Reconstructing Leonardo's Ideal City - From Handwritten Codexes To Webtalk-II: A 3D Collaborative Virtual Environment System

Thimoty Barbieri, Paolo Paolini
barbieri@elet.polimi.it, paolini@elet.polimi.it

HOC Laboratory – Department of Computer Science and Electronics
Politecnico di Milano, Italy

Abstract

Collaborative Virtual Environments are a class of desktop applications that allow the user to explore a 3D environment, being aware of the presence, the position and the activity of other users, which share the same space. In virtual environments oriented to Cultural Heritage contents, it is thus possible to envision collaboration between users, focused to learning in an innovative and intriguing way. While several CVE frameworks are present both in commercial and research contexts, most of them overlook the issue of regulating in an ordered fashion the collaboration between users to support their learning. The WebTalk framework developed at Politecnico di Milano aims at supporting CSCL via complex collaboration between peers and teachers connected to a Virtual Environment.

Based on the experience of our previous collaborative 3D projects for museums, we recently implemented a new environment, the reconstruction of the 'Ideal City' of Leonardo da Vinci, excerpted from various portions of his manuscripts. The curatorial side of the project was led by the National Science Museum 'Leonardo da Vinci' in Milan, Italy, while a team of modelers and programmers used our new Collaborative Framework, named WebTalk-II, to deploy the application. The Collaborative 3D Virtual Ideal City will be soon online at the National Science Museum's WebSite.

The project website is at the following URL: http://webtalk.elet.polimi.it

Keywords

Virtual Reality, Collaborative Virtual Environments, Computer Supported Collaborative Learning, Java, Java3D

1 Foreword

Collaborative Virtual Environments are a class of networking applications that support collaboration between remote users by graphically representing a common spatial environment using 3D graphics, updated in real time to reflect the actions and the movements of each of the participants. While these applications are getting rather common in gaming, military, and engineering contexts [1], interesting results are obtained by the use of these technologies for virtual exhibitions and representation of cultural contents [2, 3]. The rationale behind Collaborative Virtual Environments - both on the technical and applicative sides - is quite complex, and we believe that real case studies are the best way to understand how this technology can be applied to museums in various research projects. In our efforts to study how Collaborative 3D Environments for a Cultural Heritage application can be designed and deployed, and which are the basic enabling technologies that can be used, our labs developed a theory of collaboration and some proprietary frameworks to support them, nicknamed WebTalk-I and WebTalk-II [4, 5], mostly built with Java, VRML, and Java 3D. We developed several test museums, and some of the applications have been deployed on real sites to examine results.

In a partnership with the National Science Museum 'Leonardo da Vinci', which followed the curatorial issues, we developed a new Virtual Cultural Heritage Collaborative Experience using our new framework, WebTalk-II. The new project consists in a 3D reconstruction of Leonardo's Ideal City, assembled from different portions the Master sketched in various of his manuscripts.

In this paper we will explain:

1. how our collaborative framework works
2. the reasons why we designed it like it is
3. some of the cultural aspects of this particular project
4. how we developed the 3D Collaborative Ideal City
5. the results we expect.

2 Collaborative Virtual Environments

During the exploration of a complex virtual environment, collaboration proves crucial to the full understanding of all its cultural aspects. In a real museum, the visit is always more enlightening and inspiring if led by an expert guide or experienced with friends, with which to exchange comments and discoveries. The same applies to virtual environments: lonely exploration of a 3D world does not differ much from solitary reading of information on a web page.

3D Networked Virtual Worlds, however, might host several users simultaneously connected to the same environment, and represent them as *avatars*, little figurines which mark each user's position in time and space. This alone allows to convey a notion of *Workspace Awareness* [6]. All participants are instantly aware of the whereabouts of other users, and of their actions, by means of a 3D representation which comes natural to everyone, as this is the same way with which we build our Workspace Awareness in real life situations.

It becomes thus possible for virtual visitors to be guided by an expert connected in real time, or follow an automated avatar in a pre-recorded guided tour. Being in a media-rich environment, it is possible to jump to related web resources linked to hot spots placed within the environment. Users can follow and lead each other, discussing the exhibits in the virtual environment, by means of a chat system, typing their questions and reading the answers. [7]

There are several software systems, both commercial and academic [8-13], that allow to support a Collaborative Virtual Environment. However, in most of them, the users meet in space and wander freely, chatting of the most diverse topics, without focusing their collaboration on working or learning something.

This is why, in our opinion, the way users are supposed to collaborate with each other, and with a virtual guide or teacher, is an issue that must be carefully planned and enforced within the system. In this way users will be able to better learn the message that the environment wants to convey. We have designed rules for collaboration, named *cooperation metaphors*, which can be enforced within a Collaborative Virtual Environment [14, 15]. Cooperation metaphors are not strictly the subject of this paper, as well as several other technical aspects of this project (such as networking [16-18]), but it suffices to know that by this concept it could be possible to program a collaboration system to support teaching and guiding users, to decide when it is question time, or when users are allowed, for example, to chat freely together, form independent groups, wander through the environment without following the teacher or the guide, pick objects around, examine and use them [19-24; 2].

3 The Technical Framework

To support the Collaborative Ideal City, we used the new version of our collaborative framework, codenamed WebTalk-II. The previous framework, WebTalk-I [5], was mainly built as a Java Applet, to be loaded in an HTML embed together with the Cosmo Player plug-in [25]. The whole system was loaded and worked inside a browser's window (Netscape or Internet Explorer). Communication between the VRML nodes managed by Cosmo Player, and the networking and collaboration layer managed by the client-side portion of WebTalk-I was handled via the EAI API. [26] The events gathered from the VRML by the client-side applet were relayed to a centralized server, which took care of distributing them to other participating users, and of maintaining up-to-date the central shared state of the users and of the environment. An application based on this framework was put online in 1999 inside the National Science Museum Leonardo da Vinci. This particular Virtual Exhibition was called "Virtual Leonardo" and encouraged visitors to interact together inside a VRML world, working and studying Leonardo's machines. [2]

From the log usage data we collected from the running system, we could understand which were the disadvantages of the framework and of the design of that particular Collaborative Cultural Heritage application [16]. Just to name a few results, 76% of visitors tried to start the system without the appropriate hardware or software pre-requisites (even if clearly stated in the login html page of the system); 50% of users that successfully logged in had trouble in using it properly, 30% did not find other people with whom to collaborate. But when people understood the system and started collaborating with each other (20% of the connections) or with an available museum virtual guide, the average connection time to the virtual world was over 53 minutes, spent visiting the exhibition and learning [27].

In our analysis, the main problems were:

1. a high technical barrier, which required users to possess technical knowledge of the requirements they should meet to use the system, both in terms of software (operating system and installation of the plug-in)

and hardware

2. poor confidence with navigation within 3D environments (how to use the mouse to navigate in 3D?)

3. a poorly populated environment. When users logged into the environment, they found very few users or no users at all. Without other participants, it is not possible to engage in collaborative activities, which is the very purpose of a Cultural Heritage Collaborative Virtual System.

To tackle all these problems, we designed a new framework, WebTalk-II, which, as already stated, we used to deploy the new cultural heritage application presented in this paper.

The new framework has been completely rewritten using Java and Java 3D [28], a graphics programming API based on OpenGL. The client-side portion is a self-installing, stand alone program. It does not work inside a browser, and it is not a plugin. Being written in Java, it also works cross-platform, and performance is satisfying. We compared our Java 3D graphic engine with a similar engine written in C++ over OpenGL, and performance is comparable, when a 3D accelerated graphics card is used.

This will allow users to click on the installation button on the Install webpage, and have the application up and running without a particular knowledge of software prerequisites. More important, the platform is proving stable across all different flavors of Windows. However, the users are still required to have some kind of 3D accelerated card on board, to experience a good level of performance.

Aiding the users during navigation and exploration of the environment is another issue to which we devoted several features of the new system. Along with a much more detailed and structured online help, provided with a standard user interface, it is possible to use automated helper agents within the virtual world. These agents detect particular situations which may identify difficulties or problems of the users (e.g. a user has logged in but his avatar is not moving in any direction). The avatar of the agent approaches the user which needs help and provides information. The user can also ask for information, questions or directions. Several visual tips were also added to the user interface. Since we did not rely anymore on Cosmo Player or a browser, we could implement any navigational interface we needed. Moreover, all additional controls provided by the browser, not strictly related to the virtual navigation, (like, for example, the Back button or the Update button of the browser) were not there anymore to confuse the user.

A third issue was populating the world. As we think this simplified version might encourage a more intense usage and thus allow for a bigger number of users within the virtual environment, we also added a mechanism for automated agents, which can follow prerecorded paths. These can give the impression of a more populated world, and, very important, they show by example what can be done within a virtual world. They might fly around, climb stairs, use and manipulate virtual objects, and so forth. This alone is a powerful way to give human users useful tips about what can be done within the environment, without forcing them to read a textual help. Another feature to allow users to engage in collaboration even in an under-populated environment are pre-programmed virtual guides. These are robotic avatars which can follow a predesigned script. They can pick visitors up at meeting points, and guide them to spots of interest of any world, providing textual information. They also pause and turn back when the users are not following or seem lost, encouraging participation.

Another problem that arose while we were building previous 3D applications, is that the authoring workflow in constructing 3D contents for museums was not flexible enough, when using entire VRML worlds. After a VRML world was deployed, it was clumsy to reshape it or re-layout it following curatorial advices.

The new WebTalk-II system builds the virtual scene in real time, fetching the separate geometries from a database. The geometries can be in any of the most common formats currently available, be it VRML, 3DS, or Lightwave. A special XML file is used to describe how the 3D geometries have to be combined to form the virtual environment. To each object is it possible to associate particular *behaviors*. Thus, an object can be clicked to follow a 2D or 3D hyperlink, it can be manipulated, picked up, rotated, and so forth. These behaviors are in fact mobile Java code, that can be written to implement particular new behaviors for objects. In this way the system should be able to provide the flexibility needed to reuse components and code to provide different environments for different online exhibitions, that museums might want to publish through time. [5]

XML description files are also extensively used to program the aforementioned automated guided tours, and will be used to describe which collaboration metaphors have to be enforced during the exploration of the particular application. A specific editor or tool is envisioned to allow the building of the worlds, the tours and the collaboration patterns as easily as possible.

As the developing team is reaching completion of the development of this new framework,

```
<?xml version="1.0" encoding="UTF-8"?>

<!DOCTYPE PartSYSTEM"..\CML.dtd">

<Part Name=Science Museum Cloister">
   <Initial_pos X="0.0" Y="-1.0" Z="4.0"
        angleX="0.0" angleY="0.0"
        angleZ="0.0"/>
   <Object Name="Door"
     id="idNewVRWorld7"
    shared="No">
      <Geometry>
         <Location URL=scientist.wrl"/>
      </Geometry>
      <Pos X="0.0" Y="0.0" Z="0.0"
         angleX="0.0" angleY="0.0"
         angleZ="0.0"/>
   </Object>
   <Object Name=Table"
    id="idNewVRWorld22"
    shared="No">
      <Geometry>
         <Location URL="table.wrl"/>
       <Appearance URL=wood.jpg"/>
      </Geometry>
      <Pos X="-7.5.0" Y="0.0" Z="-10.4"
          angleX="0.0" angleY="0.0"
          angleZ="0.0"/>
   </Object>

</Part>
```

Figure 1: ***an example of the XML file that allows to dynamically build a virtual collaborative exhibition. 3D components are taken from the database according to these rules, and attached to programmable behaviors.***

we teamed up again with curators at the National Science Museum of Milan to develop a new testbed application, and to gather user responses to the new system.

We will now describe the cultural issues of the project, and how we developed the related online collaborative version.

4 Historical Background

Among the typical Renaissance myths, you can frequently find the Ideal City. Imagine to build a perfect, orderly and rational city, using rules and pointers to draw a strictly geometrical plan. You would obtain a wholly theoretical and intellectual city, such as frequently described by famous essayists of the time, from Leon Battista Alberti to Filarete and Francesco Giovanni Martini, up to the great architects of the 16^{th} century.

The Ideal City was aimed at exhibiting the power and wealth of the Princes, but nearly always the project remained on paper, because of the high expenses and long time of construction involved. It was easier to reshape and ameliorate the town districts surrounding the Prince's palace than building a town ex-novo.

The dream of an Ideal City also fascinated Leonardo da Vinci. He began to work at it in Milan towards the end of the 15^{th} century. Unlike his contemporaries, though, he had a more functional than geometrical approach, his main aim being to improve the quality of daily urban life.

He studied the solution to practical problems, such as traffic, delivery of provisions and bad sanitary conditions. Leonardo' studies were not fortuitous, following as they were a great plague epidemic that spread out in Milan in 1485. The medieval town in fact made it very easy for contagions to spread, due to narrow and winding streets, high population density, especially in poor districts, together with open-air sewers and big colonies of rats and parasites.

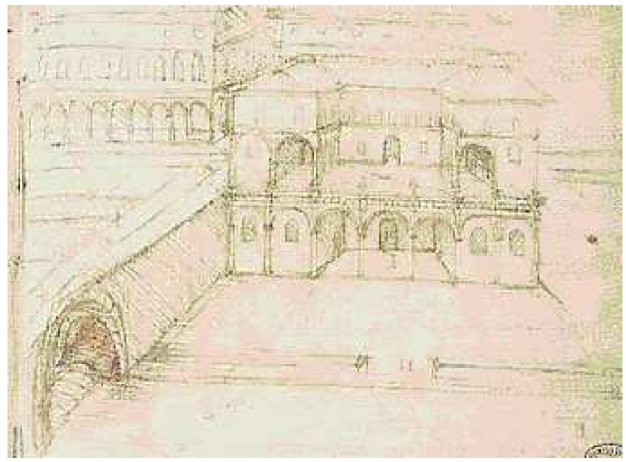

Figure 2: ***a sketch for the Ideal City excerpted from the Codex of the Institute du France. Sketches like this one were at the foundation for the reconstruction studies of Leonardo's Ideal City.***

To stand up to such dangerous hygienic conditions, Leonardo proposes a thorough remodelling of the town structure, planning large and straight streets and water canals everywhere.

The Ideal City should therefore be located near a fast-flowing river, avoiding any proximity to air-polluting stagnant waters. A system of canals, sluice-gates and locks will convey running water to the town area in order to clean it and underground conduits will be constructed for sewage disposal. Channels will also guarantee easier communications and logistic: goods in fact are transported partly by waterway, even reaching the basement store-houses of some of the greater buildings.

This system of channels fits together well with the town street-pattern, which includes roads for vehicles and people's activities and upper-level roads where only "*gentili omini*" can go. The town has in fact a double-level structure, which reflects the strict separation between people's and gentry's activities. The same pattern is found inside upper-classes residences, where the owner's family lives at the first floor, while the ground floor houses the functional rooms and opens on to a large yard and the lower street.

As Leonardo was a man of his time, no wonder he maintained a class-conscious view in this new way of town-planning. Eventually, though more functional than others, also his project was discarded, when the necessity arose of re-planning the city of Milan.

Notwithstanding, the beauty and innovation of his ideas have survived and the Museum of Science has built a small-scale model of the Ideal Town in order to revive the suggestion of the dream which took form in the artist's mind.

This model is on display at the museum, but it does not allow interaction with it and it does not provide links to multimedia information. The new 3D VR version, which will be soon made available on line [29], will allow people from all over the world to meet together inside the Virtual City and explore it in an immersive and collaborative fashion.

5 Building The Virtual City

In order to build the Virtual City, the team divided basically into three groups. The first group took care of dealing with the curators, collect their requirements, and layout all information within a conventional website, linked to the main National Science Museum site. The resources of this website can be reached from particular points of the 3D world. The Virtual Environment thus provides a collaborative access shell to media-rich information.

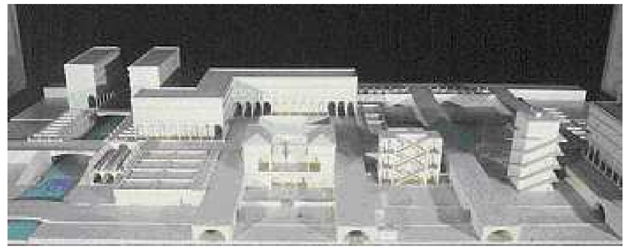

Figure 3: ***The wooden model on display at the National Science Museum in Milan. It was the starting point for the online 3D Collaborative Virtual City version.***

At the same time, the modelers' team used POVRay under Linux and 3D Studio Max to create the models and populate WebTalk's geometry database.

There were basically three kind of geometries:

1. the City Terrain, modeling the ground level of the city and the sewer system underneath. This was taken mainly from the wooden model on display at the museum, with some enhancements to accommodate some more features.

2. the Buildings; these were taken both from the model and from the sketches of Leonardo. As we considered texture-mapping them to convey a better sense of realism, the curators at the museum forbid us to do it. In their vision, as Leonardo never hinted in any of his works which materials were to be used for the buildings, the Virtual Environment should not suggest anything on this issue as well. We thus decided to cover each building with an even, plaster color.

3. the Machines; these were taken directly from small wooden models at the Museum. The modelers also studied their working principles, and built the machines with all their separate components, to be assembled later, in order to provide a completely functioning 3D virtual machine, which the users could operate at will.

The third team was formed by the Programmers. They had to write the XML files to build a particular instance of the virtual environment from the database. This stage will eventually become more user friendly as a drag-and-drop configuration tool will be finalized. They also programmed some particular Java behaviors that were needed to make some parts of each Leonardo machine work in the correct way. They then wrote some experimental scripts for the virtual tours inside the city. These will have to be reviewed together with the curators in a subsequent stage of deployment. Some basic cooperative metaphors were also implemented.

In total, the Ideal City counted over 140,000 polygons. This called for dividing the Terrain in three parts, in order to allow a smooth download of the geometries during the virtual exploration. As this mechanism is fully provided for inside the framework, it was just a matter of programming how the parts were divided and how the users were supposed to jump from one to the other, by means of the usual XML structural description.

The structural description also specified which particular portions of the buildings or objects were related to the underlying website, and which parts of the machines could be operated by the users. As part of the environment, the programmers pre-recorded several paths inside the city, and activated a few robotic avatars along them. The system could support easily a reasonable number of them (around 20), along with real users.

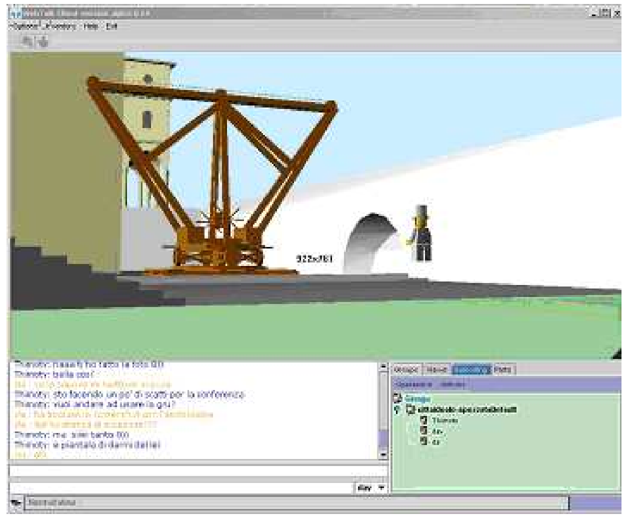

Figure 4: ***A shot from the online virtual city. A user is approaching an interactive machine and operating it. All other users are aware of his movements and his actions over this particular object.***

6 Conclusions And Future Work

As we are still defining the last details of this environment with the Curators, and refining some of its features, we expect to put the whole system online soon. The client portion will be downloadable from the main museum web site [29], and will offer direct access to the 3D city. We will log all activities of the users with the new system, to better understand if the solutions we provided were effective in relation to the problems highlighted during our previous experiences.

As we did with our previous project with this museum, we expect to support the deployment of the Ideal City with a press announcement and a

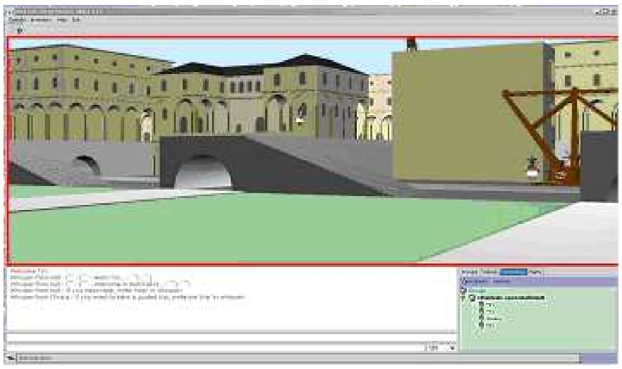

Figure 5: ***Another shot during the navigation of the ideal city. Beneath the 3D navigation area, the chat window (bottom left) and the collaboration area (bottom right) allow users to communicate with each other and with the virtual guides.***

meeting held at the museum's premises, in order to gather as large an audience as possible.

In the development agenda in the near future, we will delve even further in providing flexible and programmable collaborative mechanisms to support Computer Supported Collaborative Learning by means of Virtual Environments. As our framework is completely programmable, we expect to build more experience and insights deploying as many different applications as we can, not only in the Cultural Heritage area, but also in experimental applications in the field of e-Learning and e-Commerce.

Acknowledgments

Many people were involved in the development of this project. At the National Science Museum, Claudio Giorgione and Giuliano Gaia made the historical research and organized the content. At the Politecnico, Roberto Ciatti, Filippo Naggi, Matteo Foccoli, Davide Affaticati, Ferdinando Carella, Matteo Arru, Piergiovanni Santini, Andrea Massioli deployed the application, while the models are by Giuseppe Neri and Fabrizio Ferrari. Francesca Alonzo coordinated the content layout for the related website. Professor Paolo Paolini, at Politecnico di Milano, is the mentor of this research project.

References

[1] M. Zyda, S. Singhal, *Networked Virtual Environments*, ACM Press, 1999

[2] Paolini P., Barbieri T., et al. – *Visiting a Museum Together: how to share a visit to a virtual world*, in Proceedings Museums&Web '99, New Orleans (USA), March 99, pg. 27-35

[3] Barbieri T, Garzotto F., et al – *From Dust to Stardust: a Collaborative 3D Virtual Museum of Computer Science*, in Proceedings ICHIM 01, Milano, Italy, 2001

[4] Barbieri T., Paolini P. – WebTalk: a 3D *Collaborative Environment to Access the Web* in Proceedings EUROGRAPHICS '99, Short Papers pg. 111-113, September 99

[5] Barbieri T. – *Networked Virtual Environments for the Web: The WebTalk-I and WebTalk-II Architectures*, in Proceedings IEEE for Computer Multimedia & Expo 2000 (ICME), New York, USA, July 2000

[6] C. Gutwin, S. Greenberg, *A Framework of Awareness for Small Groups in Shared-Workspace Groupware*. Technical Report 99-1, Department of Computer Science, University of Saskatchewan, Canada, 1999

[7] Kristoffersen S., Ljunberg F., *An Empirical Study of How People Establish Interaction: Implications for CSCW Session Management Models*, in Proceedings CHI99, Pittsburgh USA, 1999

[8] *Microsoft Virtual Worlds*, available at http://www.vworlds.org

[9] *Active Worlds,* available at http://www.activeworlds.com

[10] *Adobe Atmosphere,* available at http://www.adobe.com

[11] Musse S., Babski C., Capin T, Thalmann D., *Crowd Modelling in Collaborative Virtual Environments*, Proceedings of VRST98, Taipei Taiwan, 1998

[12] S. Benford, D. Snowdon, et al. *Visualising and Populating the Web: Collaborative Virtual Environments for Browsing, Searching and Inhabiting Workspace*, in proceedings JENC8

[13] M. Hearst, C. Karadi, *Cat-a-cone: An Interactive Interface for Specifying Searches andViewing Retrieval Results using a Large Category Hierarchy,* proceedings of 20th Annual International ACM/SIGIR Conference, Philadelphia, PA, July 1997

[14] Barbieri T., Paolini P. – – *Cooperation Metaphors for Virtual Museums*, in Proceedings Museums & Web 2001, Seattle, USA, March 2001

[15] Greenberg S., Roseman M., *Using a Room Metaphor to Ease Transition in Groupware*, Research report 98/611/02, Dept. of Computer Science, University of Calgary, Calgary, Alberta, Canada, 1998

[16] T. Barbieri, *Webtalk-II: un'infrastruttura per la cooperazione sul web*, Politecnico di Milano, Thesis for the Engineering Degree, Milan, Italy, 1999

[17] Broll W., *Populating the Internet: Supporting Multiple Users and Shared Applications with VRML*, Proceedings of VRML97, Monterey USA, 1997

[18] Frecon E., Nou A., *Building Distributed Virtual Environments to Support Collaborative Work*, Proceedings of VRST98, Taipei Taiwan, 1998

[19] Schuckmann C., Schummer J., Seitz P., *Modeling Collaboration using Shared Objects*, Proceedings of GROUP99, Phoenix USA, 1999

[20] C. Cerulli, *Exploiting the Potential of 3D navigable Virtual Exhibition Spaces,* in proceedings Museum&Web 99, New Orleans

[21] Charitos, D., Rutherford, P., *Ways of aiding navigation within VRML Worlds,* Proceedings of the 6 th EuropIA Conference, Edimburgh, 1997

[22] Campbell, D., *Design in Virtual Environments Using Architectural Metaphors: a HIT La Gallery.* March Dissertation, University of Washington, 1996

[23] Charitos, D., *Defining existential space in virtual environments*, Proceedings of Virtual Reality Worlds '96, February '96, IDG Magazines, Stuttgart, 1996

[24] Bridges, H.A. and Charitos, D., *The architectural design in virtual environments*, R. Junge (ed) CAAD Futures'97, Kluwer Academic Publishers, Dordrecht, 1997

[25] Cosmo Player plug-in available at http://www.cosmosoftware.com

[26] B. Rohel, et al. *Late Night VRML 2.0 with Java*, Ziff Davis, 1997

[27] Barbieri T., Paolini P. – *Cooperative Visits to WWW Museum Sites a Year Later: Evaluating the effect*, in Proceeding Museums&Web2000, Minneapolis (USA), April 2000

[28] Java 3D Main Page available at http://java.sun.com/products/java-media/3D/index.html

[29] The National Science Museum of Milan *Leonardo da Vinci*, available at http://www.museoscienza.org