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Abstract — **Cultural institutions have to deal with an enormous amount of data, which are stored in cultural databases usually designed for and managed by professionals. Difficulties in accessing such databases usually preclude or limit their use for the general public. Moreover, in the historic, artistic and cultural areas, an important part of the information associated to an object is related to its original historical and spatial context, an evidence that is often not disclosed, or is difficult to explain, to the non experts. For this reason, it is important to try to re-contextualize, where possible, elements of cultural collections in the places where these objects were in the past. To this end, in this work we propose the integration of databases and Virtual Reality technologies to develop novel visual interfaces to improve the accessibility, for the non experts, to the contents of cultural databases. Virtual Reality is used to re-create the contextual environment of the objects in the database, which can be explored to gain new insights on specific elements and to improve the awareness of relationships between them. The use of two different types of Virtual Environments has been investigated. Results of the evaluation through a user panel of their accessibility and effectiveness, in relation to each other and with a classic text-based interface, is also presented.**

Keywords-component; virtual heritage, multimedia, user interfaces, cultural collections

I. INTRODUCTION

Cultural collections, managed and maintained by archival institutions, galleries and museums, typically contain a huge amount of up-to-date information related to historic sites, buildings, documents, artistic elements, objects and art works. Such collections are usually composed by a combination of structured data, text, photographs, maps, plans and other similar things. Nowadays, most of their contents have been digitized, and stored with their associated metadata into multimedia databases. These "cultural archives" have been often designed for a professional or specialized target. However, cultural institutions are more and more faced with the problem of providing access to contents to a wide and assorted audience. This is also due to requests from governments or other funding entities, which are often supporting cultural archives having among their goals the development of a shared cultural experience for their citizens, and from specialized agencies like the UNESCO. As written in the Charter on the Preservation of Digital Heritage [1], "The purpose of preserving the digital heritage is to ensure that it remains accessible to the public. Accordingly, access to digital heritage materials [...] should be free of unreasonable restrictions" and "Member States may wish to cooperate with relevant organizations and institutions in encouraging a legal and practical environment which will maximize accessibility of the digital heritage".

Therefore, the immediate goal of finding better access to the knowledge maintained in cultural archives is to provide an appropriate fruition of their contents to the general, non-expert users. On the contrary, as already stated, database structures have been designed with specialists in mind and it often needs an expert to extract and interpret the data. The access methods provided are usually difficult to use by the non professional users, who often look for information according to their personal curiosity and interest, with poor specific knowledge of the subject. Furthermore, traditional interfaces, mostly relying on text-based forms, are not well suited for searching data whose characteristics are difficult to express through few keywords, as those concerning historical representations, traditions and non-verbal sources. Hence, one step towards opening up access to cultural databases is to find better ways to search contents, using easier interfaces and finding more compelling and exciting ways to present the results. Furthermore, the presentation layer should be effective and, preferably, specifically designed to reach different audiences.

Current database systems provides different ways of accessing contents, either through the direct use of query languages or by means of different kind of form-based interfaces. These methods, however, often require some computer skills and still do not provide users with easy and natural tools for exploring database contents. Many systems, like ubiquitous and recommenders systems ([2], [3]), have been designed to improve access and navigation through data. These systems suggest, based on previous choices and preferences expressed by users, the navigation between elements. The development of interactive curatorial narratives ([4]), based on user choices and ontologies, allows to create unique narrative paths and to generate meaning and understanding from the relationships between objects. Ontologies are based on the creation of an information flow, related to user preferences, through a process of discovery of logical knowledge, based on closeness of meaning or cause/effect. But this kind of process is not natural for human beings, which generally

discover and learn about things coming into direct contact with objects and relating them to the surrounding world. Meanings and knowledge usually come from a comparison of items, from previous knowledge of the person and, especially in the cultural/artistic/historical field, from an analysis of the contextual environment surrounding those items. However, while professionals and specialists are aware of such context information, this is not disclosed to, or is difficult to explain to, the general public. For this reason, it is important to try to recreate, where possible, a condition of "discovery and knowledge", re-contextualizing the elements of cultural collections in the places where these objects were in the past.

Virtual Reality (VR) technologies can help to reach these goals. VR allows the creation of novel paradigms for presenting cultural elements, rich in informative and emotional contents. For libraries or art galleries, VR allows displaying and interacting with digitized books ([5]) or animating historical paintings ([6]). VR can be used to create displays for objects and architectural elements for which there are records, but where the actual object has been destroyed or lost at some point in time. Virtual restoration of lost sites and buildings is a powerful way of educating people on cultural aspects of past civilizations. Moreover, VR can allow people to experience objects that are too fragile to be shown to the public without compromising their integrity. Therefore, virtual environments (VE) both enhance visitors' comprehension of cultural contents, making them more readily understandable, and provide a powerful tool for research and teaching ([7]).

The project presented in this paper stems from these ideas and aims at developing novel interfaces for accessing and managing a cultural database by integrating its contents within a VE, which is used to (virtually) re-create the original spatial and historical context of records, where visualization and sounds can be used to improve the users' sense of immersion and presence. The re-created context can then be explored virtually to gain new insights on specific elements, and to improve the awareness of relationships between objects in the database. The proposed interface is divided in two parts, closely related and synchronized: (i) a 3D graphic view of an interactive VE showing the reconstructed environments, where database items have been inserted as "sensible" objects that, when clicked, send a query to the database to access the information related to a specific object; (ii) a text-based form, where objects can be searched by keywords, tags and/or metadata, their related (multimedia) information can be accessed and, at the same time, their context can be visualized into the VE.

The strengths of our project are the possibilities to navigate the VE as if you were browsing among the records of the database, to always re-contextualize the search item within its historic ambience and to perform searches of different types using the possibilities offered by both textual and visual methods, which are complementary and strongly integrated for more targeted queries.

To test and evaluate the effectiveness and usability of the proposed interface, we collected a database of historical documents, photographs, videos and archival materials related to the Riviera Casino in Las Vegas, one of the most famous casinos of the 60s. We then build the 3D models of the main areas of the casino that were used to create the contextual environment in which to place the archive material. Two different types of VE were experimented: a real-time navigable environment and an image-based VE, exploiting high-quality 360° panoramic renderings. Both interfaces were then evaluated by a panel of human experts, comparing them with each other and with a classic textual interface.

The rest of the paper is organized as follows. Section 2 briefly summarizes previous works. Section 3 describes the VR-based visual interfaces. Section 4 discusses the results of the user-evaluation. Section 5 concludes the paper.

II. RELATED WORKS

In recent years, thanks also to the evolution of Internet, the number of available data - personal, economic, scientific - have massively rose, gaining enormous importance. Managing and updating databases has become a fundamental practice for companies and organizations in different areas, involving an increasing number of users with poor computer skills. Therefore, studying and developing novel interfaces, suitable and easy to use for the general user, has become essential. To this end, especially in the last years, experiments have been done to investigate the integration of VR and 3D environments with databases. The main field of application of the 3D interfaces is undoubtedly that of GIS (Geographic Information System), where data are geolocated and their integration into navigable 3D maps (or VEs) right in the location where they refer to, allows to significantly improve the data representation. A review of the literature on VR and GIS can be found in [8].

Concerning the specific field of Virtual Heritage, the reconstruction of 3D environments has been used in several researches to present historical and artistic data included in a database. In [9], the authors present a framework for archeological applications, which allows describing the excavation phases and all the artifacts found. Objects, reconstructed in 3D with laser scanning techniques, are integrated into Digital Terrain Models of the excavation area in different epochs, which can be freely navigated into a VE. However, no interfaces to query the content database are provided, nor it is possible for users to access detail information related to the displayed artifacts. The main goal of the "Memory and Reality: Monument to the dead soldiers of the Great War" project ([10]) is to simplify the access for the general users to the large amounts of documents available in the "Archive of the Fallen" of the Certosa di Bologna, in Italy, since the version of the database for specialists was far too complex. Therefore, a simpler interface for the non skilled users has been created, showing a VR reconstruction of the Certosa where tombs outside and inside the monument are linked to a biography. An interactive digital narrative and real-time visualization of an Italian theatre during the 19th century is presented in [11]. Users are guided in their tour by a virtual avatar, telling them the history of the theater, and can query, through a text-based form, a multimedia database to browse the available documents, which,

however, are not integrated into the VE. Another framework combining VR and database technologies has been presented in [12]. The main idea was to embed information into a 3D spatial context, and to exploit sight, naturally used by humans to focus on something, to retrieve this information. An innovative aspect of this approach is the definition of "relevance of information", defined as the percentage of overlap between the view area of the user and the "information zone", a region around each data, to sort the contents available in the user surroundings in order of importance. However, this system does not provide any tools to directly browse the database and, therefore, it is not possible to follow the backward path from each cultural object to its spatial/historical context.

III. DESCRIPTION OF THE PROJECT

As we stated in the introduction, the main idea of our project is to combine VR and database technologies to improve the accessibility, for the general public, to the contents of cultural databases. Our aim was to develop novel visual interfaces that are compelling, intuitive and easy to use, allowing also an easier understanding of the historical and cultural context related to items in the database, helping to increase knowledge and create links and relationships around them. Furthermore, as confirmed by modern neuroscience studies ([13], [14]), the interaction with a 3D environment represents the most intuitive paradigm for a majority of humans, since it is rooted on common everyday experience. Therefore, using this paradigm to access information can be fruitful in several domains, increasing comprehension of learning contents, and for different target users, especially the not trained ones.

The general organization of the proposed interface, sketched in Figure 1, is the following.

(i) A *graphic panel*, laid out on the left of the main application window, showing a virtual representation of the reconstructed environments. Users are free to navigate into the VE to discover the context related to the cultural objects stored into the database. The database items are inserted into the displayed environments as "sensible" objects (hotspots) that, when clicked, send a query to the database to access the information related to that specific object, information that are accessible through the right panel, described in the following item. Hotspots are highlighted into the environment by means of specific graphic elements, which make them immediately recognizable by users. The VE is associated with a 2D map of the reconstructed spaces, which provides users with a general overview of the reconstructed area, showing at the same time their current position, and allows them to be teleported into a specific location of their choice. When entering an area of the environment, information related to its historical, artistic and social traits are shown in the right window panel. Moreover, the list of hyperlinks to database objects present in that area is shown, allowing to immediately access them. As for the characteristics of the VEs, in order to understand which are the most suited to reach the proposed goals, we experimented two different types of VEs, an interactive real-time VE and an image-based VE, described in details in the following subsections.

(ii) A *form*, laid out on the right of the main application window, allowing both a "Google-style" textual query within the database and the visualization of the contents of the database cards. The query can be targeted to different elements of the stored objects (name, keywords/tags, description, associated multimedia contents and so on), and the results are shown as a list of hyperlinks, allowing to access the full description of each element. A panel can be overlaid on the interface to display images and videos related to the selected object, while associated audio contents are managed through a simple player embedded into the form. When an object is selected, the view on the VE can be changed to show the same object into its original context. Finally, at the bottom of the form, a list of objects correlated to the selected one are presented to the user, suggesting possible navigations through contents that can help to delve into the topics of interest.

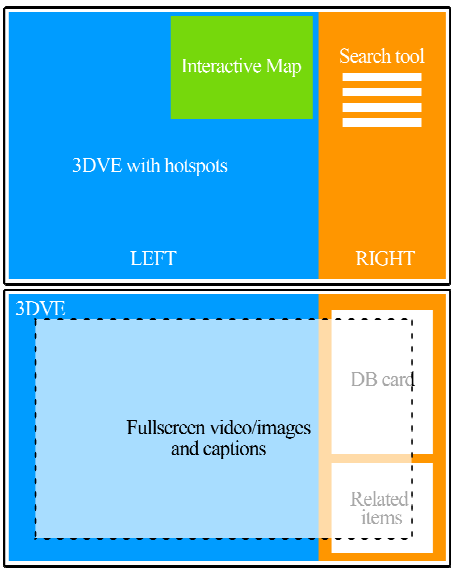

Figure 1. Layout of the proposed interface: the graphic view and the form-based search panel (above); results of a research and the overlaid fullscreen document window (below)

It is important to underline the close relationship between the left (graphic) and right (the textual search) panels. When the user navigates into the VE, he/she can always access information related to hotspots into the environment or to the displayed area. This information is presented through the right panel, which allows also accessing the multimedia contents related to the cultural objects. On the contrary, when users look for items into the right panel, they always have the possibility to access their related context in the left panel. Therefore, both types of queries, the visual and the text-based one, coexist and are fully integrated in order to provide users with an immediate and easy to use interface.

In the following subsections we will describe the materials and documents used to develop a case study to test the proposed interfaces and we will provide details concerning the characteristics of the two types of VEs used

in our experiments. Finally, in the next section, we will discuss the results of the user evaluation of the interfaces.

A. *Case study: documentation and materials*

In order to test our interfaces, we built, as case study, a prototypal application aimed at presenting the collection of historical documents related to the Riviera casino-resort, in Las Vegas. The Riviera, opened in 1955 on the Las Vegas Boulevard ("the Strip"), was the first skyscraper in Las Vegas and became one of the most important and luxurious resort in the city. Several famous singers and artists of the period, including the showman Liberace, the highest paid artist in the world in the '50s, performed in its theater. The primary source of documentation was UNLV's Special Collections archive, established at the end of the 1960s with the purpose of documenting the history, culture, and events that contributed to the development of the city of Las Vegas. The section dedicated to the Riviera includes project documents, images of the resort, photographs and documents of the leading characters and of the most important events related to the resort. Other information was found in books, newspapers and magazines of the period. The research data were digitized and stored in a database, with accompanying metadata concerning the collection and management thereof. This information was also used to create the 3D models of the original premises for the Riviera virtual reconstruction and of all the objects, furniture, and elements included therein (Figure 2).

Figure 2. Some digitized historical sources - photos, videos, postcards – and a view of the virtual reconstruction of the Riviera casino

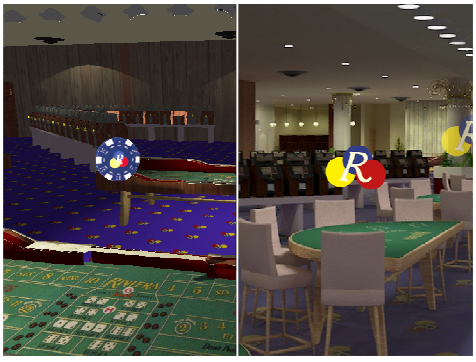

Figure 3. Graphical elements used in the two VEs (RTVE on the left and IBVE on the right) to indicate the presence of an hotspot

B. *Interactive real-time VE (RTVE)*

Traditional techniques for visualizing VR environments are based on real-time rendering of 3D models, which are described geometrically in terms of polygonal meshes, with associated surface properties and textures. The view on the virtual world is changed interactively by the user, which is free to move at his/her own will into the VE. Database elements have been inserted into the environment as hotspots, and their presence highlighted with a recognizable graphic element (Figure 3, left).

Figure 4. Images of the rendered VEs: (a) RTVE, (b) IBVE

A VR application does not involve merely 3D graphics, but also physics, 3D audio, user interaction, avatar management and artificial intelligence handling. Designing and managing such an application can be a complex task, involving advanced programming skills. In the last decade, the situation has improved, thanks to the large availability of simple development environments for creating computer games ([15]). Many computer games are indeed VR applications, and they have been used in several application scenarios as collaborative tools for educational and learning purposes, representing a powerful tool for supporting cultural heritage too ([16]). Game development is based primarily on Game Engines (GEs), the software that forms the core of any computer game, handling all of its components. Using GEs for developing VR applications provides several advantages. First, many GEs can be completely customized using scripting languages, which are easy to learn and do not require an expertise in programming, allowing non-skilled users to easily adopt them. Second, the developed products are often directly portable on different execution environments (PC, game consoles, browsers and mobile devices). Finally, using GE to develop virtual environments for Virtual Heritage applications have proven to take almost half the effort than

with traditional techniques ([17]). Taking these points into consideration, we also used a GE for developing and managing our real-time VE. In particular, we chose the Unity engine ([18]), which allows both offline and online execution, the latter by means of a Web Player, a plug-in available for the most common browser and Operating Systems. An example of the quality of the created VE is shown in Figure 4(a).

The main disadvantage of RTVEs is that, to enhance the realism of rendering, the complexity of geometry and lighting must be increased. This can have a dramatic effect on the computational resources required to maintain interactive frame rates, and the developers must find the proper trade-off between realism and complexity, especially for on-line fruition, where it is not possible to rely on a known hardware configuration.

C. *Image-Based VE (IBVE)*

A practical and cost effective alternative approach to RTVR is the so-called *Image-Based Virtual Reality* (IBVR [19], [20]). With this technique, the virtual world is represented as a set of initial images, which are used to synthesize the user's view at new and arbitrary viewpoints. Reference images can be captured with normal digital or analog cameras or using special panoramic lenses. These images are then stitched together, using automatic mosaicking software, to create 360° panoramic images, which are displayed on an interactive viewer that allows rotation, tilt and zoom of the surrounding scene. Navigation in such VEs is provided allowing the user to move between predefined viewing locations, which are linked together to create a specified path.

IBVEs offer several advantages over the traditional 3D geometric approach. First, high-quality photorealistic views of the environment can be displayed in real-time and manipulated interactively with simple algorithms. Second, the requested computational resources and rendering times are independent of the complexity of the virtual environment; therefore, the VR application does not require specific hardware (which is important for fruition over the web). Finally, even with the lack of geometric information, users are provided with a 3D illusion; therefore, the sense of immersion, or the feeling of being inside the virtual world, which is the very essence of any VE, is preserved and even enhanced by a photo-quality realism that resembles that of the real world. However, the limited freedom of movements inside the environment and the fact that image-based VEs are necessarily static (that is, no moving objects or characters can be included into them), are their very limitations.

In our project, "virtual" panoramic images of each Riviera space were synthesized from multiple high-resolution photo realistic renderings, obtained from a virtual camera that is rotated by 360° in 10 steps to create three image strips taken at different elevations (one horizontal and the other two tilting up and down the camera). The offline rendering process allowed us to improve image realism by using high-resolution 3D models and textures, complex shaders, volumetric effects and advanced rendering techniques. Renderings are then projected from their viewpoints into an imaginary sphere enclosing the viewer's position and finally stitched together. The resulting panoramas have a resolution of 7.000x2.450 pixels (see Figure 5). An example of the view on the VE can be seen in Figure 4(b). Again, the items in the database were modeled and added to the reconstructed environments, and their projection on the panoramic images has been used as hotspots (Figure 3, right). The viewer for panoramic images is based on Flash technology, allowing it to be executed on different platforms and embedded into HTML pages.

Figure 5. 360° panorama of the Riviera Gaming Room

IV. EVALUATION AND DISCUSSION

The two interfaces were evaluated, and compared with a classical textual interface, through a usability test that involved 51 subjects. Volunteers were students and workers of our University, males (59%) and females (41%), in the age range 19-45, half of them being in the range 21-25, with different education and technical competencies. The tests were organized as follows. First, we showed volunteers the 3 interfaces with a brief explanation on how they work, then we submitted to each subject 12 assignments to be performed with different interfaces, and finally we asked them to fill a questionnaire. For each assignment, we also recorded the task completion time in order to get an objective assessment of the effectiveness of the interfaces. The assignments were structured in the form of questions, which could be answered looking for the proper information into the database. The questions were divided into 3 groups, representing different possible types of searches: 1) information related to a specific item; 2) information related to the social and/or historical context; 3) information related to the spatial location of objects or areas and the relationships among them. We asked volunteers to complete each assignment using a specific interface, which was chosen in a pseudo-random fashion in order to guarantee an even distribution of task-interface couples between users.

An overall evaluation of the interfaces efficiency can be obtained analyzing the average completion time. For group 1 questions, the textual search appears to be the fastest (an average of 2:07 min), followed by the IBVE (2:47 min) and the RTVE (3:00 min). This result is certainly due to the fact that, in this case, searching the proper information required some knowledge of the item characteristics, which were easier to express in a textual form. However, it is important to emphasize that, although the recorded times suggest a better efficiency of the textual interface, the precision and details given in the responses are significantly greater using the visual interfaces. On the contrary, combining group 2 and 3 tasks, the RTVE is the most efficient interface (0:52 min), followed by IBVE (1:22 min) and the textual one (2:26 min). In this case, answering the question is simplified by the possibility of

analyzing the relationships between the objects and their contextual environment, an information that is completely missing in the textual interface.

As for the subjective evaluation, the preferred interface was the RTVE (78%), followed by the IBVE (12%) and textual (6%). Volunteers' comments indicate that the real-time interface creates a "complete interactive experience" with a "great personal involvement". While the textual interface was found to be appropriate for simple queries, it was perceived as "having poor flexibility" and "unable to properly relate the historical elements together". The capabilities of both visual interfaces of contextualizing cultural items was appreciated by all volunteers, which pointed out as most relevant features the realism of the visual representation for the IBVE and the freedom of navigation into the environment for the RTVE. This characteristic of the RTVE was particularly appreciated by users, since it allowed them to "better orient within the environment", encouraging the contextualization of objects and, according to most of the respondents, capturing their curiosity. As for the drawbacks, due to the fact that the navigation into the environment was constrained to some predefined viewpoints, the IBVE was perceived as "lacking interactivity" and, therefore, less appreciated. On the contrary, the lower realism of the RTVE was not underlined as a negative factor.

Concluding, the two visual interfaces – especially the RTVE – appear to be the effective in improving the accessibility to cultural databases contents. This is particularly relevant for tourism and leisure purposes, where visitors with a not professional background approach the cultural experience with curiosity and interest, attracted not only by the works of art, but also by the relationships between them and by the historical period to which they refer to.

V. CONCLUSIONS

The availability of novel interfaces for accessing databases of cultural contents, tailored for the general public, easy to use and immediate to adopt, is sorely needed. To this end, in this paper we have proposed a strict integration of VR and database technologies. Starting from the observation that a large amount of information about cultural elements is related to their original spatial and historical context, an information which is often undisclosed to the general public, we investigated the use of a virtual environment to immerse visitors into a recreation of such context. Users can navigate the VE as if they were browsing the DB contents and, at the same time, combine the possibilities offered by the different kinds, visual and textual, of search methods, helping to gain new insights about elements in the database and to discover the relationships between them. Two different types of VE, an interactive real-time and an image-based VE, were experimented on a case study, related to the history of the Riviera, one of the oldest and most famous casino-resort in Las Vegas. Users' evaluation showed the appreciation of the proposed interfaces, especially in terms of their capacity to capture the curiosity of visitors and to foster the search process and the discovery of new elements, which are essential to the learning process. The outcomes of our work provide a general framework that can be applied to the presentation of the contents of different cultural archives. We believe that, as far as curators and archivists are concerned with the development process, they can provide valuable tools to improve the accessibility to cultural archive contents and to increase the comprehension of learning contents for different target users.

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