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Web-based authoring tool for Virtual Exhibitions

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Abstract. This work presents a web-based authoring tool that enables museum curators and individuals to make digital collections of exhibits accessible and explorable via the Web. It allows users to create interactive and immersive virtual 3D/VR exhibitions using a unified collaborative authoring environment based on a Human-Centered Design approach with the active participation of museum curators and end-users. Main contributions are pertinent to the fields of (a) user-designed dynamic virtual exhibitions, (b) exhibition tours, (c) visualization in web-based 3D/VR technologies, and (d) immersive navigation and interaction.

Keywords: Virtual Exhibition, Virtual Museum, Web-based 3D/VR exhibitions, Photorealistic renderings.

1 Introduction

Virtual Exhibitions (VEs) have become easily available to the public, fostering a more efficient exchange of information and interaction with museum visitors in the virtual display arena [1]. The ever-increasing role of such technological breakthroughs has led to accessible, affordable virtual exhibitions available worldwide, delivered through multiple platforms and technologies, aiming to visually present history, architecture, and or artworks [2]. Web-delivered VEs provide content globally through the Web and are facilitated by a wide variety of 3D viewers aiming to provide 3D interactive applications "embedded" in browsers. However, existing VEs set various obstacles, including lack of a unified platform for the presentation of virtual exhibitions on any device and lack of mechanisms for personalized interaction with knowledge and digital information.

In this context, this research work presents the Web-based authoring tool of VEs that allows users to create interactive exhibitions using a unified collaborative authoring environment. The proposed tool comprises technologies that allow novice and expert users to create original exhibitions in a collaborative fashion. Thus, digital collections of exhibits can be promoted to different target groups to foster knowledge, promote cultural heritage, and enhance education, history, science, or art in a user-friendly and interactive way [3].

The ambition of this research work is to provide a useful and meaningful medium for creating and experiencing cultural content, setting the foundation for a framework with direct benefits for museums, Cultural and Creative Industries, as well as the society.

2 Background and Related Work

The most popular technology for the World Wide Web (WWW) visualization includes Web3D [4], which offers standards and tools that allow numerous functionalities such as (a) animations providing dynamic and continuous 360 views [5], (b) panning and high-quality zooming [6, 7], and (c) hotspots and panoramas interconnection with other files [8]. Additionally, there are tools able to combine both geometry and runtime behavioral descriptions into a single file, incorporating advanced physics functionality such as collision detection and friction (e.g., X3D, COLLADA) [9]. Powerful technologies including open-source multiplatform high-performance 3D graphics toolkits and a variety of 3D game engines have been used in museum environments [10, 11, 12].

This work builds upon the aforementioned advancements and introduces technical contributions in the field of (a) user-designed dynamic virtual exhibitions, (b) exhibition tours, (c) visualization in Web-based 3D environments, and (d) immersive navigation and interaction in photorealistic renderings.

3 A Web-based Authoring Environment

The aim of the tool has been formulated after a thorough user requirements analysis, including (a) structured interviews with curators, (b) co-creation workshops, and (c) use case analysis with user groups that defined its functionality and target groups.

The presented tool aims at facilitating curators to design the virtual exhibitions of their preference. The web-based authoring environment provides predefined spaces based on existing templates or spaces created in the past, as well as virtual spaces to be designed from scratch. Firstly, the surrounding of the environment should be formed in

a two-dimensional floorplan. Afterwards, the system automatically generates a 3D representation of the exhibition, allowing users to add details including doors, windows, and decorative elements (e.g., furniture, floor textures, etc.). To add an exhibit in the 3D virtual space, users are able to select the exhibit of their preference in the given formats (i.e., 2D images, 3D models, videos) and position it in the exhibition space as depicted in Fig. 1. Users are allowed to enter exhibits in the platform through an integrated content management system, using standardized semantic web technologies (e.g., Europeana Data Model – EDM [13]).

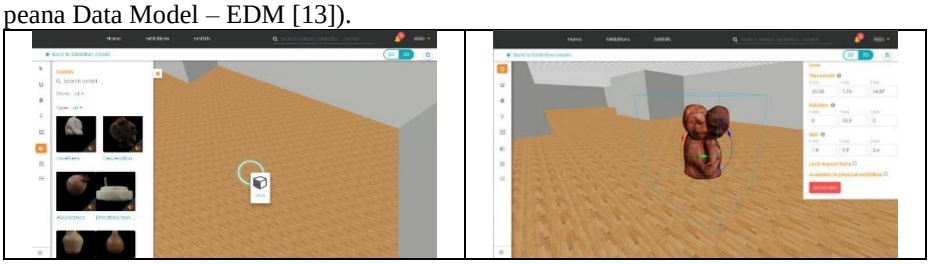

Fig. 1. A 3D design tool for creating virtual museums.

Moreover, the exhibits can be rotated and scaled properly in all three dimensions. Different types of showcases (i.e., glass, frame, stand, etc.) and lights (i.e., ceiling/floor/wall lighting) with customizable characteristics are provided. Free navigation within the 2D/3D environment is supported through the use of the keyboard and the mouse. Users are also able to preview the virtual exhibition tour before finalized and generated into a fully explorable virtual exhibition.

3.1 Co-Creation of Virtual Exhibitions

The presented authoring tool facilitates the creation of virtual exhibitions in a collaborative fashion. In detail, the owner of an exhibition is able to invite other registered users as potential co-creators. In case an invited co-creator does not own an account in the platform, they receive an invitation link via email.

Co-creators have editing permissions in exhibitions; however, the owner is responsible to review all the entries, suggestions, and modifications made and eventually decide whether to approve, edit, or discard them. This feature works more as a safety net toward creating consistent and qualitative content in the platform. More specifically, a notification mechanism informs the owner when edits or adjustments have been submitted by co-creators. The platform also allows users to exchange private messages, thus facilitating the collaboration between two or more parties (i.e., museums, organizations, etc.) through integrated communication channels.

3.2 Exhibition Tours

The provided authoring tool supports tour-oriented exhibitions including (a) free tours displaying all the available exhibits, (b) short tours comprising the most popular artifacts of a virtual exhibition, (c) tours oriented to the age group of users, (d) thematic tours, (f) chronological tours, and so on. The platform automatically creates at least one free virtual tour. When creating a new tour, curators need to enter information, such as starting point, language, title, short description, sequence of the exhibits, and other.

3.3 Interaction in VR

Visitors of the platform can navigate in 3D virtual exhibitions and interact with the exhibits using either a web browser or any VR headset consisting of a head-mounted display, stereo sound, and tracking sensors (e.g., Oculus Quest).

Navigation in VR is readily available upon the selection of a virtual tour. By initiating a virtual tour, the Exhibition Viewer, a Web-based 3D/VR application, provides the 3D construction of the exhibition area, giving prominence to the virtual exhibits. Visitors can interact with any exhibit and retrieve related information.

The platform automatically recognizes whether a VR headset is connected to the computer and enables the virtual tour through the VR headset. Otherwise, the virtual exhibition is loaded in the web browser. In case a VR headset is connected to the computer but the visitor wishes to proceed through the web browser, the platform offers the option to enable the VR tour later on. Through a dedicated menu additional information about the virtual tour progress is provided, including total number of available exhibits, elapsed time of the tour, option to switch the current tour to VR headset, settings, and full-screen view option.

The way visitors may interact during a virtual tour depends on the selected navigation method (i.e., web browser or VR headset). In the case of web browser navigation, the interaction can be achieved by clicking on each exhibit. Whereas, VR headsets allow a more immersive interaction with the assistance of their tracking sensors. Keeping track of a user's hand motion in the physical world has as a result the conversion of their movements in the virtual world, allowing the interaction with virtual exhibits and the navigation in the virtual environment.

4 System Implementation

The platform was implemented following the Representational State Transfer (REST) architectural style, exposing the necessary endpoints that any client application (web or mobile) can consume to exchange information with the system and interface with its

resources. The back-end API was developed using the NestJS framework, which is an advanced JavaScript back-end framework that combines robust design patterns with best practices offering the fundamental infrastructure capable of building and deploying highly scalable and performant server-side applications. User authentication and authorization services were built upon the OAuth 2.0 industry-standard authorization protocol with the use of JavaScript Web Tokens. At the deployment level, the Web Services are packaged as containerized Docker applications.

The proposed web-based authoring tool is based on MongoDB [14], allowing developers to process data naturally and intuitively, mainly due to its JSON data format. This approach ensures short application development cycles, decreased estimated time for developing new features or tackled potential issues. In this way, the authoring tool is considered flexible to changes and upgrades. The back-end services utilize libraries such as Mongoose, an Object Data Modeling (ODM) library for MongoDB and NestJS, to apply schemas to these entities aiming to provide software constrained resource specifications that prevent data inconsistency or even data loss.

4.1 Employing Web-Based 3D/VR technologies

The authoring tool is based on the Angular frontend framework that constitutes a scalable web app solution. The Angular framework allows building features quickly with simple and declarative templates [15]. It achieves maximum speed and performance, while at the same time meets huge data requirements. The frontend architecture implementation takes advantage of the Angular module system to create a maintainable codebase. The main modules are derived for the major resources of the platform, namely its Users, Exhibits, and Exhibitions. However, separate models are used to handle Authentication and User Profiles. Modules implement their business logic in the form of Angular components and their services. These components are reusable by any service via dependency injection, thus minimizing duplicate code. Some of the functions that these services are responsible for are user registration and authentication, exhibit and exhibition creation, and user profile customization. The Web application support responsive design principles by incorporating the Bootstrap front-end framework and uses Sassy CSS (SCSS), an extension to basic CSS, to style and customize its UI components. In that way, user experience on both desktop and mobile devices is equally pleasing and intuitive.

4.2 Photorealistic Renderings

To deliver Web-based 3D/VR experiences, the platform is based on a Web framework named A-Frame [16] supporting all WebXR browsers available for both desktops and standalone VR headsets (e.g., Oculus Quest) [17].

A-Frame [16], the Web framework for building 3D/AR/VR applications based on HTML/Javascript, is useful for multiplatform applications, however performance tests revealed a limitation on the number of light sources a scene, since numerous light sources might affect the performance of the application and aggravate the user experience. A-Frame's rendering engine calculates only direct lighting. However, the absence of indirect lighting disengages users from gaining an immersive experience, simply because a flat-shaded scene falls into the uncanny valley of computer graphics. For that reason, the framework was further explored following different approaches on lighting the scene. After experimenting with the framework, a number of basic guidelines were concluded aiming to enhance the visualization of an exhibition room to look more attractive and at the same time save performance. These include the following: **(i)** the less ambient lighting, the more realistic the scene, **(ii)** windowless interior spaces are preferable, since windows increase the cognitive expectations of lighting, **(iii)** the more point lights or spotlights in combination with ambient lighting the better, and **(iv)** more than 5–6 lights should be avoided, in case of standalone VR headsets, to significantly reduce the performance.

The best possible result has been achieved given the available resources on the real time lighting pipeline of A-Frame (see Fig.).

Fig. 2. (a) Lighting of virtual exhibition space and 3D exhibits; **(b)** Displaying exhibits' information.

Taking into consideration that A-Frame does not support baking functionality, the Blender Bakery pipeline was additionally integrated [18]. Its main use in the industry is 3D modeling and animation, however it is also able to perform baking and scripting, making it a perfect match for the specific case. The pipeline is being activated automatically at the time a curator finishes the design of a virtual exhibition space. The virtual exhibition serves real-time, low-quality graphics rendered by A-Frame and saves user-

changes continuously on the database. On completion, the Blender Bakery pipeline is triggered. The baking process takes place on Blender, using the ray-tracing rendering engine of Blender called "Cycles", producing as output a .glb file that will be stored back to the database. As a result, when visitors start an exhibition tour, a photorealistic virtual space with great performance will be activated.

5 Evaluation Results

Different evaluation methodologies throughout the development cycle of the proposed tool were applied following a Human-Centered Design approach[1]. Thus, ensuring that the platform will serve user needs in the best possible way and provide an engaging experience both for content creators and content consumers. In particular, the following evaluation iterations were carried out: (a) heuristic evaluation of the designed mockups applied iteratively, (b) group inspection of the final implemented mockups, ensuring that they are usable for the target users, and (c) cognitive walkthrough to assess the intuitiveness of the application at each step of the interaction.

The heuristic evaluation with UX experts took place during the design phase, in which initial mockups were created. Based on the feedback acquired, an extensive set of mockups both for the Web and the VR environment were designed, which were further evaluated by end-users, as well as by domain and UX experts.

During the group usability inspection, comprising three evaluation sessions, mockups of the implemented system were presented and evaluated through group discussions, aiming to assess whether the requirements defined during previous phases were met.

A cognitive walkthrough was conducted with the participation of three UX experts and one domain expert, in separate one-hour sessions, driven by a set of tasks that should be executed, aiming to assess the system actions and responses. A facilitator observed the evaluators and kept notes regarding whether they tried and achieved the desired outcome.

Several conclusions were drawn concerning the design of the tool, addressing to cultural institutions and individual content creators. Overall, evaluators appraised the clear design and the UI consistency, as well as the well-integrated functions into a logical flow. The most severe problems identified referred to the lack of adequate information about the exhibits and of more detailed guidance during a tour. Moreover, the functionality for creating and editing a 3D virtual space can entail difficulties, especially since some functionality appears to be hidden. Finally, some improvements were

[1] The study was approved by the Ethics Committee of the Foundation for Research and Technology—Hellas (Approval date: 12 April 2019 / Reference number: 40/12-4-2019).

pointed out concerning the terminology used especially affecting the non-professional content creators.

Future evaluation efforts will target larger numbers of end-users, including professional and non-professional content creators, as well as museum visitors.

6 Conclusions and Future Work

This work presented a Web-based authoring tool for Virtual Exhibitions that allows users to create interactive and immersive virtual 3D/VR exhibitions using a unified collaborative authoring environment. In summary, the platform offers (a) user-designed dynamic virtual exhibitions, (b) exhibition tours, (c) visualization in Web-based 3D/VR technologies, and (d) immersive navigation and interaction in photorealistic renderings.

The platform differentiates from other similar works in the sense that it is a generic technological framework not paired to a specific real-world museum. Its main ambition is to act as a tool that supports the representation and presentation of virtual exhibitions through Web-based 3D/VR immersive visiting experiences.

With regard to future improvements, emphasis will be placed on the experiential part of the visit focusing on hybrid exhibition tours that combine AR augmentation of physical exhibitions.

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