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3D WEBGIS APPLICATIONS FOR DIGITAL HUMANITIES STUDIES: THE TURIN 1911 PROJECT / Spreafico, A., Chiabrando, F., Della Coletta, C.. - In: INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES. - ISSN 1682-1750. - ELETTRONICO. - XLVIII-M-2-2023:(2023), pp. 1501-1508. [10.5194/isprs-archives-XLVIII-M-2-2023-1501-2023]

Availability:
This version is available at: 11583/2979794 since: 2023-07-03T13:35:19Z

Publisher:
Copernicus

Published
DOI:10.5194/isprs-archives-XLVIII-M-2-2023-1501-2023

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07 November 2026

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
29th CIPA Symposium "Documenting, Understanding, Preserving Cultural Heritage:
Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

3D WEBGIS APPLICATIONS FOR DIGITAL HUMANITIES STUDIES: THE TURIN 1911 PROJECT

A. Spreafico [1]*, F. Chiabrando [1], C. Della Coletta [2]

[1] LabG4CH, Laboratory of Geomatics for Cultural Heritage, DAD, Dipartimento di Architettura e Design, Politecnico di Torino, Viale Mattioli 39, 10125 Torino, Italy
(alessandra.spreafico, filiberto.chiabrando)@polito.it
[2] SAH, School of Arts and Humanities, University of California San Diego, 9500 Gilman Dr. La Jolla, 92093 California, USA
cdellacoletta@ucsd.edu

KEY WORDS: BIM, GIS, Cultural Heritage, online sharing, World's Fairs, geo-databases, 3D digital reconstruction

ABSTRACT:

Documentation of CH is paramount to preserve its memory and allow its study, especially when CH is meant to be dismantled, as for the architectures of World's Fairs. Very few efforts are undertaken to achieve this goal and national and international institutions rarely adopt innovative digital technologies. Digital technologies and products like 3D digital models are successfully and largely applied in CH domains, while webGIS is less explored for CH. Nevertheless, 3D digital models are rarely adopted to accompany digital archives and Digital Humanities studies. Very few cases use 3D models for World's Fairs' study and documentation. WebGIS is not used for World's Fairs, and are scarcely adopted and not fully exploited by Digital Humanities and digital archives for sharing data and information about CH. *Turin 1911* is the first digital project aimed to virtually document, recreate, and study an entire World's Fair. Combining digital technologies (geo-DB, 3D digital reconstruction, and 3D webGIS) with cataloging standards, Turin 1911 is a pioneering initiative that applies these innovations to Digital Humanities in order to share information online. In this paper, dedicated webGIS applications are developed for the Turin 1911 needs, reporting the designed procedure, challenges in the development phase, and potentialities for Digital Humanities research. Finally, BIM models are also integrated in webGIS apps, making visible no more visible architectures. The paper discusses how webGIS apps could become a way for sharing information and data, but also a working environment for Digital Humanities studies where the research takes place in 3D environments.

1. INTRODUCTION

When dealing with Cultural Heritage (CH) sites that have been dismantled or destroyed, either deliberately or accidentally, the only traces of documentation are historical sources that are often difficult to access, even if many institutions are undertaking massive digitization projects and creating online digital archives (Bitelli et al., 2019). Historical documents often remain inaccessible in storage facilities or libraries. Digital documents also risk remaining stored on local hard disks because of budget limitations that prevent these files from being included in repositories accessible to the public. In addition, often online sharing is challenged by the format and weight of the files. In many cases, digital archives are digital copies of physical archives that do not take advantage of the capabilities that computers provide (Münster et al., 2019). Few of these projects and initiatives, such as Europeana, CyArk 3D Heritage Archive, and Open Heritage 3D, display 3D models in their digital repositories. When 3D models are used, they are often individual models detached from their context, with no relation to other CH and relevant natural environment. Digital technologies such as BIM and webGIS provide interesting solutions that enable scholars to access and analyze ephemeral CH structures in all their complexity, with the opportunity to avail oneself of support studies in humanistic fields. The advent of WebGIS has reduced costs, increased the ability to reach wider audience, and facilitated the use of GIS functionalities and spatial data sharing and usage. Nevertheless, only a few studies apply 2D and 3D webGIS to Digital Humanities. Fiorini (Fiorini et al., 2022) uses webGIS only to visualize a virtual tour of Venice during Napoleon's visit in 1807 and not as a research tool. In addition, the link to the webGIS is not provided. Wei (Wei et al., 2022) created a webGIS for Chinese historical information, in order to visualize and study past events through a webGIS. The webGIS retrieves data from a database (DB) based on structured terms and ontological relations among events, people, places, literature, and time. This project however is only based on a 2D environment and fails to consider the potentialities of a 3D space. Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) geoportal (Pantaloni et al., 2021) offers a webGIS for historical geological maps of Italy, and the maps are cataloged according to International Standard Bibliographic Description (ISBD) standards and georeferenced. However, the maps are displayed onto a 2D map of today, and the project does not provide the digital reconstruction in 3D of the historical territory, or the relations to people or the institutions that authored the maps. The webGIS of Yunnan-Vietnam Railway (Sang et al., 2021) shows geotagged historical photos cataloged in a DB with relation to the photographer and framed locations, but is developed only in 2D. The MayaArch3D (von Schwerin et al., 2013) digitally reconstructs in 3D the architecture of the UNESCO site of Copan using different Levels of Detail (LoD). The architectures are linked to 2D and 3D archaeological data, but they are not cataloged. The webGIS is no longer available, thus missing the possibility offered by the webGIS to share information. None of these projects uses BIM models inside the webGIS. BIM modelling effectively gives 3D life to 'paper architectures', improving cognitive access to technical drawings (Bagnolo et al., 2022). The merging of BIM and GIS is a topic addressed by many studies (Breunig et al., 2020). These studies, however, are mostly focused on discussing technical solutions rather than engaging with the historical and cultural queries that define the field of Digital Humanities, especially when dealing with architectural structures that no longer exist. In this framework, World's Fairs could represent a sub-category of CH that is scarcely documented digitally. Historical World's Fairs were the mirror of societies at a

* Corresponding author

specific moment in time, and were made of ephemera: Fairs were fictional worlds conceived to disappear at their closing, alongside all the ephemeral items documenting them. Facing a complex phenomenon made of hundreds of architectures, people, documents, and their connections, traditional studies published in books cannot fully express this complexity, while digital technologies can break the physical limitations of repositories and printed matter (Della Coletta, 2006). World Expo Museum (http://www.expo-museum.org/) - the only official institution dedicated to World's Fairs - has a Documentation Center, the Literature Research Center and Library (devoted to the collection and study of World's Fairs phenomena). The Documentation Center displays an online collection of the artifacts preserved in the museum but does not have an online catalog for the library, nor a list of World's Fairs. Very few institutions, mainly based in the UK and USA, have undertaken the digitization and online publishing of archival materials devoted to individual World's Fairs; amongst the most relevant are the Museum of the City of New York and Queens Museum in New York, the *Louisiana Purchase Exposition: The 1904 St. Louis World's Fair* led by the Missouri State Archives and Missouri State Library, and the *Century 21 World's Fair Digital Document Library* by the Seattle Public Library. These projects do not use shared terminology and they do not fully exploit database (DB) functionalities and web interfaces potential. Only one project, the *World's Columbian Exposition of 1893 reconstruction* by UCLA, tests the virtual recreation in 3D of a World's Fair, but this project does not give access to the original source materials. Recently, two publishing companies (Adam Matthew and GALE) have developed digital collections dedicated to World's Fairs documentation. These collections, which curate materials borrowed from many public archives and libraries, require a paid subscription to be accessed. Besides, all these initiatives lack shared procedures and coordination between them. WebGIS potential is relevant not only as georeferenced repository of archival materials, as in the case of the ISPRA geoportal, but also to study past events and support the analysis of specific relations between historical events, locations, people, and timeframes, allowing spatial and non spatial queries, as done by Fiorini et al., 2022; Wei et al., 2022; Sang et al., 2021; von Schwerin et al., 2013. However, a digital archive that includes 3D reconstructions of ephemeral architectural structures and that allows to perform spatial and non-spatial queries does not exist. This system should include a 3D space where digital reconstructions of ephemeral architectural structures are inserted in their environment, put in relation to the urban city blocks, and linked to the archival materials describing them and cataloged according to relevant standards. Only in this way, researchers can have all the necessary sources in a single environment, complete with analytical and search tools offered by a webGIS.

This paper focuses on developing such a system based on a 2D/3D webGIS associated with GIS-BIM applications and integrated in a website to document and study the Turin 1911 World's Fair, showing potentialities and challenges in these applications' creation and use.

2. THE TURIN 1911 PROJECT

This study is part of *Turin 1911: The World's Fair in Italy*, a research project led by the University of California San Diego and Politecnico di Torino where a multidisciplinary team cooperates to document and investigate the 1911 World's Fair held in Turin. The *Esposizione Internazionale delle Industrie e del Lavoro* played an interesting role in the forging of alliances for Italy and Italy's role in the international stage of politics, economy, technology, and art (Della Coletta, 2006). Around 200 structures were specifically designed for the event and dismantled after its closing. Today, only archival traces remain in historical materials spread worldwide.

The *Turin 1911* project aims to identify, collect, digitize, and catalog archival material, and extract information about people and built environment objects from this material. Starting from original documents, the project also digitally recreates many of the Fair's architectural structures in 3D. The archival goal responds to many needs. No specific archives devoted to Universal Expositions existed before 2010 when the World Fairs Museum was created. Regarding the 1911 Turin Fair, the original materials documenting the event are heterogeneous, and spread across many physical locations worldwide - both public and private. Consequently, these materials are not easy to identify and consult, and are often not cataloged. A catalog describing the architectures of the Turin 1911 Fair does not exist, some built environment objects are drawn in the exposition's map but their names are unknown. The precise location of some of them is not known, and there are very few descriptions of the people related to these artifacts (like makers and exhibitors). An initial website entirely dedicated to the Turin 1911 Fair - https://italyworldsfairs.org - aimed to create a more durable and organized space for the many materials related to this Fair, facilitating research and providing an innovative forum for investigation. The website displayed the data retrieved in an ad-hoc DB created in 2009, combining efforts from specialists in humanities and IT experts. Free access to information was granted to both disciplinary experts and amateurs in a user-friendly way, requiring only a browser and an internet connection. The virtual reconstruction of 1911 Turin's pavilions began with the contributions of experts in the humanities, architects and engineers (Einaudi et al., 2020) and different techniques were tested for the 3D metric survey of the still existing structures of the Valentino Castle and *Borgo Medievale* (Chiabrando et al., 2019). However, the website is currently being reconceived in order to improve its content structuring and include the 3D models. These steps are ongoing and they are partially illustrated in this paper.

3. DATA PREPARATION AND ENVIRONMENT ARCHITECTURE

Historical documents constitute the basis for the documentation and 3D virtual recreation of the Turin fair. Many public and private archives, libraries, collections, and museums preserve items documenting the Turin 1911 Fair. The largest known collections are the Cristina Della Coletta collection (CDC) in San Diego (USA), a dedicated unit in the Stefano Molli's Archive at the Fondazione Marazza of Borgomanero (Italy), and documents preserved at the Biblioteca Civica Centrale di Torino (BCT) (Italy). These items are heterogeneous (such as guidebooks, postcards, photographs, magazines, newspapers, architectural documents (**Figure 1**)), and only very few are already digitized and cataloged, and only in Italian. All the identified items are inventoried and digitized following international guidelines. The digitized archival materials are cataloged and linked to the geometries to which they refer in a new dedicated geo-DB. After approximately 10 year from its creation, the former DB presented many limitations: it did not contain the spatial content and did not follow shared thesauri and cataloging standards. The first attempt to enable the spatial component in the existing relational DB (Spreafico&Della Coletta, 2021) was abandoned due to many implementation challenges in favor of a new dedicated geo-DB containing the spatial content. A new strategy has been designed and followed to create a new geo-DB to combine the PostgreSQL DB with

ArcGIS Pro and Lavarel for website development. A new DB has been designed starting from a new conceptual model where entities (archival materials, architectural documents, built environment objects, components, glossary, lists, locations, and secondary sources) and relations between them have been identified (**Figure 2**).

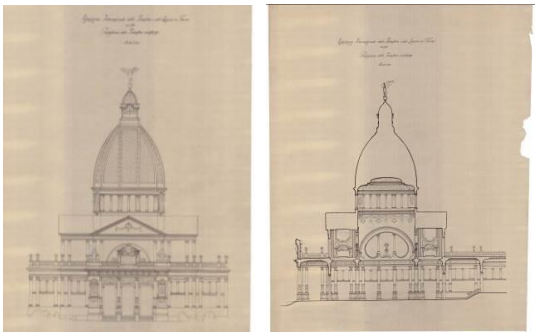

Figure 1. Elevation (left) and section (right) of the Pavilion of the City of Turin, original scale 1:100 (Courtesy of Fondazione Achille Marazza).

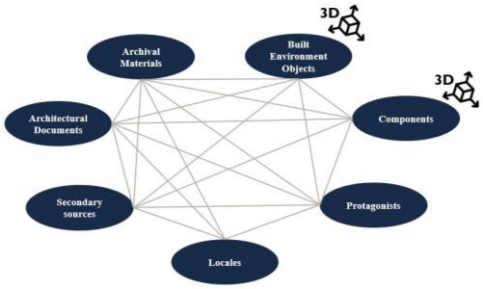

Figure 2. Conceptual model of the new geo-DB.

The architecture for geo-DB management and data visualization follows the schema in **Figure 3** and controls two types of interaction: a more common one from a website and a less common one through a webGIS.

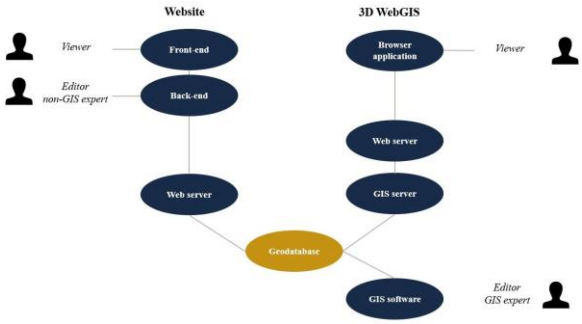

Figure 3. Environment architecture.

This type of combined interaction is generally not applied to Humanities studies. It is uncommon even in the literature regarding CH, where the publishing of a webGIS is typically the last step of research – like in (Fiorini et al., 2022). By using the website, non-GIS expert users can access the back end to edit data using specific credentials for access, while any users can visualize data on the website's front end. In the webGIS system, a GIS expert with specific credentials can access the geo-DB using GIS software to edit the spatial data. At the same time, any user can visualize the webGIS through a browser application without log-in. Data is stored in a unique geo-DB, and the GIS software, GIS server, and WEB servers are connected to it to retrieve data and have access to edit it. In this way, data inconsistency is avoided, and the designed procedure guarantees that the same result is achieved in editing, independently from where the editing is applied, and the editing is visible in real-time everywhere.

4. 2D/3D WEBGIS DESIGN AND CREATION

The designed webGIS is a simple tool to provide an overview of all the *Built Environment Objects* and *Components* constructed for the exposition, assisting the user in localizing and contextualizing each element in the 2D/3D space of the Valentino Park. It works as a point of access for the elements, giving only a little information and basic search and inspection tools for non-GIS experts. It lets the in-depth analysis to the new traditional web pages. In fact, the webGIS is going to be inserted into the new traditional website. The existing website has an old-fashioned look and needs to be re-platformed; the content is not perfectly organized and displayed, and the tools to visualize images and books are obsolete. The new website is currently under development and not visible to the public, but it will replace the already existing https://italyworldsfairs.org/ website[1]; a preview is available at https://youtu.be/0FNLKIhIH5s. The webGIS is created following these three steps:

1. Environment and data preparation,
2. Connection to Enterprise and online sharing,
3. Creation of the webGIS application.

4.1 Environment and data preparation

After comparing several maps and textual sources, a map of the fairground (**Figure 4**) and a map of the city of Turin (**Figure 5**) were selected and georeferenced in GIS environment. Subsequently, the 2D footprint of the *Built Environment Objects* was redrawn from the map of the fairground and the *city blocks of Turin in 1911* from the map of the city of Turin.

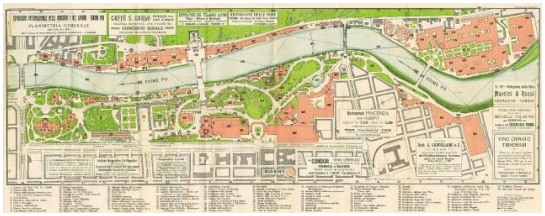

Figure 4. 1911 Fairground map (CDC, CDC-TM-0001)

Local data representing the actual shape of the Valentino Park (DTM and orthoimage) integrate the Turin 1911 geo-DB entities. As Abualdenien suggests (Abualdenien & Borrmann, 2022), LoD is more appropriate for archiving and visualization of city models. In this research LoD is preferred to Level of Development (LOD). LOD has been designed for new contructions in the Architecture, Engineering, and Construction (AEC) industry. Three types of elements are available to create a 3D webGIS: *polygonal feature class*, *multi-patch feature class*, or *3D object*. 3D geometries can be easily generated by extruding 2D *polygonal feature classes* according to a field where the height is stored. The 3D is editable online simply by typing a different value for the height, so no 3D editing skills are necessary. This 3D model is suitable for LoD 1 representation. With a *multi-patch feature class*, complex 3D geometries can be created reaching LoD 2 and more, but skills in 3D modeling are necessary and geometries cannot be edited online without API for JavaScript. *3D objects* are similar in usage to multi patches, but display more fields in order to manage each record's origin, rotation, and scale. The scope of the Turin 1911 geo-DB and webGIS is to provide an overall position and dimension for each 3D object in the fairground at

[1] The old website is being replaced with the new in Autumn 2023.

large. Also bearing in mind that for a few objects some information is missing and research is still ongoing, an easy solution is necessary. Therefore, the *polygonal feature class* is the most suitable one. A numeric field in *Built Environment Objects* and *Components* defines the height. Hypothetic 3D models are rendered as extrusion of 2D geometries in the ArcGIS Pro. In the webGIS environment geometries have an LoD 1 for exteriors and no interiors, following the LoD schema proposed by Tang (Tang et al., 2018). A 2D map is generated in ArcGIS Pro containing the city blocks of the city of Turin, all feature classes, tables, relationship classes, and the historical map of the fairground stored on the geo-DB. The local 2D map is rotated to preserve the configuration of the historical map.

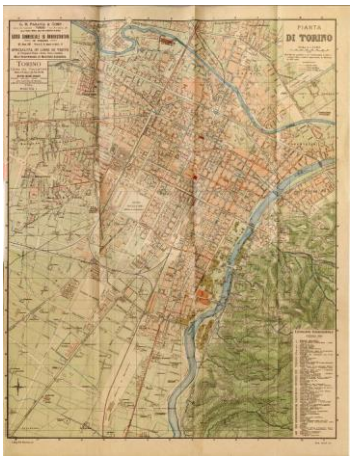

Figure 5. 1911 City of Turin map (CDC, CDC-GB-0008-197)

4.2 Connection to ArcGIS Enterprise and online sharing

Two commercial GIS solutions by ESRI have been tested, ArcGIS Online and ArcGIS Enterprise. A webGIS pointing directly to the geo-DB cannot be created with an ArcGIS Online account, therefore, the ArcGIS Enterprise account is used to register the geo-DB connection (.sde file) with the ArcGIS server on ArcGIS Enterprise Portal and publish the content as Web Feature Service (WFS) and Web Map Service (WMS) pointing directly to the geo-DB. Two typologies of visualization can be generated when publishing data stored in a geo-DB on the GIS server; data can *reference registered data* or be a *copy of data*. *Referencing registered data* allows displaying data stored in the geo-DB and their real-time updates. *Copy all data* creates a copy of the data on the GIS server at the time of the online sharing, losing the connection to the geo-DB. Editing can be enabled on both the reference registered data and the copied data, but if an edit is applied in the case of copied data, the data is not edited in the geo-DB since there is no connection to it. In contrast, if editing is applied to referenced registered data, this edit is visible in real-time in the geo-DB. Both ways are tested to publish webGIS applications. In the case of *reference registered data*, geometries are not always loaded in the map viewer. Often, an alert reports an unknown error in loading data, making creating a webGIS based on this data impossible. Hence, the *copy of data* option is preferred. The historical map of the fairground is shared as copied Web Map Tile Service (WMTS) cached with predefined scales and corresponding boxes so it can be visualized faster. *Built Environment Objects* and *Components* are shared as not-editable copied data as a single WFS containing the two layers, while City Blocks of Turin 1911 is shared as individual WFS. This solution is preferred to provide a reliable web application with fast data loading. With copied data option, the historical fairground map of 4.56 GB and all the geometries are rapidly rendered online, large georeferenced images and datasets with numerous geometries can be easily shared amongst experts by using a webGIS. Since they are copies, the editable function is useless and, thus, not applied. The WFS layers can be easily overwritten when needed to preserve the webGIS content up to date, keeping in mind that if the data schema changes, the layer cannot be overwritten, but it has to be republished.

4.3 Creation of the 2D/3D WebGIS Application

To develop a web app or website, various applications are available online on ArcGIS Online and ArcGIS Enterprise. Amongst them, *Web App Builder* (WAB) and *Experience Builder* are tested, two ESRI products to create 2D and 3D web apps integrating spatial data without writing code. Once data is published in ArcGIS Online or Enterprise, data can be visualized online with *Map viewer* or *Map Viewer Classic* online interfaces provided by ESRI. *Map Viewer* is the newer version of *Map Viewer Classic* but does not have the same options of the newer one (such as map rotation management and pop-up configuration). Nevertheless, if an ArcGIS map is published with a rotation and opened in *Map Viewer Classic*, it is displayed incorrectly since rotation is not supported in the *classic* version (**Figure 6** up). In contrast, the same map opened in *Map Viewer* is displayed correctly (**Figure 6** down).

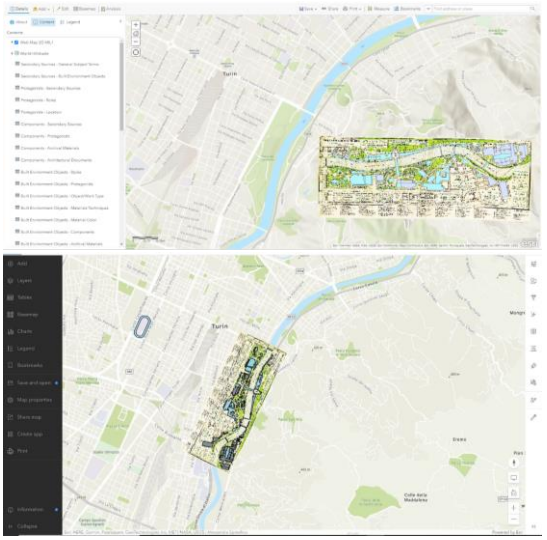

Figure 6. Rotated map with World Topographic Map (by ESRI) as basemap displayed incorrectly (up) in *Map Viewer Classic* and correctly (down) in *Map Viewer*.

Map rotation is necessary to display the historical map that is not configured with north up. Since WAB does not support all the options available in *Map Viewer*, as map rotation and pop-ups configuration, *Map Viewer Classic* and WAB are abandoned in favor of *Map Viewer* and *Experience Builder*. Since the same *Map Viewer* on *ArcGIS Online* and *ArcGIS Enterprise* shows different options (no rotation and no pop-up configuration are available in *Enterprise*), *ArcGIS Online* is preferred because it has been decided to work with copied data and not referenced registered data. Once the historical map and feature classes are shared online, starting from them, a 2D map is created in *Map Viewer* in ArcGIS Online, where the rotation is correctly displayed. Pop-ups are configured for *Built Environment Objects* and *Components* with data retrieved from the related field for each geometry (Title, an image, link to the single webpage with full description, Alternate Title, Object/work Type, Creator Description, and Code in the 1911 Map). The base map is selected, and layers style (color and

transparency) and labels are already set in ArcGIS Pro and here preserved. A 3D local scene is created with *Scene viewer*. The 3D is created as a *drawing style* thanks to 3D extrusion based on the *Elevation* field. After the web services, map, and scene are prepared, the webGIS is created using *ArcGIS Experience Builder* using configurable widgets. The webGIS (**Figure 7**) is visible at https://arcg.is/1HfSqG.

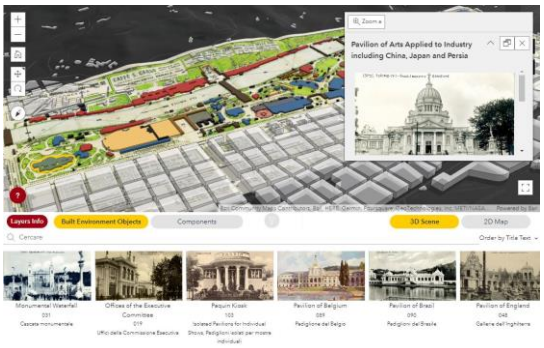

Figure 7. The 2D/3D webGIS application

The 2D and 3D environments are synchronized, so when the user switches from one to the other, the framed portion and zoom are the same. The map/scene displays the Map of Turin 1911 World's Fair, *Components*, *Built Environment Objects*, and the *City Blocks of Turin 1911*. Two lists are designed as a gallery of images to display all the *Components* and *Built Environment Objects* stored in the geo-DB. The lists are synchronized with the 2D map and 3D scene; they display only elements framed in the map/scene, so when the user zooms in, only the objects displayed at that moment on the map are shown in the gallery. Vice-versa, when a filter is applied in the list, only the results present in the list are displayed on the 2D map/3D scene. Several tools (searching, selection of 2D map/3D scene, layer list and legend, layer info, informative button, navigation) are designed in the webGIS. The search bar allows the free-text search and insists on the *Title Text* and *Alternate Title Text* fields of the *Built Environment Objects* and *Components*. A filter allows displaying *Built Environment Objects* according to the *Object/Work Type* (such as National Pavilions, Office Buildings, Recreation Structures, …). Besides, a button switches on/off the geo-localization of the device, so when the user walks in the Valentino Park with a tablet or a smartphone, it can observe its real position retrieved from the GNSS of the device and see where it is located on the historical map using the webGIS (**Figure 8**).

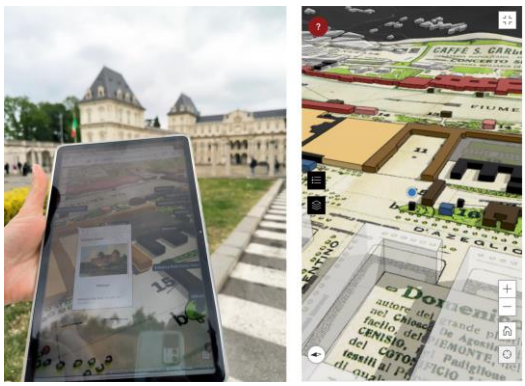

Figure 8. By using a tablet (left) the webGIS (right) the user's location is identified (blue dot) in the Valentino Park.

Once the webGIS is created and customized for the desktop version, the automatic configuration for medium (as tablets) and small-size devices (as smartphones) are verified and manually adjusted.

5. BIM-GIS WEB APPS DESIGN AND CREATION

We collected the plans, elevations, and sections of some *Built Environment Objects* because they report the shape and dimensions of the entire structures. 3D models are created for *Built Environment Objects*. We rejected the reconstruction based only on photographs because there are very few pictures for each object. They are low-resolution images and refer to the most interesting portions; the other parts are not captured. Using technical drawings, 3D models are generated and compared with historical photographs to verify the correspondence with the structures that were actually built, as reported in Einaudi et al., 2020. Detailed models are developed following the LoD schema proposed by Tang (Tang et al., 2018), according to an outdoor LoD 3 and indoor LoD 0. The web apps retrieve data from the geo-DB, integrate BIM models and other digital products to contextualize the 3D data in space. As for the webGIS, they are going to be inserted in the new traditional website, accompanying the cataloging webpage dedicated to each Built Environment Object. GIS-BIM web applications are developed following the overall workflow:

1. BIM georeferencing and sharing,
2. Actual context creation and sharing: the DTM and the orthoimage,
3. BIM-GIS web app creation.

5.1 BIM georeferencing and sharing

A first test is performed with the Revit file (*.rvt*) of the Pavilion of Siam, which size is 34.1 MB (**Figure 9** left) – since it is the lightest file – and a second test with the Pavilion of the City of Turin (**Figure 9** right) - which weights 256.9 MB that is the heaviest *.rvt* file of the BIM models currently created.

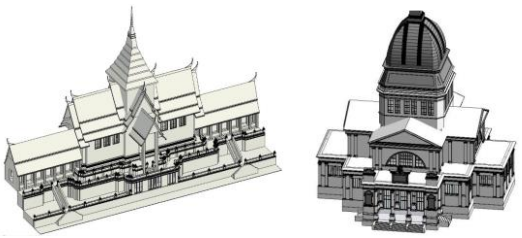

Figure 9. Pavilions of the Siam (left) and City of Turin (right) digitally reconstructed in Revit.

The models have arbitrary coordinates; since no remains are identified on or above the ground at the time of writing, the origin of the global reference system and rotation are calculated for each model using a corner of the related geometry in the georeferenced GIS 2D map. The WGS84UTM32N system - EPSG 32632 - is preferred to the Web Mercator – EPSG 3857 - since the first one is more suitable to minimize distortions in a local area, such as the Valentino Park. Values for origin and rotation are set in BIM software, and then the model is saved and loaded in GIS software, using the integration method from BIM to GIS and using the procedure of georeferencing in Revit and importing in ArcGIS exploited in Sammartano et al., 2021. The values defining the origin and rotation of the BIM project are set in Revit, then the *.rvt* file is saved. The EPSG 32632 *.prj* file containing coordinates system and projection information is associated with the *.rvt* file. The *.rvt* file is loaded in ArcGIS Pro, which reads the coordinate system and projection information from the associated file; then all the geometries are correctly displayed, and the file is read as BIM file data type and subdivided into Revit families. From the BIM model loaded in ArcGIS Pro a *.slpk* file is generated in ArcGIS Pro. In a few minutes a file size of 6 MB is generated for the Pavilion of Siam and 112 MB for the City of Turin, which are lighter

than the related *.rvt* files. Finally, the *.slpk* files are copied on ArcGIS Online to create a scene layer. The scene layer displays the entire model (**Figure 10**), the data structure of the BIM is retrieved, each Revit category can be turned on/off, also levels can be selected, and each element can be queried to retrieved associated data.

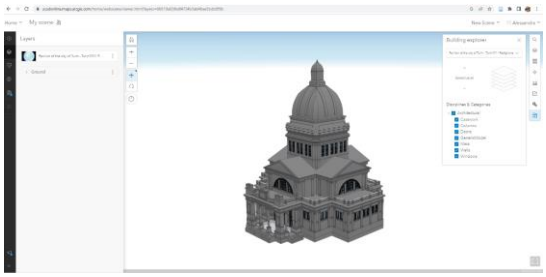

Figure 10. Scene layer for the Pavilion of the City of Turin, Revit categories and levels are retrieved.

5.2 Actual context creation and sharing: the DTM and the orthoimage

The Digital Terrain Model (DTM) is derived from the *Carta Tecnica Regionale Numerica* (CTRN) at a scale of 1:10000 with a resolution of 10 meters and an accuracy of 5 meters, the reference system is congruent with the reference system of the BIM model (EPSG 32632). The DTM is set as the *ground source* in ArcGIS Pro instead of the world topographic map. The elevation surface used as ground defines the height values of all the geometries on the map and are laid down onto the ground; if the ground is turned off, the elements are located at altitude 0 m, both in ArcGIS Pro and Online. The DTM will be used as the *custom elevation layer* in ArcGIS Online scene viewer since the ESRI base maps are in Web Mercator and cannot be used with WGS84UTM32N. The elevation source must match the layers' spatial reference. To create a custom elevation layer, a specific tiling scheme has to be generated based on the DTM. The cached DTM (*.tpk*) is published as an elevation layer in ArcGIS Online, where the tiles are loaded for each scale and occupy a total space of 938.75 MB. 3D metric products of the actual shape of the Valentino Park are created starting from an aerial photogrammetric acquisition at 1˙470 m above the ground. From the entire dataset, 23 nadir images (14˙790x23˙010 pixels and 978 MB each *.tif* file) - captured with an UltraCam Eagle Mark 2 f100 with a 100 mm focal length and 4.6 µm pixel size – are selected and processed in Agisoft Metashape. 14 Ground Control Points (GCPs) and 7 Control Points (CPs) measured with Real Time Kinematic (RTK) are used. The precision is about 5 cm, and accuracy is 11 cm; the covered total area is about 3 km^2, and the GSD is 7.56 cm/pixel. An orthoimage is achieved with a pixel size of 15 cm, obtaining a 14˙856x20˙386 pixels *.tif* file of 1.2 GB. The orthoimage is loaded in ArcGIS Pro as a raster file and published online as a WMTS with the same tile cache scheme of the DTM.

5.3 BIM-GIS web app creation

An empty local web scene is created in ArcGIS Online, then the DTM is set as the elevation layer. The DTM, 2018 orthoimage of the park, and Map of Turin 1911 World's Fair – previously published online as a WMTS with the same tile cache scheme of the DTM - are loaded as WMTS. The *Components*, *Built Environment Objects*, and *City Blocks of Turin 1911* are loaded as WFS in EPSG 3857 and automatically projected in EPSG 32632. The two scene layers containing the BIM models are loaded. Similarly to what was done for the webGIS creation, the BIM-GIS web app is created in *Experience Builder*. The Pavilion of Siam app is visible at https://arcg.is/9u9uD0 (**Figure 11** up), and the Pavilion of the City of Turin at https://arcg.is/jin0O (**Figure 11** down). The selected template is edited, inserting the created web scene, setting the bookmarks, navigation and measurement tools, and 3D tools like measurement and daylight control. Bookmarks provide a rapid tool for visualizing preconfigured views. In bookmarks, layers can be selected, and camera orientation set, to created tailored views such as main façade, general view, and view with the 2018 orthoimage. As done for the webGIS, the localizer option is set to enable users visiting the Valentino Park to discover their real position in the BIM-GIS web app.

Figure 11. WebGIS application with integrated BIM model of the reconstructed Pavilion of Siam (up) and of City of Turin (down).

The *Built Environment Objects* layer provides general context, but the element for which the BIM model is available is hidden using SQL code. As done for the webGIS, configurations for tablets and smartphones are also developed. Each *Built Environment Object*'s individual web apps are created with the same design. The embedding code is generated for each of them and copied in the *3D Model* field of the related record in the *Built Environment Object* feature class in the geo-DB.

6. ANALISIS

The webGIS and GIS-BIM web apps are interactive tools to digitally navigate and query the environment. In the webGIS when a geometry is queried, a pop-up with related information appears, the link to the single webpage brings the user to the *Built Environment Object* details (**Figure 12**). Otherwise, the user can browse the image gallery or search for a desired element from the list and, once found and selected, the active 2D map or 3D scene is panned and zoomed to the selected geometry, the geometry is highlighted, and the pop-up is displayed. The designed webGIS not only represent a navigation tool, but also a research tool able to unveil hidden observations, assisting the user in studying the Fair's design. For instance, a filter can be applied to show *Built Environment Objects* according to *Object/Work Type*, and only National Pavilions can be viewed, they are mostly aligned on the right

bank of the Po river, or on the left bank as Hungary, and the small India, Bulgaria, and Russia, except for Great Britain and Turkey (**Figure 13**). The integration of historical images with a simplified 2D/3D representation of the objects assists in the discovery of new buildings, as in the case of the International Bar Valcauda. An unknown geometry retrieved onto the historical map is identified as the Bar Valcauda because it is depicted on the right of the Turkey Pavilion in a photograph (**Figure 14**). Layers can be hidden or displayed; their transparency can be set to observe overlapped layers (the 1911 map and the 2018 orthoimage) with the BIM model on the DTM (**Figure 15**).

Figure 12. BIM-GIS web app integrated in the single Built Environment Object webpage on the new website

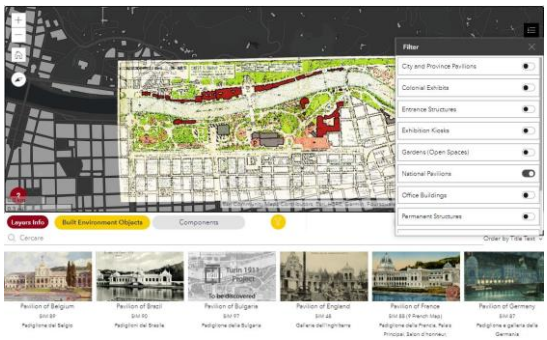

Figure 13. Filter applied on the 2D map displaying only National Pavilions.

Figure 14. The International Bar Valcauda is localized thanks to historical pictures and georeferenced geometries on the historical map.

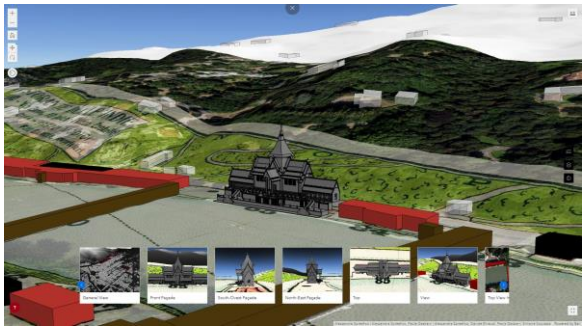

Figure 15. The BIM of Siam with the semi-transparent Map of Turin 1911 World's Fair on the 2018 orthoimage on the DTM.

7. DISCUSSSION AND CONCLUSIONS

Documentation of ephemeral CH sites, such as World’s Fairs, is crucial for their virtual preservation.Specific guidelines should be shared across the many institutions involved in similar research projects. This paper demonstrates that 3D webGIS applications can be easily integrated in websites for Digital Humanities studies and CH documentation. By taking advantage of machine capabilities, human tasks are accelerated and physical archives expanded. 2D and 3D metric products (like orthoimages and BIM models) can be integrated into a webGIS environment, enabling the visualization of reconstructed structures and contextualizing them into the historical and actual environments. Conceived in this way, a ‘digital repository’ is not solely the digital copy of physical materials but an effective research tool. In the Turin 1911 case, 3D models (LoD 3) – document-based and metrically controlled - have great potential because they represent the geometries of ephemeral objects, providing extensive understanding to other scholars. Looking at past architectures with navigable and queryable 3D models makes what is lost more attractive and perceptible. Even if heavy, BIM models can be loaded online and easily navigated, as for the Pavilion of the City of Turin. In general, online archives provide 2D visualization of documents, and research is performed starting from a bar where the user can type a few words. By integrating webGIS and web apps, research can start by navigating in 2D or 3D spaces. Commonly used smart devices – like tablets or smartphones - could foster new discoveries. The geolocalization provided by these devices enables users walking in the Valentino Park to be located on the webGIS and web app; therefore, users can compare their physical location with the virtual navigation in the reconstructed 1911 environment. The spatialization of artifacts on the georeferenced historical map assists in the analysis of less evident choices and dynamics, such as the distribution of the national pavilions along the riverfront. Many issues are technical and depend on the software. In general, commercial solutions, like the ones provided by ESRI, request less expertise in ICT than open-and-free software. The hard task is discovering the overall process and software to be used, from 3D modeling to online visualization, passing through the model georeferencing and coordinate system definition, and avoiding data file conversion issues. In this research, the combination of Revit and ESRI products has successfully integrated BIM in the webGIS. Nevertheless, some problems are related to incompatibilities between products by ESRI itself. Currently, the direct connection of the webGIS to the geo-DB runs too slowly to render 3D geometries online efficiently. Therefore, data are copied online, and their updating on the webGIS and web apps has to be done by a GIS expert following a brief procedure. An efficient webGIS pointing directly at the geo-DB

has to be developed. Finally, mantaining the system update can be challenging. Software updates are released yearly and compatibilities across the employed software have to be verified before updating the entire system. Often, if a maintenance plan is missing, platforms are no longer available, and what was achieved is lost, as was the case with the Maya project. This paper demonstrates how 3D webGIS integrated with BIM models can assist researchers in digital humanities and enable experts and non-expert users to collect, catalog, share, analyze, and locate information. A 3D webGIS, integrated in a website and based on the same geo-DB, becomes not only a digital archive, but also an up-to-date working environment where collaborative research takes place and results are immediately visible to everyone in a user-friendly manner. Free access to data is given to everyone and everywhere, guaranteeing wide and public access to information, safeguarding and disseminating knowledge about CH sites. Furthermore, the data structure can be adapted, and the procedure replicated to meet the needs of other cases studies, and other World's Fairs.

ACKNOWLEDGEMENTS

The authors acknowledge the School of Arts and Humanities' IT team and the Data and GIS Lab of the UC San Diego for the IT support in the webGIS development. The new website has been developed by 3Juice (https://www.3juice.com/).

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