An Integrative Tool Chain for Collaborative Virtual Museums in Immersive Virtual Environments

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Abstract. Various conceptual approaches for the creation and presentation of virtual museums can be found. However, less work exists that concentrates on collaboration in virtual museums. The support of collaboration in virtual museums provides various benefits for the visit as well as the preparation and creation of virtual exhibits. This paper addresses one major problem of collaboration in virtual museums: the awareness of visitors. We use a Cave Automated Virtual Environment (CAVE) for the visualization of generated virtual museums to offer simple awareness through co-location. Furthermore, the use of smartphones during the visit enables the visitors to create comments or to access exhibit related metadata. Thus, the main contribution of this ongoing work is the presentation of a workflow that enables an integrated deployment of generic virtual museums into a CAVE, which will be demonstrated by deploying the virtual Leopold Fleischhacker Museum.

1 Introduction

Various conceptual approaches for the creation and presentation of virtual museums are presented on annual conferences dedicated to (virtual) museums and digital heritage, as well as in publications of the virtual museum transitional network[1]. Visiting a virtual museum prior to a classical museum has many advantages [1]. Nevertheless, it is hard to find existing solutions—besides multi-user gaming environments such as Second Life—which explicitly enable visitors of virtual museums to interact with each other or to collaborate directly. Therefore, this work in progress presents an approach for the implementation of collaboration in virtual museums using immersive virtual environments and various types of display systems, including a 5-sided CAVE-like projection system. This work further discusses and evaluates other existing hardware solutions for immersive

[1] https://www.v-must.net.

© Springer International Publishing Switzerland 2015
N. Baloian et al. (Eds.): CRIWG 2015, LNCS 9334, pp. 86–94, 2015.
DOI: 10.1007/978-3-319-22747-4_7

virtual environments, such as low-cost implementations, which are affordable for nearly every type of user and facilitates the use at home. The presented approach further includes the use of a metadata standard called ViMCOX for the specification of virtual museums [2]. The use of an appropriate modeling language and standards is a precondition for the flexible generation of virtual museums including meta information for the artwork on display and describing the architectural structure of the museum itself. The introduction of this metadata-based description of a virtual museum into a seamless tool chain enables the implementation of virtual museums for their use in virtual environments. This workflow also provides a feedback loop of user generated content gathered in collaborative visits of virtual museums. The generated data from collaboration can range from visitor's annotations or comments regarding specific exhibits up to complete exhibit models and room (re-)designs created in a virtual environment. Nevertheless, the latter is not focus of this work at hand but presents a relevant next step. Virtual environments offer the capability to enrich 3D museum models by collaboration support through the use of different display systems and accompanied interaction techniques. The latter facilitate the use of a museum instance by more than one visitor simultaneously, a precondition for face-to-face collaboration.

In conclusion, the main contribution of this work is the presentation of a tool chain offering the deployment of virtual museums specified in the ViMCOX metadata standard into virtual environments, which enable collaborative work. Collaboration in this regard is implemented as users being co-located in the virtual museum, which enables information exchange and awareness of users actions via face-to-face communication. As mentioned above, the tool chains aims at the deployment of virtual museums to virtual reality hardware that enable the defined face-to-face communication such as a CAVE-like environment. Furthermore, the data collected during the collaborative work in the virtual museum is captured by a commenting system and can thereby be used in conjunction with the metadata for subsequent discussions or for reuse in other sessions. The solution will be evaluated by means of a virtual museum dedicated to the German-Jewish artist Leopold Fleischhacker brought into a 5-sided CAVE-like virtual environment.

The paper is structured as follows. Section 2 presents related work focusing on collaboration in virtual museums and the use of virtual environments. Section 3 introduces the tool chain and presents the software solution, where Paragraph 3.2 focuses on possible collaboration methodologies enabled through immersive virtual environments. Section 4 describes the application of this tool chain and collaboration methodology by presenting the use case of the Fleischhacker museum in the aixCAVE at RWTH Aachen University. Section 5 concludes this paper and identifies certain aspects of future work.

2 Related Work

In recent papers, the modeling and 3D visualization capabilities of the curator software suite Virtual Museum Exhibition Designer using an Enhanced ARCO Standard (ViMEDEAS) has been presented for the digitization of heritage sites or virtual museums with access to outdoor areas ([2–5]). As visualization platforms—for local or online presentation—VRML, X3D and X3Dom has been utilized [4]. The modeling of the exhibition areas is carried out using the Virtual Museum and Cultural Object Exchange Format (ViMCOX) as metadata format. ViMCOX is based on international metadata standards and uses LIDO (Lightweight Information Describing Objects) as an interchange and harvesting format for cultural objects. ViMCOX was developed to support the hierarchical description of virtual museums and provides stylistic devices for sophisticated and vivid exhibition design, which cannot be achieved using classic museums standards.

The use of virtual environments in the context of virtual museums has been investigated beforehand. Roussos et al. [6] presented an approach for the use of virtual environments in the context of collaborative learning in a distributed setting. This approach focuses on the use of narrative concepts and story telling for the implementation of learning systems. Roussos further published a work on the application of immersive interactive virtual reality concepts in informal education [7], which further lead to a work describing a use case for cultural education [8]. Further works on the use of virtual environments for education and learning has been published by Kriner et al. [9] as well as Taxén et al. [10], which both concentrate on the investigation of virtual environments for the use in learning and teaching contexts. Although these works describe important research, none of them present a coherent tool chain, which implements a closed loop from content creation, metadata description, up to the deployment in a CAVE-like environment for collaborative use.

As basis for our case study serves The Virtual Leopold Fleischhacker Museum, a joint-project initiated by Prof. Dr. Michael Brocke, director of the Salomon Ludwig Steinheim-Institut in Essen and the University of Duisburg-Essen [11]. The museum depicts the life and work of the German-Jewish sculptor and artist Leopold Fleischhacker. On display are 200 photographs with metadata and descriptions as well as 30 reconstructed tombstones. The exhibition space is organized into 10 thematic areas that span across 13 rooms and one large outdoor area in style of an Ashkenazic cemetery.

3 Tool Chain for Applying Virtual Museums in Immersive Virtual Environments

3.1 Tool Chain

An abstract architectural overview of ViMEDEAS is presented in Fig. 1 which is based on the work presented in [4]. Multimedia content, cultural object metadata (DC/LIDO), 3D models like (interactive) exhibits, 3D buildings or interior, 2D pictures, or floor plans as 2D point set can be used in ViMCOX. In addition, content creators can re-use open data repositories (OAI-PMH) to include real artworks and metadata from cultural heritage institutions [5]. Algorithms can facilitate 2D floor planning and automatic determination of exhibit distribution or room layout. Authoring tools help to modify the content base as well as ViMCOX metadata instances [3]. The dissemination and visualization layers are middleware for assembling and publishing virtual museum instances, locally or on the web, as well as interpreting and rendering ViMCOX metadata instances on different visualization platforms. ViMEDEAS currently supports VRML, X3D and X3Dom via Replicave. Replicave supports native export to X3D and X3Dom and supports backwards compatibility to VRML via XSL Transformations (XSLT).

The VRML models generated by Replicave are loaded by Inside, an extension of the ViSTA toolkit [12] (cf. Fig. 1). ViSTA is a software framework, which enables the implementation and execution of virtual environments and applications. It is based on OpenGL for rendering and implements various interaction methods common in virtual environments, such as flysticks or infrared tracked targets, e.g., for head tracking. Furthermore, ViSTA supports multi-display systems and stereoscopic rendering, such as needed for CAVEs and other display hardware for virtual environments. Both, the stereoscopic rendering as well as the supported interaction hardware and navigation metaphors for virtual environments are used in the collaborative museum to gain presences as well as offer tools and mechanisms for free exploration of the exhibition. The latter will be discussed in more detail in Sect. 4.

Based on the presented tools, the tool chain as shown in Fig. 1 is composed as follows: Using the authoring tools, a curator or content creator specifies a virtual museum design expressed as ViMCOX metadata file. Based on this metadata, Replicave generates a content bundle and a VRML file, which will be passed to Inside for interactive rendering in a CAVE. In this environment, the visitors virtually walk through the virtual museum. Visitors are able to access supplementary materials or comment/annotate exhibits by photographing Quick Response Codes (QR) placed in direct proximity to each exhibit item. The next section will discuss this aspect in more detail.

Since our toolchain supports X3Dom as rending platform, it is also possible to use low cost VR systems such as Google CardBoard or the Oculus Rift as well as other tangible or multi-touch interfaces, gamepad input and other VR input devices such as the Leap Motion via InstantIO and WebSockets [13]. The use of head-mounted displays as hardware solutions requires the integration of avatars into the virtual museum to offer spatial, contextual and content-related awareness for the users. As avatars offer a great potential to the collaborative use of virtual museums, we identified an extensive study as a future work for an extension of the current implementation of Replicave, for example by creating a Collada exporter to support multi-user scenarios via Second Life [14]. Nevertheless, this work focuses on the use of CAVE-like environments for collaborative work and visits of virtual museums.

3.2 Collaboration Methodologies for Virtual Museums in Immersive Virtual Environments

This section introduces the necessary interaction methodologies to implement well known aspects of collaboration, which are essential for collaborative virtual museums. As the whole concept is based on co-location of the users during the visit of the virtual museum, a CAVE-like environment is expect.

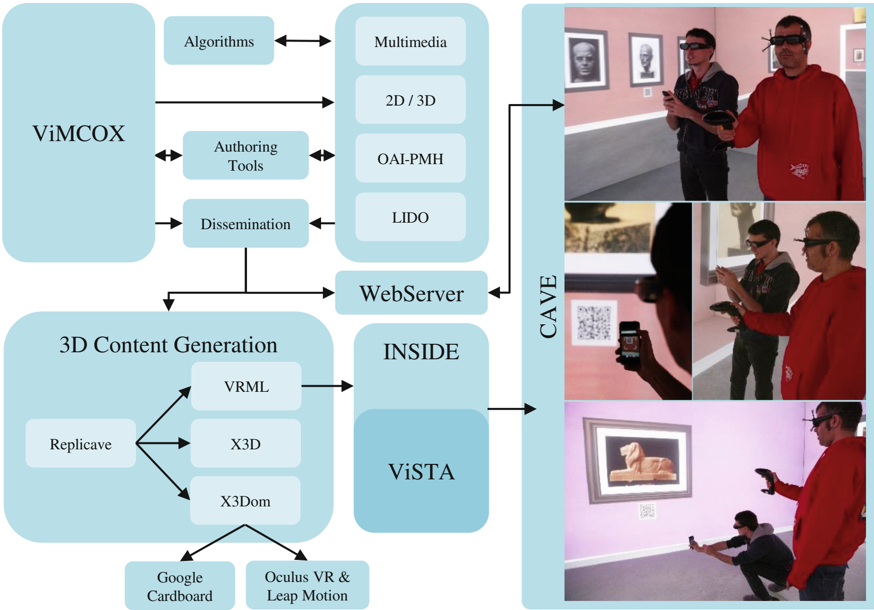

Fig. 1. Integration tool chain: On the top left part the various technologies are shown, which are used for the authoring of the virtual museum. On the lower left, the transformation technologies and tools are depicted, which deploy the content model into the virtual environment, such as a CAVE shown on the right. Here, user navigate in the museum and access metadata through scanning the exhibit's QR codes.

Awareness and Information Exchange. Both, awareness and information exchange are handled in this environment directly by the visitors' co-location in the CAVE-like environment. They are able to directly communicate with each other without the need for any computer-supported communication facilities. Pointing a co-located user's attention to specific content, a user only points to this information with a gesture. The users can further discuss all questions and problems aurally without the need of technical support. This differentiates the presented approach to classic groupware or telepresence approaches. Nevertheless, if it is needed to integrate remote users to a session, an avatar can be used to visualize the partners in the virtual museum, which is a subject of future work (see above).

Content Generation and Retrieval. As discussed in the next section, the visitors can use their own smart phones to retrieve additional information for the artwork presented by, e.g., scanning the provided QR codes in the virtual environment. This metadata is available on a shared web page accessible via the smart phone's web browser. Using the web site's form, visitors can annotated selected artwork or define further tasks for other visitors. This information can be attached to a pre-defined session to offer provenance information, such as who added the comments and when. Thus, the visitors are able to work collaboratively on specific tasks in the CAVE-like environment by directly communicating with each other and using the latter mentioned metadata and data input facilities provided by the web browser. This process can thereby be used for content generation and retrieval including the generation of provenance information. Furthermore, the web-based data access enables all imaginable post-processing and subsequent usage scenarios for this data. This includes re-use of the information in other situations, such as a school lesson in which the visit is discussed and analysed or in a follow-up meeting to pick up certain previous discussions or questions.

Navigation. Besides accessing information, one of the visitors has to lead and to navigate through the museum, which should be done in consensus with other collaborators. This could be relevant, e.g., for supporting visitors' discussions, reviewing of curator's design decisions, or in a collaborative learning scenario, as it will be presented, below. Especially relevant for the latter is the discussion emerging from the question 'where to navigate to, next?' These discussions have the potential to lead to refocusing the solution strategy, to solve a given task, or to develop a solution strategy previously.

Comparison to Groupware and Social Networks. Since our current approach is based on the concept of co-location (users work physically side-by-side), various communication concepts (asynchronous or synchronous) and awareness mechanisms (user status or content changes, etc.) as known from groupware as well as social networks are not relevant in the presented system at this preliminary stage. Nevertheless, it is crucial to combine the presented approach with the above mentioned collaborative solutions and concepts, which is enabled by the used web-based technologies and is planned as future work.

4 A Testbed for a Learning Scenario - The Fleischhacker Museum in the aixCAVE

The initial room design and layout was designed for an on-site kiosk-systems and touch-screen input. Thus, the curator Dr. Barbara Kaufhold was able to design the rooms without observing artwork and room dimensions. Therefore, we used standalone room instances that are linked via a teleporter metaphor (cf. Fig. 2, left) and enlarged the exhibits and room dimensions for proper touch-screen input. This approach is not suitable for a CAVE environment and limits the embodiment and movement freedom. Additionally, a few visitors could not keep track of their orientation and current position within the museum, which has been identified in a survey [15]. Therefore, we transformed the virtual museum rooms into a large floor plan with passages connecting other exhibition areas (cf. Fig. 3). This was achieved using connectivity graphs and our generative approach methodology [4] by varying the gaps between the paintings and inserting

Fig. 2. Metaphoric connector for changing rooms in the virtual museum. On the left a connector is shown for a web-based implementation enabling the user to teleport into another room. On the right, the solution used for virtual environments is shown, where the user navigate virtually through the door.

passages. At this exploratory stage, the outdoor area has been excluded and the room dimensions have been scaled down to prevent overlapping of rooms and to present authentic artwork dimensions. In addition, we now use generated 3D frames for each painting to achieve a more lifelike presentation of the artworks (cf. Fig. 2, right).

As mentioned above, we use QR codes to access audio recordings and other materials, which are placed in direct proximity to the exhibits, that link to our HTML-based metadata renderer and 3D object browser. Furthermore, the digital object browser allows visitors to browse the 2D/3D exhibition items and their corresponding metadata as well as rotating, zooming and panning the 3D reconstructions or watching pre-defined animations. In addition, we plan to support annotations and user feedback[2].

Our approach includes a suitable learning scenario, where students have the task to gather specific information on the life and work of Leopold Fleischhacker and his art work throughout the visit of the virtual museum in a CAVE-like environment. We tested this scenario in the aixCAVE–a five-sided CAVE located in Aachen, Germany. The scenario contains the previously mentioned interaction operations, such as to retrieve metadata, adding comments and provenance to it to finally consolidate the walkthrough in the CAVE in a, e.g., class room setting. The CAVE's dimension are 5.25×5.25 meter and it is operated with 24 cinema projectors with a resolution of 1920×1200 pixels each. The rendering is performed by a 24 node cluster, which enables the installation to render stereo images at the desired resolution and appropriate frame rates, which are at a minimum of 60fps. The running museum in the aixCAVE is shown in Fig. 1 on the right.

[2] http://examples.x3dom.org/v-must/index.html.

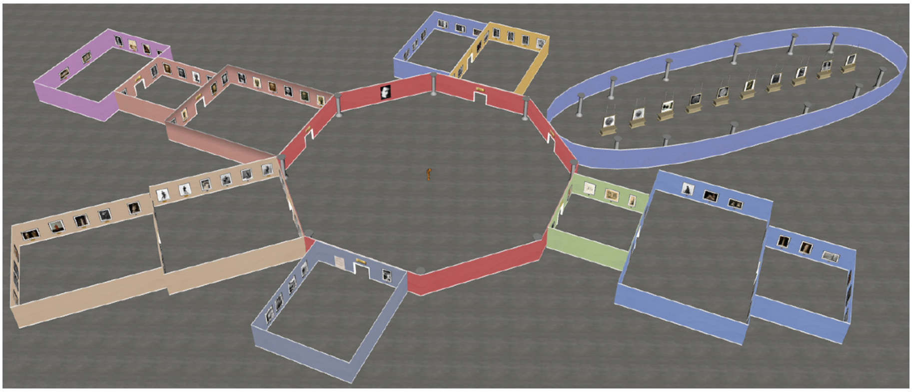

Fig. 3. Room layout as bird eye's view of the Leopold Fleischhacker virtual museum as it has been deployed to the aixCAVE at RWTH Aachen University. All rooms are arranged around a central room, which enables the access to the different exhibition's topics.

5 Conclusion and Future Work

This paper introduced a tool chain for the modeling of virtual museums, which includes the description of single exhibits up to complete exhibitions, metadata and room concepts. Furthermore, the tool chain provides the extraction of 3D models in various formats and includes a software that supports the rendering and the integration of virtual museums in a CAVE-like environment. Using QR codes and metadata provided through a web server, we were able to show the feasibility of the approach for an exemplary learning scenario. Future work comprises an extensive evaluation of the presented approach. The goal of this study will be to quantify how far our approach supports the visit of virtual museums or learning scenarios as well as identifying the impact of immersion in comparison to classic interaction on computer screens or other projections. We further aim at extending the approach to the use of head mounted displays, especially because decent solutions are affordable. Finally, our solution will be used in an interactive installation enriching a real museum exhibition on-site. Therefore, we are going to develop a cooperative interaction concept for navigation and interaction with the museum in a non-stereo projection environment. This will be accompanied with a further evaluation to gather data on the specific use case as well as on newly developed interaction concepts.

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