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CREATING VIRTUAL REALITY USING A SOCIAL VIRTUAL ENVIRONMENT: PHYGITAL EXHIBITION AT THE MUSEUM PASSION IN SORDEVOLO

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KEY WORDS: Virtual tours, museum collection, intangible heritage, documentary heritage, digital curation.

ABSTRACT:

The paper addresses the digital curation of immersive and virtual spaces for the cultural heritage sector. One of the research objectives is to define a methodological and operational workflow for developing a virtual environment designed using a social virtual environment. The use of social worlds in virtual reality (VR) is one of the possible entry points to the metaverse, understood as a way of experiencing digital reality. The possibility of creating a digital space that replicates real space offers not only the opportunity for people to gather in a virtual place but also allows designers to provide a parallel and augmented experience in terms of content.
The case study aims to create the digital twin of the temporary Phygital Exhibition, which opened in July 2022 at the Sordevolo Passion Museum in the Church of Santa Marta. Unlike the permanent collection, which recounts the tradition of popular theatre in Sordevolo for the performance of the Passion of Christ, the Phygital Exhibition focuses on documenting the activity related to the design and construction of the scenography. In the virtual environment, the physical space is replicated with a low level of detail to emphasize the VR exhibition, composed of a series of panels with the possibility to interact with historical documentation, drawings, and pictures. The virtual space is also enriched by video and 3D models not available in real space, which documents the transformation of the scenography over the years.

1. INTRODUCTION

Virtual reality and virtual environments are recognized mediums for accessing cultural content and museum collections. Diverse institutions nowadays offer free online access internationally to the public. The developed solutions are generally based on a 360 virtual environment that provides a virtual tour of the real space. The use of 360 cameras and low-cost or open-access solutions offer the possibility to create virtual tours and enrich them with a diverse type of 2D/3D objects, pop-ups, and links.
Virtual tours, in the latest years, have become a valuable supplement to in-person visits and help bring museum collections and cultural content to a broader audience.
Also, virtual tours based on virtual reality (VR), for example, virtual exhibitions, can be an excellent way for people to experience museum collections, especially if they cannot visit the museum in person. One of the benefits of this virtuality-based type of solution is that they can provide a more immersive experience than simply viewing 360° images of museum rooms online. They can also include the 3D models of the museum/institution collection, adding an immersive and visual experience of the artifact. The use of other elements in the environment, such as, for example, the audio, can also increase the emotional response to the experience and help maintain its memory.
With the advent of the COVID-19 pandemic, we have witnessed an increasing use of web platforms to communicate between groups (Vayanou et al., 2020). We also assist in the growth of Social Virtual Reality (SVR) as an emerging medium that invites multiple users to join a collaborative virtual environment (VE) that can support remote communication in a natural and immersive way. (Li et al., 2021) Social interaction in VR is well-known in gaming, where the game design provides a shared experience beyond the virtual game world. (Liszio and Masuch, 2016)
In the cultural heritage sector, digital transformation generally involves institutions in digitization campaigns to preserve and document their heritage.
Another goal of contemporary museums today is the necessity to respond to their community needs and maximize the impact of their digitization projects adding value to the heritage they preserve.
During the lockdown, museums and cultural institutions used digital platforms and social media to connect with their audience and expand their public. The most used were Facebook, YouTube, Twitter, and Instagram. What emerged from that experience was that most people accessed content not only through the Web by desktop but primarily via smartphones. This behavior also affects the way of thinking and designing virtual reality solutions.
The paper presents an alternative approach to developing virtual reality solutions using a social virtual environment easily accessible by smartphones. The virtual exhibition created is developed using Hubs by Mozilla[1] and the Spoke[2] 3D scene editor.
Hubs is an open-source and Web-based virtual collaboration platform that allows users to enter a virtual room and talk to other people as if they were in the same real space. Hubs make it easy to connect and share images, videos, 3D models, and many resources available on the Web and retrievable by using their URLs. With Hubs it is possible to create customized and personal 3D spaces and invite others to join using a URL to access the

[*]Although the contribution was conceived jointly, Elisabetta. C. Giovannini is author of pharagraphs 1 and 3. Jacopo Bono is author of paragraphs 2 and 5. The authors wrote together paraghaph 4.
[1] The platform is available at https://hubs.mozilla.com/
[2] The scene editor is accessible via https://hubs.mozilla.com/spoke

room. No installation or app store is required.
Spoke, developed by the Mozilla Mixed Reality team, is the built-in scene editor for creating environments that can be used in Hubs rooms. The 3D editor runs entirely in the browser and allows users to upload their own 3D models, images, and files to use in their projects.
Thanks to the Spoke tool and integrations from Sketchfab and Google Poly, it is also possible to create digital environments using, as primary sources, 3D models previously uploaded in Sketchfab. (Iglesias et al., 2021)
The proposed methodology offers a panorama of open-access tools and digital ecosystems uncommonly used in the cultural heritage sector for dissemination purposes. The literacy review showed how there is still a gap in the exploration of this method for disseminating digital cultural heritage online. Otherwise, low-cost solutions for virtual exhibitions can be an opportunity to make digitized content accessible and engage a wider audience.
As reported in the Mozilla Hubs documentation website,[3] the platform can be used for various purposes, including poster sessions, conferences, performances, and exhibitions.
The platform is also used in universities in the edutainment sector and for learning experience design. (Back et al., 2021; Canniff and Cliburn, 2022; Glaser et al., 2022; Tsiamalou et al., 2023)
Interesting edutainment activities with Mozilla Hubs and Spoke were organized, for example, by the Europeana Pro mentoring program and educational challenge, which contributed to the New European Bauhaus movement by inviting students and educators to design beautiful and sustainable spaces with Mozilla Hubs[4].

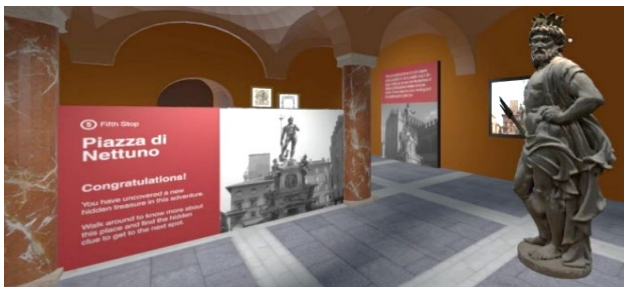

Figure 1. Screenshot from the 'Bologna Untold' space on Mozilla Hubs created by D. Federici in 2022.

Europeana had a program entitled 'Built with Bits' to explore how virtual experiences can be used in education. The program involved teachers and educators working with students in secondary education in Greece, Italy, Spain, and Portugal. They also created a challenge with the possibility for the winners to participate in a masterclass to develop their Hubs project further. Also, the art sector and artists were not immune to the platform's use, which offers diverse opportunities for developing digital art projects focused on visual arts.
One example is The Ars Electronica project, which began with a festival in 1979. In 2020, the festival led to the creation of 60 Hubs with a multitude of content created by the Ars Electronica community and its partner gardens worldwide. (Wright and Howden, 2022) For the event, Ars Electronica used the Hubs cloud that allows users to customize the deployment of the Hubs platform, offers configuration tools for rooms and accounts, and is better suited for more significant events. By default, Hubs allow to share the virtual space with a maximum of 24 users, but this limit can be increased to 30.

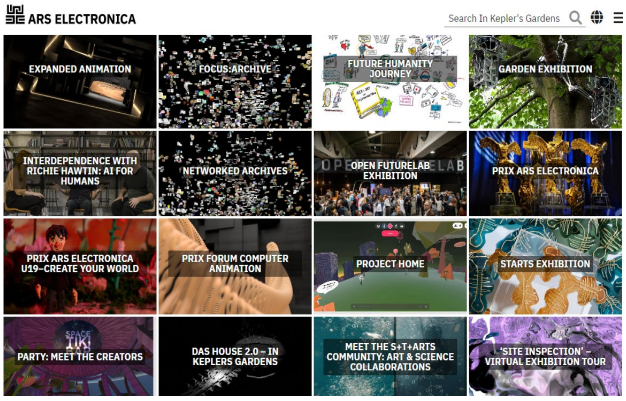

Figure 2. Screenshot from the Ars Electronica website space that collects the Mozilla Hubs rooms developed for the festival. https://ars.electronica.art/keplersgardens/en/mozillahubs/

2. CURATING THE PHYSICAL SPACE

The Passion of Christ represented in Sordevolo is part of the Italian immaterial cultural heritage. This heritage is fundamental in maintaining cultural diversity in the face of globalization, and its understanding helps intercultural dialogue by encouraging mutual respect for different ways of life.
Enhancement of intangible cultural heritage is considered a challenge that digital tools may be able to address. The path of digitization processes started with the design of part of the 3D video animation content developed for the renovation of The Passion Museum in Sordevolo, which reopened in June 2021.
The Phygital Exhibition, intended as a temporary exhibition, is a natural outgrowth of the collaboration between the Department of Architecture and Design of the Politecnico di Torino and the Museum of the Passion. The first collaboration outcomes were 3D modeling of the performance sets in 1934 and 1950 and two videos with 3D animations that are now part of the permanent exhibit. (E C Giovannini et al., 2021)
The Passion Museum consists of two exhibition halls with eight thematic corners showing the following aspects: the Scenography, the history of the Passion Text, all the moments of the performance, the work of the volunteers (technicians, tailoring, actors, directing, service workers), the Children's Passion, costumes, artifacts and documents that tell the story of the Sordevolese tradition. In the museum are displayed more than 300 photographs and seven historical films, including the most important ones from the 1924 and 1934 editions of The Passion, filmed by the Istituto Luce.
The Phygital Exhibition layout comprises eight panels documenting the evolution of the scenography used in the popular tradition of the Representation of the Passion of Sordevolo, played since 1814. Since at least 1850, the text has been composed of a succession of scenes that punctuate the representation. Some scenes present in the past are now disappeared. Despite the quinquennial cadence of the representation, the process of preparation of the Passion cultural event is distributed over two long years of work, where nothing is left to chance: the casting of the "citizen actors," the distribution of roles for interpreting the texts, the choice of costumes, choreography, and scenography. (Associazione Teatro Popolare di Sordevolo, 2019, 2015; Orsi, 2000)
The exhibition adds to the previously developed content, the archival and iconographic repertoire covering a broader period, from 1886 to the present.

[3] The https://hubs.mozilla.com/docs/welcome.html
[4] The initiative was part of the 'Built with Bits'. https://pro.europeana.eu/page/built-with-bits-designing-virtual-spaces-for-the-future

Figure 3. Interior of the church of Santa Marta with previous set up of the temporary exhibition. © The Passion Museum.

Figure 4. The Phygital Exhibition physical space inside Santa Marta church. Picture by E.C. Giovannini.

Figure 5. The Physical Exhibition layout comprises panels with images and textual descriptions of the main scene elements. Picture by E.C. Giovannini.

The exhibition path was enriched by three Augmented Reality (AR) solutions. AR solutions show the 3D models used to produce some of the images included in the panels. The aim was to make the visitors interact with the collection.
All the content exposed in the Phygital Exhibition was gathered, selected, and digitalized from documents and photographic archives owned by the museum.
The exhibition area of the real space consists of four pairs of panels in correspondence with the intercolumniations that separate the central nave from the side aisles of the Church of Santa Marta. The panels have a thematic approach to diverse set scene elements to describe their evolution over time.
The curatorial activity followed a thematic reading focused on the central scenic apparatus, their appearance, and the documentary heritage that documents their commissioning.

The first pair of panels focuses on the evolution of the stage layout and associated documents. The staging includes four aedicula, a covered scaffold, and additional props such as palm trees (Garden of Gethsemane), a severed column (Flagellation), and a bare tree (Hanging). Over the years, these elements have remained unchanged but transmuted in form. In the minutes of the Passion of Sordevolo, there is a trace of the management and implementation process of the set design.
The second pair of panels realizes a focus on the part of the scenic installation intended to welcome visitors, the stages. Specifically, the development of its implementation using temporary structures to a permanent solution in the early 2000s. The use of elements with different materials and dimensions is highlighted in the narrative through iconography and the Tender Specifications, a technical-textual document.
The third pair of panels analyses the central element of the scenic apparatus, the four chairs of Anna, Caiphas, Herod, and Pilate. They have evolved considerably over time from a technical-constructive point of view. Initially, they were stand-alone elements and purely two-dimensional. Later, they merged with additional scenic features and acquired a greater three-dimensionality. In recent years, the chairs have given way to more complex scenic elements such as the Praetorium, the site of the Last Supper, the Garden of Gethsemane, the Judas Tree, and the Sanhedrin.
The last pair of panels has the scenic element of the Calvary as its focus. As with the chairs, it has evolved, acquiring a solid three-dimensionality and changing its material component. The increase in complexity, which has taken it from a simple scenic apparatus to becoming the protagonist in the performance, has led to the deaf and dumb community of design studios joining in. This attitude is evidenced by drafting technical drawings in plan and elevation.

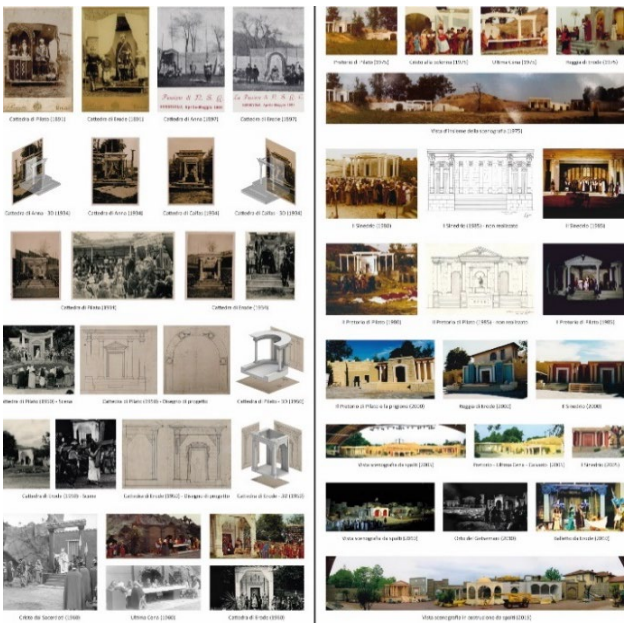

Figure 6. Detail of two panels layout designed by J. Bono.

3. FROM PHYSICAL TO DIGITAL

The digital transition of the museum sector enlighted how VR can be assumed as the most used digital technology by museums. (Kang and Yang, 2022)
The proposed workflow can be integrated into the work practices of heritage institutions, considering their need for affordable and sustainable digital solutions to manage their digital heritage.

It is also emerging that many museums nowadays are massively producing 3D models of their collections and making them accessible via the Internet using diverse platforms, such as, Sketchfab. (Champion and Rahaman, 2020)
This research defines a workflow to create a digital exhibition using a low-cost VR solution. This approach differs from more specialistic ones: unreal engine and unity.
An attempt to a simplified workflow to create VR and immersive 3D environment has been undertaken by Twinmotion. (Hajirasouli et al., 2021) The tool is also interoperable with BIM software, allowing to reuse of 3D models to create virtual tours using an Unreal Engine plugin. (Banfi et al., 2023, 2021)
Unity, as Unreal Engine, is configured as a game engine tool that requires advanced programming skills, and sometimes the developed contents are not directly accessible over the Web. (Morse, 2021)
Both Unreal Engine and Unity have already standardized protocols for developing VR content oriented to the Cultural Heritage sector, including virtual exhibitions. (Checa et al., 2017; Ciekanowska et al., 2021; Pybus, 2019)
This research aims to investigate the possibilities Hubs and Spoke offers for creating immersive environments from 3D models built specifically for virtual tour/digital exhibition use and as a navigable and interactive virtual environment.
Hubs can be oriented to the Cultural Heritage sector, offering a low-cost and easy-to-use solution. This VR environment allows the integration of different 3D objects in a framework that differs from the conventional gallery of digitized objects provided by Sketchfab. Otherwise, the platform has increasingly changed over the years, offering the possibility to add annotations on 3D models and VR view mode using desktop or mobile devices. (Cruz Franco et al., 2022)
Despite the potential of Hubs combined with Spoke, examples of digital cultural heritage exhibitions are virtually lacking. This also happens because there is, to date, no ability to search for rooms created by users. The content is private and accessible only if you know the direct link to access Hubs rooms.

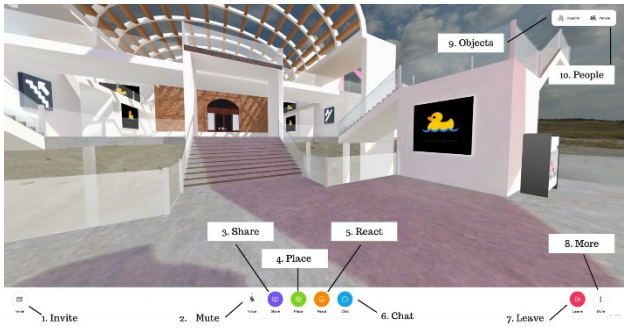

Figure 7. Hubs user interface.

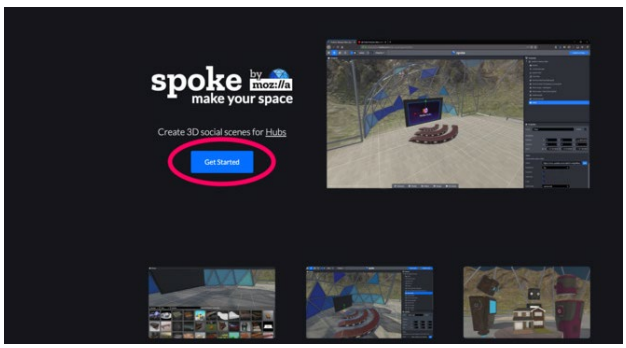

Figure 8. Spoke user interface.

Hubs allow the scene to be enriched with various types of data using a simplified interface after the web publication of the room, and is also possible to enrich the environment with 360 content, images, and video creating 360 spaces inside a VR ecosystem. (Karataş, 2022)
Users can create and move objects, pin content, draw, and create cameras by default. The room owner can also remove this permission to reduce the possibility of changing the 3D environment.
With Hubs, creating customized scenes to use as the environment rooms is possible. Any scene can be used to create multiple rooms, and it is allowed to remix existing scenes that have been shared with a Creative Commons license in Spoke to make edits and personalize spaces.
The methodological approach to the transition from the physical and digital spaces of the Phygital Exhibition layout is based on the concept that an exhibition comprises two main elements: the container and the content. (E. C. Giovannini et al., 2021)
In the case of a temporary exhibition, the container is generally a room or a physical space that collects the curated content.
In the case of the Physical Exhibition, the container is the Church of Santa Marta. The content comprises bi-dimensional and three-dimensional digitalized materials. Their digital acquisition was performed using diverse technologies such as Structure from Motion (SfM) photogrammetry and laser scanning.
Creating a virtual reality of the exhibition allowed us to define a methodological pipeline for developing the 3D scene hosted by free and open-source web-based solutions.
For the 3D models, the platform used was Sketchfab, while for bidimensional digitized content, the images are hosted by a GitHub repository.
The use of affordable online repositories answers the need for third parties tools to have direct access to the URL of each resource to retrieve it instead of hosting it. The project collected a heterogeneous data set with a diverse digital acquisition pipeline. As happens for real exhibitions, the content was classified and managed in different ways.

4. CURATING THE DIGITAL SPACE

Across the cultural heritage sector, digital curation encompasses the selection, acquisition, preservation, maintenance, and delivery of digital data.
In the case of 3D content, digital curation has the mission to define the purposes of using digital resources to enhance visitor or customer experiences. The role of digital curation for virtual tours and exhibitions also regards the balance between the metric accuracy of 3D objects, their resolution, and their possibility to be accessible using tools that can have limits in managing heavy file formats.
For the Mozilla Hub scene, the 3D models created were uploaded online to the SketchFab gallery with free access. In particular, it should be mentioned that the platform allows uploading 3D files that do not exceed 200MB, including files for textures.
This bottleneck makes the post-processing pipeline of models created from instrumental acquisition time-consuming. This reduction in the resolution of files was deemed acceptable according to the dissemination purposes of the project.

4.1 The container/The digital environment

There are two currents of thought in virtual tours and digital exhibitions: one that imagines the immersive virtual experience within the digital replica of reality, creating a digital twin. The second current envisions the potential of VR to expand the physical boundaries of places and create imaginary environments.

Digital curating, in this case, took an intermediate position: to create an environment that could in some way replicate reality while stripping it of its decorative apparatus and reducing its impact in fruition. Although it was possible to acquire the environment of the church of Santa Marta, it was decided to opt for a simplified digital environment to highlight the objects and panels on display. In this way, virtual reality offers a different experience from the visitors in the real space. At the same time, differentiating the virtual from the real allows for adding material that would otherwise not be visible.
The space was considered a room with a side aisle and a central apse. On the sides are three niches on each side. The main architectural elements were kept by simplifying them. The model was created using Rhinoceros and was textured to maintain the original colors of the marbles that punctuate the environment.
The vaulted system that is richly decorated in reality remained in the digital environment with a neutral color.

Figure 9. 3D model of the digital environment modeled and textured in Rhinoceros (E.C. Giovannini)

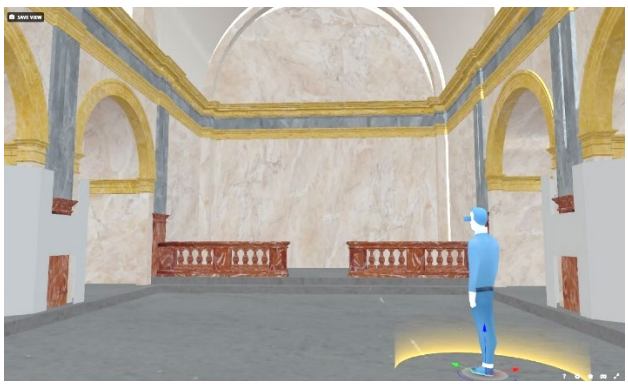

Figure 10. Preview of the SketchFab model to be enriched with 3D objects, images, and videos. (E.C. Giovannini)

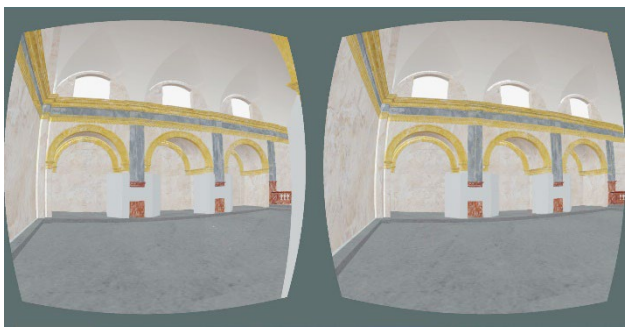

Figure 11. Virtual Reality view mode offered by SketchFab platform and tested using a mobile phone. (E.C. Giovannini)

The model of the scene was also integrated with the exhibition layout. The main panels were modeled in the principal environment and enriched with diverse kinds of content in Spoke using text (1D) and image (2D) elements. The interior space of the side niches, which in reality contain altars and paintings, in the digital environment was arranged to accommodate a digital collection of 3D models of the scenography.

4.2 The content/The digital collection

The digital collection reflects reality in terms of textual information and iconographic content.
Because the Passion of Sordevolo is also well known abroad, the text is in Italian and English.
The original layout of panels was designed using InDesign to organize the digitized content with heterogeneous file formats. While some format arrangements were not necessary for the physical exhibition setup, the pipeline for reproducing the panels in the virtual environment required a specific workflow to normalize the material in terms of image format, resolution, and bit depth.
Regarding the 3D content, the workflow focused on the post-processing phase, remeshing, repairing, and reducing the high-resolution of textures.
In the Spoke environment, custom content is added through the Asset panel in the Elements tab. The Spoke front-end is built with React for 2D components and Three.js and A-Frame for the 3D scene.

4.2.1 The informative layer (1D): informative layer in the exhibition was composed of the title of panels and their brief description.
Spoke offers two ways of introducing this type of content in the scene: the Trojka Text and image elements. Trojka Text is customizable using the user interface. The image element introduces an image in the scene that can be updated only when the online resource it refers to is updated.

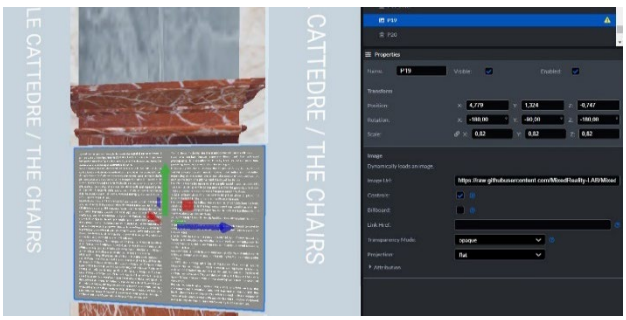

Figure 12. Spoke interface showing the use of Image element for informative layer. (J. Bono)

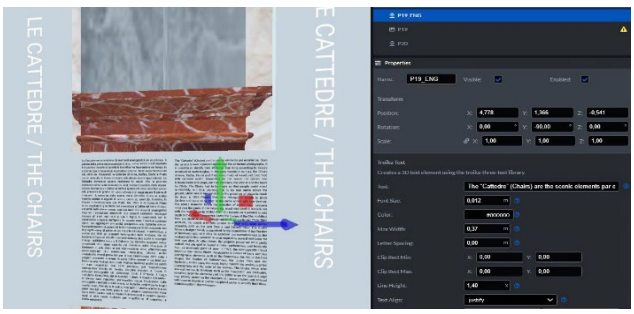

Figure 13. Spoke interface showing the use of Troika Text element for informative layer. (E.C. Giovannini)

For the Phygital Exhibition environment, we opt for the Trojka Text. Once inserted in the scene, the element has a panel for its available properties. On the top, are general properties related to the position of the object in the scene, its default scale, and rotation. Below the general properties panel are specific parameters of the element used. For a more user-friendly experience, parameters have a question mark beside them providing a brief description. The parameters that have been explored within this scene are multiple.
The Text field allows the typing of the text to be inserted within the scene. Parameters related to the visual appearance of the text are the Font Size, in local world units (m), and the Color for set Hex or RGB codes.
The paragraph style is controlled by the MaxWidth, which defines the maximum width of the text block. This relates to the WhiteSpace parameters determining whether the text should wrap. The Text Align allows the control of the horizontal alignment of each line; Anchors establish the position of the anchor point of the text block.
To position the text in the scene, we use a translation and rotation of the object to adapt the element used to the surface on which it is to be placed: the panels.

4.2.2 The iconographic layer (2D): The Image element was used to insert images. Spoke offers two ways of introducing this type of content in the scene: using the URL of the source or uploading the image in the Scene Asset.

Figure 14. Spoke interface showing the use of Image elements for the iconographic layer (digital asset creator: J. Bono)

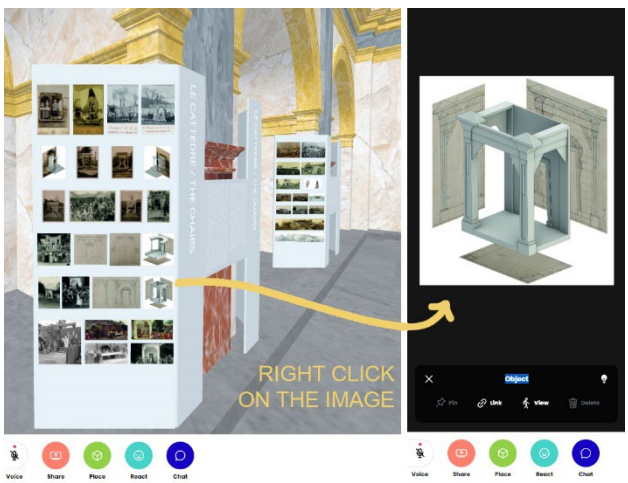

Figure 15. Hubs interface showing the user interaction with Image element. (E.C. Giovannini)

The element has the same general parameters previously described. The specific parameters are: Image URL that allows the loading of the scene using the Internet address of the resource; the Controls (on/off) toggle the visibility of the media controls in Hub. Since in Spoke, it is possible to load 2D and 360-degree equirectangular images, the Projection parameter is available.
Attribution parameters can be used to specify the title, the author, and an alternative URL, as metadata content for resource provenance.
In the project, we decided to use a Github repository, MixedReality-LAB\VR_PhygitalExhibition, to store the images used in the four pairs of panels. The images also required intensive work before being uploaded into Github. The files were all renamed according to specific coding to make them recognizable for placement in the 3D environment. In the file name, we include the panel number, the year of the representation, and the number of column and row it occupies in real panels. Each image was resized with the actual size (cm), decreased in resolution quality to facilitate their uploading (150 dpi), and equalized in color depth (32 bits). Once the insertion of images related to a single panel was completed, a group was made to facilitate the correct position of the elements on the panel surface. In Hub, it is possible to interact with objects, such as images and videos, and view them in full-screen mode using the mouse's right button. The full-screen view mode isolates the object by hiding the environment, so it is possible to observe details with a black background.

4.2.3 The digital collection (3D): The 3D model collection consists of models showing diverse scenography and the stage/arena of the Passion.
As already mentioned, two models were developed, starting from historical resources and drawings. The three-dimensional models were made in Rhinoceros (referred to years 1934 and 1950). Some of the elements inside those models were highly complex. In the case of the fence made up of numerous wooden planks, we simplified the geometries to reduce the .obj file format below the 200MB limit of Sketchfab.

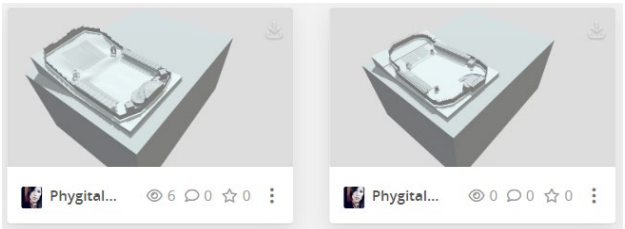

Figure 16. Sketchfab interface with 3D models of the collection modeled in Rhinoceros and based on the archival resources. (3D models: A. Tomalini, digital asset creator: J. Bono)

The other three models represent, respectively, the scenography of the years 2022 and 2000 and the coverage of the seating areas. Each model was the result of a diverse digital acquisition technique, UAVs (2022), photogrammetric (2002) and laser scanning. The models, obtained from reverse engineering processes, were imported into Meshlab to perform remeshing, simplification, and reconstruction. Then each .obj was imported into MeshMixer to be repaired and fixed. Finally, the models were integrated with a baseplate in Rhinoceros. The .obj, .mtl, and images of textures were then uploaded into SketchFab.
Within the virtual environment, the 3D models are presented as physical models placed on rectangular bases to raise them off the ground and bring them to human eye level. In the properties window, Model elements have parameters similar to those of the images. The only new parameter is the one that refers to the gITF

info, which returns additional information about the model's state (nodes, meshes, materials, textures, triangles, and vertices).
For the correct position of models in the church, the composition of the entire scene was done first inside Rhinoceros. Then every single model was exported using the same origin. This workflow allowed us to place models in the Spoke scene directly in the same original position.

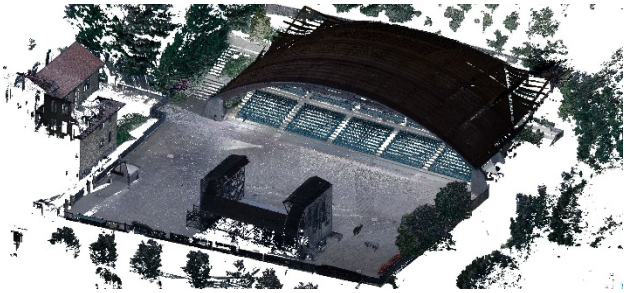

Figure 17. MetaShape interface showing the point cloud of the seating area. (laser scanning acquisition: The Museum Passion, post-processing and digital asset creator: E.C. Giovannini)

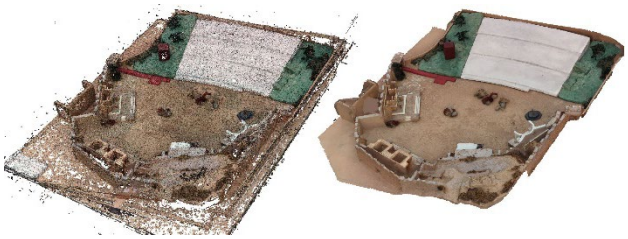

Figure 18. MetaShape interface showing the point cloud and the model of the scenography dated 2002 (data capture: A. Tomalini, post-processing, and digital asset creator: E.C. Giovannini)

Figure 19. Sketchfab interface with 3D model obtained from UAVs acquisition. (data capture: A. Tomalini, post processing and digital asset creator: E.C. Giovannini)

Figure 20. Spoke interface showing the use of Model element to enrich the scene with 3D content (E.C. Giovannini)

5. RESULTS AND CONCLUSIONS

The outcomes described represent a first approach using Spoke and Mozilla Hub to create virtual scenes related to the curatorial digital world and museum experience. The application allows the generation of scenes using 3D models, that can be published and shared on the Web through simple steps. It is, therefore, possible to create a space of educational, social, and interactive nature.
The main peculiarities of the tool can be summarized as follows:
- accessibility: through Hubs space, it is possible to improve the visitor's experience by personalizing content. This makes it possible to have greater inclusiveness towards the public, including people with reduced or poor motor skills, thanks to the use of assistive technologies;
- flexibility: content customization is made immediate and intuitive so that the user can generate a virtual environment suited to their content and vision.
- collaboration: being a social space of relationship between different users, Hubs can promote knowledge sharing. Users can interact with each other within the virtual environment and share their experiences and ideas.
- cost: Hubs can reduce costs. Particularly for museums, it has a different budget impact than traditional exhibitions. Finally, the virtual experience can have a longer duration and succeed in reaching a wider audience than physical exhibitions offering a diverse and heterogeneous type of content.

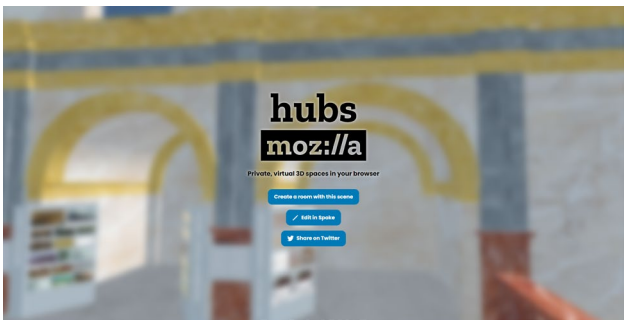

Figure 21. Hubs interface showing the creation of Phygital Exhibition room using the Spoke scene. (E.C. Giovannini)

Figure 22. Hubs interface showing The Phygital Exhibition room enriched by videos, images and 3D models. (digital curation: E.C. Giovannini, digital asset creator: J. Bono)

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