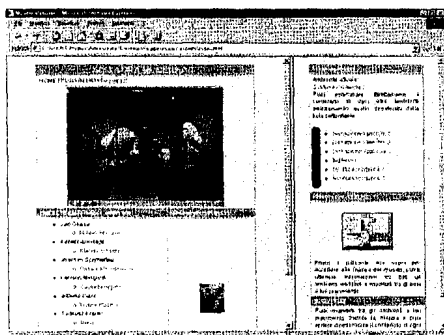


Figure 18: Representation for the expert user

The type of information presented related to a work of art depends on the current user model. Tourists often prefer not to be overloaded of information otherwise they could be bored and their attention and interest could decrease. Experts require more detailed

information because their visit is motivated not by pleasure but for conducting an in-depth study. Thus the differences among user models are in terms of amount and type of information. In particular, tourists access the basic information regarding works of art: author, material, historical period whereas experts have additional types of information such as the state of the work and further information regarding the material used. In case of students they have particular information explaining the type of work they are considering.

Also the presentation of an environment depends on the current user model. Experts would likely prefer to access the lists of authors and works of arts immediately because they may not be particularly interested in a visit but rather want to directly access a certain work of interest. In the case of tourists they probably prefer to have an overall view of the content of the environment avoiding receiving too detailed information. Students are likely to have some basic knowledge on the content, not like experts but more than tourists thus they need a level of detail intermediate between the basic provided to tourists and the specialised provided to experts.

In Figure 19 we can see how an environment and its content are presented to a tourist. Below the virtual environment there are: on the left a map with the location of the works of art identified by numbers, on the right side there is a description including the names of the works of art contained (and the related identifier) so that users can identify their position. This association is enforced: when the cursor is over the name of a work of art in the description this is highlighted and, at the same time, also the work of art in the virtual

environment is highlighted. Thus the user can understand the main features of the work of art from the virtual environment and the name and position from the textual description and the map.

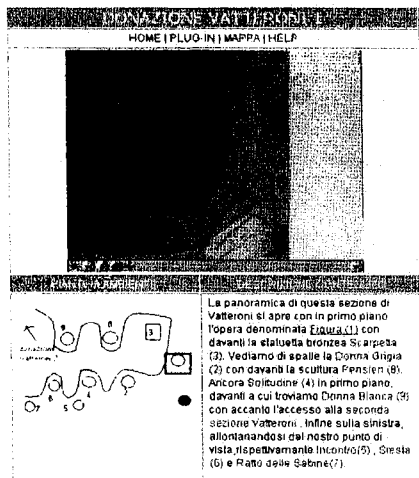


Figure 19: Representation for the tourist user

In addition, when the name of a work of art is selected then in the work area the representation is loaded and available for direct manipulation. This type of representation allows tourists to look around and receive information while navigating in the environment. These are typical needs of tourist users who often visit a virtual museum without specific goals.

In the case of expert users the interface should provide efficiently precise information. The names of the authors are available with indication of their works that are in the current environment. When the cursor is over the name of a work of art the related icon appears on the right, thus textual and visual information can complement

each other and the user just moving the cursor over the list can receive complete information regarding the content of the environment in short time.

In the case of student users, below the virtual environment there are not the names but the icons of all the works contained in it. Moving the cursor over an icon triggers the description of the work and its location inside the current environment (Figure 20, left side) otherwise instructions on how to select works of art appear (Figure 20, right side).

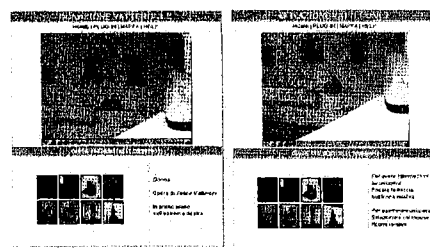


Figure 20: Representation for student users

A first usability testing has been performed even though we plan to perform more extended tests. The test was accompanied with a post-test questionnaire. The goal was to check the usability of the application and to understand whether desktop VR can stimulate further interest in a virtual visit and can be useful in improve learning of the content of the museum.

In the test users first received some short introduction on the application and the goal of the test. Then they had about 30 minutes to navigate in the application without specific goals and suggestions on what to do. Lastly, they had to fill in the questionnaire.

This first test involved 20 users (11

males and 9 females) with different levels of education and jobs. The questionnaire aimed to gather information regarding how long took to understand how to use the system, the frequency in the use of the help bar, efficiency of the help bar in supporting the users. Most users judged the learning time adequate to the complexity of the application, the help bar has often been used and it was useful except in a few cases: some users had problems to go back to the room previously visited because they did not recognise from which door they got in or the origin room from the map. This would suggest the usefulness to introduce a sort of back button also at room level.

From an analysis of the percentage of users who preferred the various techniques in changing environments it is possible to see that most users preferred the list of links whereas just a few of them choose the hot-spot (2 out of 20). This was because hot-spots were mainly used at the beginning of the navigation when users did not know the virtual environment and they aimed to explore the spatial structure but, once they were familiar with such structure they tended to move with precise goals (see again a certain sculpture, go back to a certain room, etc.) and to reach such goals they found more efficient the use of links.

The map was often used for orientation but rarely to support navigation. All users used the map at least once to orient themselves and it was useful to allow that almost nobody got lost in the visit. Thus the map confirmed its importance to support orientation but it was less useful as a tool to support navigation.

## CONCLUSIONS

We have seen how often the user interface for desktop VR is not carefully designed with consequent low usability of the resulting environments. However the increasing facility to develop such environment provides an opportunity that should be better exploited. Thus we have introduced a small set of simple but important design criteria to follow in designing such environments and then we have discussed an example of its application to the web site of the Marble Museum. Such criteria can be used as a checklist for designers and developers of museum web-accessible virtual environments in order to obtain usable results. Further work will be dedicated in performing empirical testing of the design criteria that we propose.

## ACKNOWLEDGMENTS

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## REFERENCES

1. Cronin P., "Report on the Applications of Virtual Reality Technology to Education", HCRC, University of Edinburgh, 1997. URL <http://www.cogsci.ed.ac.uk/~paulus/Work/Vranded/vr.htm>
2. Darken R.P. and Silbert J. L., "Wayfinding strategies and behaviors in large virtual environments". In *Human Factors in Computing Systems, CHI '96 Conference Proceedings*, 1996.
3. Esposito C., "User interfaces for virtual reality systems". In *Human Factors in Computing Systems, CHI '96 Conference Tutorial Notes*, 1996.

4. Gabbard L.J., Hix D., *A Taxonomy of Usability Characteristics in Virtual Environments*, Department of Computer Science, Virginia Polytechnic Institute and State University, 1997. URL <http://csgrad.cs.vt.edu/~jgabbard/ve/taxonomy/>
5. Garzotto F., Matera M., Paolini, P., To Use or Not to Use? Evaluating Usability of Museum Web Sites, *Proceedings Museums&Web'98*
6. Johnson C.W., "Why Traditional HCI Design and Evaluation Techniques Fail Withn Desktop VR", Glasgow Interactive System Group, Department of Computer Science, University of Glasgow. URL <http://www.dcs.gla.ac.uk/~johnson/papers/iee.html>
7. Kaur K., *Designing Virtual Environments for Usability*, Centre for Human-Computer Interface Design, City University, London, 1998. URL <http://www.soi.city.ac.uk/~dj524/kully.html#phd>
8. Kijima R., Task H. L., "Visually coupled systems hardware and the human interface". In *1996 IEEE Virtual Reality Annual International Symposium Proceedings*, p.195, 1996.
9. Loffren C.E., Anderson T., *The Virtual Reality Casebook*, Van Nostrand Reinhold, New York, 1994.
10. Nielsen J., *Usability Engineering*, Academic Press, New York, 1993.
11. F.Paternò, C.Mancini, "Effective Levels of Adaptation to Different Types of Users in Interactive Museum Systems", *Journal of the American Society for Information Science*, John Wiley & Sons' Volume 51, Number 1, pp.5-13, 2000.
12. Wickens C. D. and Baker P., *Virtual Environments and Advanced Interface Design*, Oxford University Press, 1995.

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