Design of Information Landscapes for Cultural Heritage Content

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ABSTRACT

The presentation of cultural heritage information is typically addressed with the use of web pages eventually integrated with specific visualization of 3d models that complete the textual information. The problem with this type of information is its extent, its complexity and the connection between the various concepts. This paper presents an Information Landscape system for the fruition of this type of information through a virtual environment, available both for desktop and immersive visualizations.

Categories and Subject Descriptors

H.5.1 [**INFORMATION INTERFACES AND PRESENTATION**]: Multimedia Information Systems - *Artificial, augmented, and virtual realities*

General Terms

Design; Human Factors

Keywords

Virtual Reality; Cultural Heritage; Visualization

1. INTRODUCTION

The increase of the available Internet bandwidth, and the improvements of the graphic capabilities of personal computers have allowed the access to large datasets of information, in the form of documents, photos and videos. The fruition of this information happens through the standard Web Browser interface that focuses the attention of the user on a single page at time along the paradigm of hypertexts and hypermedia.

The information related to Cultural Heritage, instead, is complex both in terms of structure of the relationships among the various entities, and also complex in terms of the underlying media. The understanding of art related technique, and the productions in a specific area require an intense browsing of the hypermedia. The alternative possibility is to present the same information in an immersive way, allowing the user to navigate in the information using the paradigms of virtual environments.

The focus of this work is indeed in the use of immersive systems for the fruition of content, using one particular metaphor of visualization, the Information Landscapes, that are based on the abstract presentation of information in the three dimensional space. The aim of this type of virtual environments is to place the user directly in the information and to allow him to navigate around for improving the understanding and learning process.

The construction of this type of landscapes, apart being helped by the use of automatic tools and authoring systems, requires a preliminary design effort by the landscape developer. The paper presents the design process and the decisions in the construction of an Information Landscape for Cultural Heritage content, focusing on a case study for showing the results of such an analysis. The case study is related the presentation of a particular educational content, the graphic art's collections in the Lucca's area from XV to XXI sec, which cope well with the IL visualization paradigm features. In fact this content is constituted of information inherently bi-dimensional which can benefit from being organized in the 3D space, with a particular care on data structures and connections, in order to improve the effectiveness of the communication.

The paper is structured as follow. The second section provides an introduction in the area of immersive technologies for Cultural Heritage and the concept of Information Landscapes. The third section presents the design process and the guidelines in the construction of an information landscape. The fourth section is a case study of such a design, introducing a specific example. The fifth section completes the description of the case study with some detail of the technological implementation of the system.

2. RELATED WORK

Cultural Heritage is an important resource for any country from several perspectives. Whether it deals with paintings, sculptures, monuments or other artifacts, wear and tear of time raises questions about restoration, conservation and fruition issues. Some of these questions may find an answer in the technological solutions provided by technical-scientific research. Virtual Heritage is a term being coined for the use of digital techniques to reconstruct and preserve historical monuments and artifacts. Its applications are numerous, starting from conservation [15][12], to fruition [17], to education and dissemination [32] .

An interesting survey describing trends in IT applications for Virtual Heritage [20], identified four main stages in the design and development of VH systems, namely Input Data Collection (ranging from 2D/3D scanning, photographs, video, texts, audio etc.), Data Processing, Visualization Technologies, and Applications. The analysis of the resulting diagram showed that a significant portion of the identified trends lay in the fields of 3D Graphics and Virtual/Augmented Reality for both Interactive Installations and the Web.

Several examples exist of Web 3D application dealing with Cultural Heritage, often making use of consolidated 3D (or quasi-3D) technologies like VRML or QuicktimeVR, which, however, nowadays look quite aged. Examples are the SCULPTEUR [2] project, the World Heritage Tour [27] and several virtual cities, like Saint Petersburg 300 [33] or Virtual Rome [10]. More recently the spreading of more performing rendering technologies available under the form of web browser plug-ins, along with the increasing availability of bandwidth, allowed for the realization of more sophisticated applications using large datasets and hi-quality rendering. Some examples are the 3D of Piazza dei Miracoli [9] and the Pure Form Museum [31] (which enables even haptic feedback to virtually touch digital sculptures) that make use of the XVR technology, Playing the Past [21], making use of the Quest3D technology, or Keops [1], based on the Virtools technology. Besides web applications, there are also interesting applications of real-time 3D graphics to Cultural Heritage which need dedicated clients, the most famous being Second Life-based virtual museums [28] which are either replicas/extensions of real museums or fully virtual environments with no correspondence with real institutions.

The first stages in the development of a Virtual Heritage system lead to the realization of a Virtual Environment which the user can perceive in a multimodal fashion and which he/she can interact with. As explained, the creation stage may happen in different ways. When the environment that has to be virtually created is actually existing, it is sufficient to digitize it using techniques based on photography or on 3D scanning [15]. However it may happen that the physical object is not anymore present, or only partially existing or, in any case, impossible to digitally acquire. In this case it is necessary to make very accurate surveys in order to collect the data needed for the manual modeling of the environment [4].

Nevertheless, being Virtual Reality not necessarily anchored to the physical reality, it can make use of 3D environments which are completely synthetic. In this case the VE is a completely self-standing original environment which can be either realistic (for instance a museum or a gallery not existing in the real world [31])

or even totally abstract [6], able to offer innovative representation modes of a specimen, of an art piece or of the whole opus of an artist. In any case the Virtual Environment is designed around a metaphor of visualization, navigation and interaction of the environment itself.

In the context of abstract Virtual Environment there are various types of metaphors, and many of them have been adopted from the area of scientific visualization, with the objective of addressing the problem displaying large informative spaces [3]. Several metaphors can be found in literature, like the Perspective Wall [7], the Web Book [8] or the Cone Trees [25]. Other approaches have investigated the presentation of standard 2D web pages projected into the 3D space, like WebVRI [5].

This paper adopts the metaphor of Information Landscapes [29][30] because it give the possibility of integrating information based environments like the ones of scientific visualization with the immersive power of Virtual Environments. In the context of Information Landscape the content is presented and adapted using concepts from typography [29] and immersive systems. The layout of information in this type of system, depends on the logic structure of the data and the decision of the designer, but the power of this type of systems comes from the capacity of constructing the environment from the semantic information extracted from data [26][13][34].

Although the number of automatic tools and authoring environments, there is a strong design component that need to be addressed by the author of the Information Landscape. There is indeed the need to identify the correct layout of the information depending on the topic and the message that the author wants to give to the users. This work investigate the design guidelines in the construction of such environments, presenting the various aspects of the design associated with a case study in the area of graphic arts.

3. DESIGN

The design of an Information Landscape is a process that is focused around the selection of the visualization-interaction metaphor. The landscape defines not only how the information is presented and placed in the virtual environment, but also which is the paradigm of interaction adopted for the navigation and the fruition of the content. This approach is similar to the Model View Controller (MVC) extensively used in user interfaces and websites, with the difference that it has to take into account the complexity of the hypermedia and the three-dimensional visualization.

This process focuses on four phases:

1. Identification of the entities
2. Selection of the layout
3. Connection between entities
4. Customization of the interaction

In the first phase the major entities that want to be represented are identified as the focus of the visualization. For example books, statues or pictures. The layout in the space reflects the hierarchical, spatial and time-based organization of the information, following the fundamental design choices of the landscape's author. The third aspect is the connectivity between

the entities displayed in a variety of ways, and affecting the navigational aspect of the landscape. Finally the interaction is customized depending on the layout and the types of entities. This process can be performed at multiple levels, entering into the details of the presentation of every entity.

In this work the focus will be around three principal aspects: layouts, links and interaction.

3.1 Layouts

In particular the layout describes how the logic structure of the information is mapped into a spatial representation. Each layout define the way information is displayed, and in particular it defines a logical coordinate system that is mapped into the spatial coordinate system. In the case of the Spherical layout the coordinate system is the 3D latitude-longitude-altitude. In addition every layout describes the interaction associated to the entities in the layout and the boundaries for the visualization of the contained elements.

The selection of a layout depends on the type of data and the design decisions of the author. In particular it is possible to identify various types of common layouts:

- Page – the standard page display
- Map – entities placed over a planar map
- Sphere – mapping of information over a sphere
- Hierarchical Map – multi level map
- Solar System – information is placed in orbits
- Hyperbolic Space – hyperbolic mapping of entities
- Corridor – information placed over walls of a corridor
- Sequential – sequence of planes
- Cubic – hierarchies of cubes
- Free – standard 3D space

The description of every layout goes beyond the space of this paper, but it is interesting to present some of them that have been applied in the use case presented in the fourth section.

The Cubic Space layout is based on the concept of decomposing the space in six directions, one for every face of the cube itself. The six directions are not all at the same level of usability, and in particular floor and ceiling are less used for this purpose. Then every sub-space is decomposed again along the same principle allowing to highlight the hierarchical structure of the information. The spatial subdivision is highlighted by the use of wire-framed cubes that define the space at a certain level. Figure 1 shows both the schematic representation of the layout and an example in the landscape.
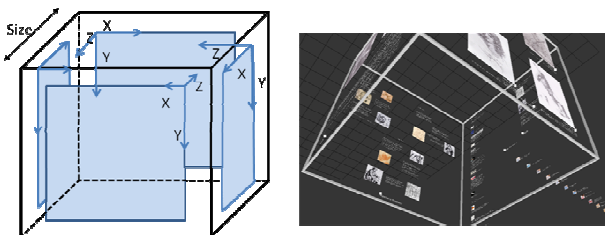

Figure 1 The Cubic layout assigns the sub element to different faces of the cube. The left image is the schematic

representation while the right image is taken from the application. Every element has a different reference system, and an associated boundary space for visualization. The same layout can be selected with faces pointing outside the cube.

The faces of the Cubic Space are based on the Page layout, that is equivalent to the page concept: entities are placed on the flat plane of the Cube face. The details associated to the entities in every Page can be placed behind the page itself, along other types of layouts. The Corridor layout places the entities on the walls of an imaginary corridor as shown in Figure 2. Finally, for presenting sequential concepts, it is possible to use the Sequence layout as shown in Figure 3.
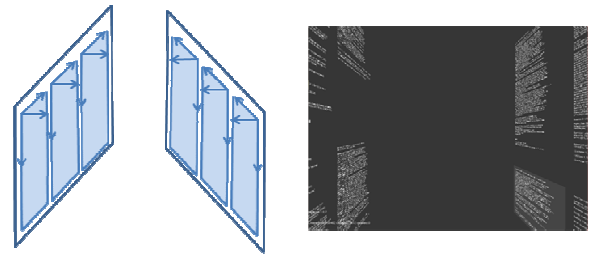

Figure 2 Corridor layout containing the details of the various elements. Every element is placed along the way of the corridor.

3.2 Links

The placement and the styling of information is only one aspect of a landscape. The other element is the design of the connections. The proposed metaphor for Information Landscapes is based on the extension of the hyperlink concept: the link is visually displayed and corresponds not only to a logic connection to a topic but to a navigation to go to a specific topic. The link is not only a point to point entity but is more a road passing by various intermediate points. The role of the designer is to define this link as defined trajectories into the conceptual space of the system, helping the user to navigate the system or showing him a pathway in the information. Figure 3 shows a case of sequence of concepts displayed along a line, and connected by the link that guides the user along the topic. In this case the layout defines the associated links.
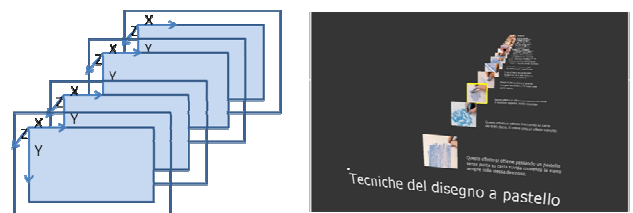

Figure 3 Sequence of elements displayed along a line. In this case the elements are displayed sequentially to the user following the link line.

The additional difference respect standard web links is that an entity can be the source of multiple links moving to different directions as shown in Figure 4.

3.3 Interaction

In terms of interaction design this type of Information Landscape is mostly devoted to navigation of the space, using four

approaches: free space navigation, focus navigation, read navigation and link navigation. The basic movement is based on the fly metaphor, that allows to move using the Mouse, SpaceMouse or Joystick. The focus navigation is obtained by a zoom operation over any entity in the space, like text, image, allowing the user to move toward the selected entity, and place him at a reading distance. This solution is typical of the zoomable interface, but in this case is effective because it aligns the user just in front of the entity. The read navigation is important in this type of landscape because there are no scroll bar, it is the user that moves respect the text, in the same way as we read a poster. This type of navigation is obtained by dragging the text, with the effect of moving the user in parallel way respect the text orientation. The last navigation mode is based on the concept of links previously exposed. When the user moves the mouse or the selection tool (in immersive setups) over an entity with links, the links are being shown allowing him the possibility of activating one of them. When a link is being activated the user is moved along the link path with the same orientation of the link curve. The navigation can be interrupted in any moment before the arrival at destination.
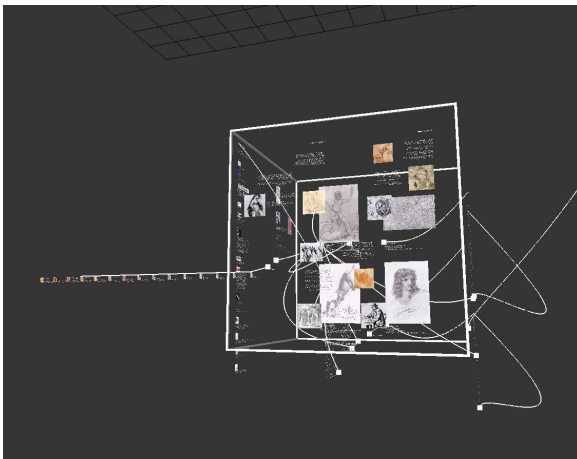

Figure 4 Example of links that connect the various aspects of the topic space.

4. A CASE STUDY

The conceived Information Landscape system applies to the case of the graphic arts collections based in Lucca (Tuscany, Italy).

This is the first attempt of building a meaningful system of valorisation and communication of this specific heritage, which exemplifies all the medium-small collections (largely diffused in Italy) of hidden heritage, i.e. not currently exposed to the general public and scattered among several different cultural institutions.

These collections witness, thank also to the presence of art works of local artists internationally renowned, the indissoluble relationship between art and territory. These assets, however, are still mis-known both for the lack of exhibition space and for the impossibility of exhibiting for a long time objects that are inherently fragile in terms of matter, in addition to the poor appeal due to the prevalent use of the black/white technique.

The communication tools commonly in use are actually catalogues, short articles and small expositions. Therefore, there is a lack of a means able to awaken the public to this kind of heritage and stimulate its interest. This is the main reason why we proposed the use of new tecnologies by levering on their most compelling features like interaction and immersion.

It is possible to access to this application also through the web, in particularly through a web site of Graphic Arts of Lucca, a thematic portal conceived in order to show an innovative and complementary approach to the art[1]. Its peculiarity – compared with the other systems on the web [11][23][22] – consists specifically in its multilevel approach, since different classes of users are concerned, from students to specialists. For each category of users, historical, artistic and technical information are provided in forms and with means which vary in relation to the different skills.

The web site has been proposed so as to render a maximum clarity of the logical structure of the information selected to the different levels of the public chosen.

The created system is modular and accessible, and makes it possible to familiarize oneself with the entire heritage of graphics of the city of Lucca as a whole or in reference to specific aspects.

The model of valorization of the heritage of the graphic art works of Lucca assembles all of the studied collections, and evaluates them as a whole: to this extent, the web results as the best tool, even if applied as a test bed. The hypothesized web interface is divided into six sections, each devoted to a public or a private collection. A menu appears on the left of the screen which permits access to the thematic areas proposed: introduction to the project, graphic arts in Lucca, the artists, the art works (divided by techniques) and the most significant themes; other areas are dedicated to the history of graphics in general and to a synthetic glossary, in alphabetical order, and to "materials and techniques". The latter is strictly didactics: the most significant graphic techniques are described step by step.

A further area of the interface, entitled "in depth examinations", is filled with news, critiques, and a space devoted to the bibliography classified by subject and one to the linkography.

The most important characteristics of the model include the possibility to access an complete database, which is duly implemented so as to be able to visualize the works of graphic art as "work model" [19], and the possibility to access the information landscape.

The convenience of the proposed IL-based system lies in the possibility of organizing information based on the relevance of the content. Information is provided by means of an "alternative" channel complementing traditional channels, it can be accessed through dedicated facilities or on the web using a visual language well suitable to convey visual signs like drawings and prints. Artworks and related documents can be accessed much more effectively with an interactive approach.

Graphic arts are proposed in all their manifold facets, both from a theoretical perspective (explicating techniques and historical backgrounds) and from a technical perspective (describing materials, tools and the execution processes). This way it is possible to show artworks related to each "laboratory", the associated documentation (following Italian Cultural Heritage ministry regulations), the artists' biographies and several possible iconographic comparisons for each proposed artwork.

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[1] http://www.humnet.unipi.it/~vneri/

The IL enables different paths for each reference target, offering different perspectives depending on the cultural background of the user (didactic, divulgative or scientific). The user is free to explore the 3D space, to choose one of the aforementioned paths and to dwell upon a specific content. When approaching a particular artwork, the user can catch the peculiarity of the graphic sign, a point of view which often is not possible even by directly viewing the asset.. Both texts and images can be selected and visualized with a higher definition, with the possibility of putting in background the rest of the information environment.

Each laboratory is composed of four sections. The first, "History and Techniques", provides the theoretical framework describing the art in different thematic areas: the technique basics, its fortune during centuries and other historical information. The subsequent "wall" (i.e. the next section) is dedicated to "Materials and Techniques". Each technique is described together with the related materials and tools, providing also bibliographical references (manuals and selected reference books). Available information regards supports (scrolls of papyrus, parchments etc.), papers (rice paper, cotton paper, prepared paper, etc.), modern tools (gravers, gouges, etc.) and related styles.

For each technique (and for each executive variation) the actual expressive possibilities are shown by means of a series of detailed demo images which reproduce, step-by-step, the process, providing a sense of continuity through a "guided" 3D link: images are placed one after the other, in a tight temporal sequence, in order to create a parallelism between the "depth" of the investigation in terms of content and the "depth" of the space where information are conveyed. So far four examples exist, but they are potentially infinite. Each image redirects, through a 3D hyperlink, to the artwork official documentation and to a short author's biography.

The fourth "wall" suggests iconographical comparisons of the selected asset with paintings, sculptures or other drawing and stamps sharing the same subject (drafts, preliminary drawings, engravings, etchings etc.) so that the most complete framework of the artwork original context is provided.

In terms of the concept of layout presented in section 3 this Information Landscape is structure as a high level Free layout in which the four thematic areas have been placed. Each area is a Cubic layout that contains one specific type of information in every face. Each face is made of a Page layout showing the content in a planar way. In the case of faces containing paintings or other artwork the details are presented on the back of the face using a Corridor layout.

5. VISUAL RENDERING

The design decisions and the content described in the previous sections have been made available inside an immersive Information Landscape engine, that allows to display and navigate the information in desktop system or in Virtual Reality setups, being based on the XVR technology.

Originally born for the development of web-enabled virtual reality applications, XVR has evolved in the recent years to an all-around technology for interactive applications. Supporting a wide range of VR devices (such as trackers, haptic interfaces, immersive rendering systems, etc.) and using a state-of-the-art graphics engine for the real-time visualization of complex three-dimensional models, XVR allows to develop applications ranging from simple 3D web presentations to advanced off-line VR installations. XVR applications are developed using a dedicated scripting language whose constructs and commands are targeted to VR and allow developers to deal with 3D animation, positional sound effects, audio/video streaming, real-time physics and advanced user interaction.

In its current form XVR is an ActiveX component running on Windows platforms, which can be embedded in several container applications including web browsers like Internet Explorer or Firefox.

The IL engine is being executed inside the XVR system and it allows to present large amount of text, displayed over flat surfaces and custom shapes. This engine is effectively a specialized scene graph system that focuses on the visualization of text and links in the form of curved lines. The text is rendered using texture mapped glyphs generated by the Open Source Freetype library,, allowing to visualize any TrueType font. This solution, integrated with a level of detail analysis, allows to provide a high quality rendering for near object and simplified rendering for far objects. Alternative approaches to 3D text rendering has been taken into consideration, like outlines, vector textures [24] or shader based solutions [16], and texture maps of full pages. The texture mapped is the most flexible and adaptable to different conditions, and also it is applicable in the case of animated or editable text as in Kinetic Typography [14].

Figure 5 shows a particular of the rendering of text near the user for full reading. The gray element behind the text is a transparent background that appears for simplifying the reading of the text partially covering the background.
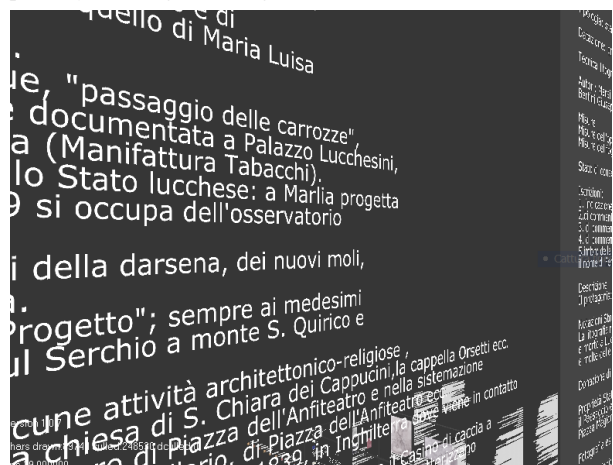

Figure 5 Detail of near text rendering, with background element used for helping the reading of the text.

The IL engine addresses visualization of large amount of text by using an efficient bounding box scheme that is used both for the placement and for the frustum culling. A level of detail technique is being adopted for simplifying the visualization of the single characters into rendering of the full line based on a noise texture that is visually similar to characters seen in distance.

The same visualization architecture has been used for the selection using the mouse. In particular the exact selection of the text is obtained using a color selection approach: every visible object is being assigned a color and the color of the pixel is fetched from the framebuffer. This solution is effective for the

selection of links, that have complex curved shapes. In any case the standard ray selection approach is available because of the bounding box system adopted in the whole engine. Figure 6 shows an example of overall scene visualization and the selection mode.
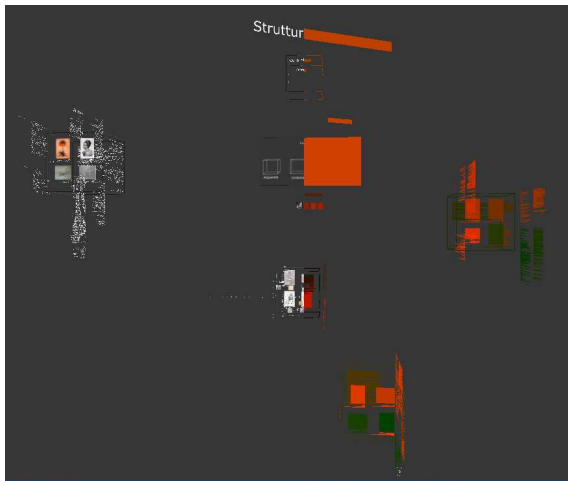

Figure 6 Example of overall landscape with the standard visualization on the left and the selection visualization on the right

The tested system is a two-sides CAVE-like environment, using a mix of frontal and back projection and a system of INFITEC filters to achieve passive stereoscopy. Each sector is driven by a *slave* graphical workstation which generates two stereo images using XVR. A third computing node acts as a *master*: the master actually runs the real-time application and distributes the rendering load to the slaves using the XVR Cluster Rendering [18] capabilities. This allows an easy calibration of the images - by means of fine-tuning software features for the overlapping zones of two confining sectors - and also an easy reconfiguration of the system (with minimal configuration changes it would be possible, for instance, to manage additional walls). The resulting setup is shown in Figure 7. In this setup the environment is displayed by a master and two slaves running Windows XP, with Intel Core Duo 1.86GHz and GeForce 8800 GTX. The user head is tracked using a Motion Capture system while the interaction is for the moment managed through a wireless 3-axis joystick.

The overall presentation is made of 16 high resolution images, 4 for every thematic area, integrated with the corresponding texts for about 100k characters at the same time.

Figure 7 The immersive fruition of the Information Landscape, showing the two screen setup, and the visualization of text entities.

6. CONCLUSIONS

The system presented in this paper allows the fruition of Cultural Heritage content in an immersive way following the metaphor of Information Landscape. The system is focused on the immersive navigation of the information, structured following a series of design principles that can be applied in a variety of contexts. Additional work is necessary in the evaluation of the effectiveness of this type of representation and the possibility of improving the it through usability studies, and with the integration of dynamic layout based on semantic data.

7. ACKNOWLEDGMENTS

8. REFERENCES

[1] http://www.3dvia.com/3d_experiences/view_experience.php?experienceId=1

[2] Addis, M. and others 2003. SCULPTEUR: Towards a New Paradigm for Multimedia Museum Information Handling. In Proceedings of the Semantic Web ISWC.

[3] Andrews, K. 1995. Visualizing Cyberspace: Information Visualization in the Harmony Internet Browser. In Proceedings of Information Visualization.

[4] Baracchini, C., Brogi, A. and Merlitti, D. 1999. Interactive Information System for the Camposanto Monumentale of Pisa. In Proceedings of EUROGRAPHICS '99, The Eurographics Associations, ISSN 1017 - 4656.

[5] Barsoum, E. and Kuester, F. 2008. Towards adaptive Web scriptable user interfaces for virtual environments. Virtual Reality, Vol. 12, Number 1, Springer, 2008.

[6] http://brunelleschi.imss.fi.it/pencil/

[7] Card, S., Lichan, H. , Mackinlay J. and Chi 2004. The perspective wall: detail and context smoothly integrated. In the Proceedings of the Conference on Human Factors in Computing Systems, CHI04.

[8] Card, S., Robertson, G. and William,Y. 1991. The WebBook and the Web Forager: An Information Workspace for the World-Wide Web. In Proceedings of the SIGCHI conference on Human factors in Computing Systems, CHI91.

[9] Carrozzino, M., Brogi, A., Tecchia, F. and Bergamasco, M. 2005. The 3D Interactive Visit to Piazza dei Miracoli, Italy. In Proceedings of ACM Computer and Entertainment Conference (ACE), Valencia Spain.

[10] http://www.compart-multimedia.com/virtuale/us/roma/movie.htm

[11] http://www.grafica.arti.beniculturali.it/

[12] Gruen, A., Remondino, F., and Zhang, L. 2002. Reconstruction of the Great Buddah of Bamiyan, Afghanistan. International Archives of Photogrammetry and RemoteSensing, 34(5), pp. 363-368, Corfu (Greece).

[13] Gutierrez, M., Vexo, F., Thalmann, D., 2005. Semantics-based representation of virtual environments. International Journal of Computer Applications in Technology. Volume 23.

[14] Lee, J. C., Forlizzi J. and Hudson,S.E., 2002. The kinetic typography engine: an extensible system for animating expressive text. In Proceedings of the 15th annual ACM symposium on User software and technologies.

[15] Levoy, M.A. 1999. The digital Michelangelo Project. In Proceedings of the Second International Conference on 3-D Digital Imaging and Modeling, Ottawa Canada.

[16] Loop, C., Blinn, J., 2005. Resolution independent curve rendering using programmable graphics hardware. In Proceedings of SIGGRAPH.

[17] Magnenat-Thalmann, N. and Papagiannakis, G. 2005. Virtual worlds and augmented reality in Cultural Heritage applications. In Proceedings of the International Workshop on Recording, Modeling and Visualization of Cultural Heritage, Ascona, Switzerland.

[18] Marino, G. , Tecchia, F. and Bergamasco, M. 2007. Cluster-based rendering of complex Virtual Environments. In Proceedings of the 4th International INTUITION Conference on Virtual Reality and Virtual Environments.

[19] Monumenta Rariora, Scuola Normale Superiore, Laboratorio L.A.R.T.T.E., http://mora.sns.it/

[20] Owen, R., Buhalis,D. and Pletinckx,D. 2005. Visitors' evaluations of icts used in cultural heritage. In Proceedings of the VAST Conference, pp. 129 - 136.

[21] http://www.playingthepast.com

[22] http://www.polomuseale.firenze.it/musei/uffizi/

[23] http://polorer.sebina.it/SebinaOsRER/

[24] Qin, Z., McCool, M.D., Kaplan, C.S., 2006. Real-time texture-mapped vector glyphs. In Proceedings of the 2006 symposium on Interactive 3D graphics and games.

[25] Robertson, G., Mackinlay, J.D., Card,S. 1991. Cone Trees: animated 3D visualizations of hierarchical information. In Proceedings of the SIGCHI conference on Human factors in Computing Systems: Reaching through technology, CHI91.

[26] Ruffaldi, E., Evangelista, C., Bergamasco, M., 2004. Populating virtual environments using semantic web. In Proceedings of 1st Italian Semantic Web Workshop: Semantic Web Applications and Perspectives, Bari.

[27] http://www.saint-petersburg.com/virtual-tour/

[28] http://secondlife.wikia.com/index.php/List_of_museums_and_galleries_in_Second_Life

[29] Small, D. 1996. Navigating large bodies of text. IBM System Journal, Vol. 35, Number 3.

[30] Sparacino, F., Davenport, G. and Pentland, A. 2000. City of News: cataloguing the World Wide Web through Virtual Architecture. KOS, 179-180.

[31] Tecchia, F., Carrozzino, M., Frisoli, A., Ruffaldi, E. and Bergamasco, M. 2007. Multimodal Interaction for the World Wide Web. In Proceedings of Museums and the Web. Toronto: Archives & Museum Informatics.

[32] Valtolina, S., Franzoni, S., Mazzoleni, P. and Bertino, E. 2005. Dissemination of Cultural Heritage Content through Virtual Reality and Multimedia Techniques: A Case Study. In Proceedings of 11th International Multimedia Modelling Conference (MMM'05), pp. 214-221.

[33] http://www.world-heritage-tour.org/

[34] Modjeska, D. K., 2000. Hierarchical Data Visualization in Desktop Virtual Reality. PhD Thesis, Department of Computer Science, University of Toronto.