

GIS-LIKE ENVIRONMENTS AND HBIM INTEGRATION FOR ANCIENT VILLAGES MANAGEMENT AND DISSEMINATION

Vincenzo Barrile¹ and Emanuela Genovese¹

DICEAM, Department of Civil, Energy, Environmental and Materials Engineering – Mediterranean University of Reggio Calabria,
89124, Reggio Calabria, Italy – vincenzo.barrile, emanuela.genovese@unirc.it

Commission II

Key words: Cultural Heritage, Virtual Reality, Augmented Reality, Mixed Reality, Cesium Platform, HBIM, 3D model.

Abstract

Over the past two decades, we have witnessed significant progress in the digitization of artistic and cultural heritage, which was initially aimed at conservation and analysis but has since expanded its scope to emphasize the dissemination and knowledge of artworks and sites of historical, archaeological, and architectural interest. For ancient villages management and dissemination, there are numerous existing tools, among these Building Information Model (BIM), Geographic Information System (GIS), virtual reality, augmented reality, and mixed reality apps and online platforms. These design and analysis systems have, however, interoperability and integration problems. In attempt to solve these problems, in this context, the research activity involves the creation of a 3D model, and HBIM of Precacore complex starting from the points cloud obtained by images acquired by DJI mini 3 pro. The procedure for importing the 3D HBIM model in a GIS environment using Autodesk InfraWorks software will be described, followed by the creation of the Virtual/Augmented/Mixed reality app using the Unity 3D platform and Microsoft HoloLens for the purpose of attempting to solve the problems relating the different data format deriving from the use of the commercial software from a virtual point of view. Finally, the methodology for the creation of a hybrid and experimental system will be proposed that, by exploiting the Cesium ion platform, allows the possible (although not complete) effective integration of the multi-scale information contained in both software used for the modeling HBIM and GIS.

1. INTRODUCTION

Over the past two decades, we have witnessed significant progress in the digitization of artistic and cultural heritage, which was initially aimed at conservation and analysis but has since expanded its scope to emphasize the dissemination and knowledge of artworks and sites of historical, archaeological, and architectural interest. Museums and archaeological sites have embarked on the path of digitizing their cultural sites to make them accessible through virtual reality, augmented reality, and mixed reality apps and online platforms. The significance of this research lies in addressing the challenge of preserving and understanding cultural heritage sites that may be in states of ruin but hold immense historical and cultural value that can be enhanced by technology-driven solutions such as apps and online platforms for cultural understanding and protection.

In the context of enhancing and disseminating ancient villages in the Greca area, the use of innovative technologies (Kantaros et al., 2023), (Yan and Li, 2023) can open up new possibilities for addressing issues related to accessibility and georeferencing of acquired information. Among these, the Historic Building Information Model (HBIM) stands out, focusing on the development of objects with the highest level of detail to support the valorization and reuse of historical assets, allowing for the simulation of new uses and optimization of design decisions (Nieto-Julian et al., 2023), (Ortiz Villarejo and Delgado Barrado, 2023); the Geographic Information System (GIS), that, in comparison to HBIM, has the capability to support geospatial functionalities and local information management (Antoniou et al., 2023), (Mendoza et al., 2023), (Baik et al., 2015); and apps for Virtual/Augmented/Mixed Reality visualization that can serve as a significant resource for the dissemination and engagement of tourists, visitors, and students (Guo and Boonyarutkalin, 2023).

In this context, integration and interoperability between different environments are necessary to associate Cultural Heritage information with geographical information. Indeed, in the context of enhancing and managing Cultural Heritage, special attention must be given to the integration and interoperability between HBIM and GIS, issue still open that this study aims to address using various methodologies (Barrile et al., 2023).

In the literature, many authors have focused on the use of software and the development of virtual and augmented reality apps applied to Cultural Heritage, (Barrile et al., 2022), (Boboc et al., 2022), (Rahaman et al., 2019). The aim is to showcase all the characteristics and hidden treasures of beautiful sites in Italy. However, there is less information available regarding the use on online platform for conducting diagnostic analyses to assess the state of preservation, identify damages or deterioration, and plan restoration and maintenance interventions.

In this framework, starting from the use of a commercial software that has made it possible to integrate the HBIM model of a Cultural Heritage within a GIS environment, we move on to the use of an experimental virtual/augmented/mixed reality app developed by the authors which allows virtual integration of HBIM, 3D model and points cloud within the territorial context, to conclude with a methodology that, by exploiting the customizable and extensible libraries of the Cesium platform (Nishanbaev, 2020) allows the integration of structural data within a 3D geospatial space. The latter will prove to be particularly promising, with significant potential in terms of interoperability, flexibility, and future developments.

In the reported case study, the authors focused on the complex located in the province of Reggio Calabria, known as Precacore. At the top of a hill, a church and a set of ruins, whose reconstruction dates back to 952, stand tall. From this vantage point, it can enjoy a particularly captivating view of the village of Ferruzzano and part of the Gelsomini coast. The ancient complex in the Grecanica area truly deserves maintenance and enhancement efforts to help preserve this cultural asset, preventing its decay and abandonment. Advanced geospatial data management platforms play a crucial role in the valorization of cultural assets. By importing HBIM and 3D models of Cultural Heritage, they can monitor the physical state of the asset over time, identifying signs of deterioration and conservation issues, and also enabling simulations of new uses that can be valuable for research purposes. Apps, on the other hand, remain the essential tool for accessibility, allowing visitors to explore the cultural asset in an immersive and informative manner. They also provide students with an interactive learning experience about the history and structure of the asset by enabling virtual exploration.

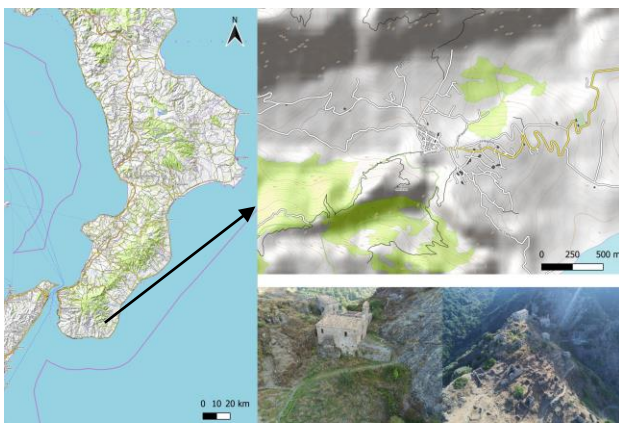


Figure 1. Case study: Precacore Complex, Ferruzzano Municipality (RC)

2. MATERIALS AND METHODS

The research activity involves the creation of a 3D model, and HBIM of Precacore complex starting from the points cloud obtained by images acquired by DJI mini 3 pro. The procedure for importing the 3D HBIM model in a GIS environment (Baik et al., 2015) using Autodesk Infravorks software will be described, followed by the creation of the Virtual/Augmented/Mixed reality app using the Unity 3D platform and Microsoft HoloLens for the purpose of attempting to solve the problems relating the different data format deriving from the use of the commercial software from a virtual point of view. Finally, the methodology for the creation of a hybrid and experimental system will be proposed that, by exploiting the Cesium ion platform, allows the possible (although not complete) effective integration of the multi-scale information contained in both software used for the modeling HBIM and GIS.

In the first phase, images were acquired via drone in order to reconstruct the 3D model of the study area. For this purpose, the DJI Mini 3 Pro drone was used, equipped with an 11.3-inch CMOS sensor, 48 MP effective pixels, 82° FOV lens, f/1.7 aperture and electronic shutter speed variable from 2 to 1/ 8000 s, with the possibility of acquiring images with a maximum size of 8064x6048.

Once the optimal flight parameters were configured based on the area of interest, considering the flight height and the characteristics of the drone, the Pix4D application was used to determine the flight path of the drone and the number of images to acquire (Figure 2).

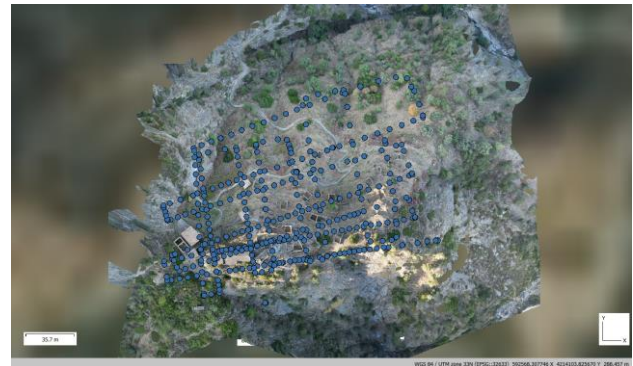


Figure 2. Drone flight scheme: blue dots highlight the acquisition points of the images.

A total of 408 images were acquired, with the following average characteristics: focal length of 6.72, camera quality of 0.80 and ISO sensitivity of 100.

The acquired images were subsequently imported into the Metashape software, which, through Structure from Motion algorithms, made it possible to initially generate the dense point cloud of the survey carried out (Figure 3). Subsequently, by applying the texture, it was possible to obtain the 3D model of the study area (Figure 4).



Figure 3. Metashape environment: Dense point cloud of Precacore Complex.



Figure 4. Metashape environment: 3D model of Precacore Complex.

From the same point cloud used to create the 3D model, the HBIM model of the Precacore Church was subsequently developed within the Revit environment. In Figure 5, the completed BIM model is presented, in which some of the set construction characteristics have been highlighted.

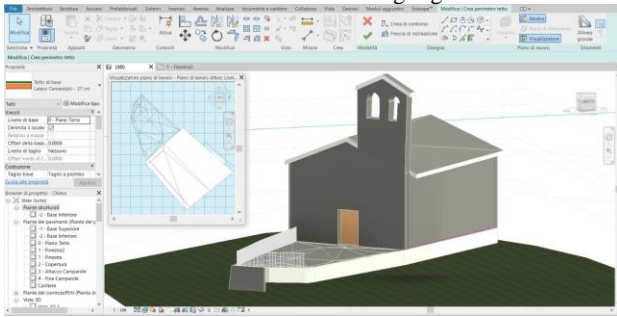


Figure 5. Revit Environment: BIM model of Precacore Church.

Within Revit, as known, it is possible to enter detailed information on construction materials, as well as view plans and elevations, thus allowing the integration of 2D views with the final 3D model, as illustrated in figure 5. In this representation, the properties of the roof structure, the plants and the various levels constituting the Church of Precacore are shown.

During the BIM modeling phase, particular attention was paid to the correct setting of a point coordinates of the Church in the WGS84-UTM 33N coordinate system, in such a way as to have the model correctly georeferenced and be able to use it in the subsequent phases of the study.

With the aim, therefore, of finding possible solutions to the interoperability problem of BIM and GIS design and analysis systems, after having obtained the point cloud, the 3D model and the BIM model of the Precacore church, the modeling phase of the Infraworks environment was started.

Infraworks is a software that allows partial integration between two distinct information environments: the GIS and BIM environments. Infraworks, in fact, allows the import of different types of files common to the two environments, such as 2D and 3D AutoCAD files, 3D models, BIM models from Revit and models in IFC format. Furthermore, the software also supports the import of native GIS information layers, such as raster images and shapefiles (Figure 6).

It also offers the possibility of importing GIS layers from projects structured in QGIS or ArcGIS. Alternatively, the "ArcGIS Connector" feature can be used, which allows access, via credentials, to the public layers present in ArcGIS Online.

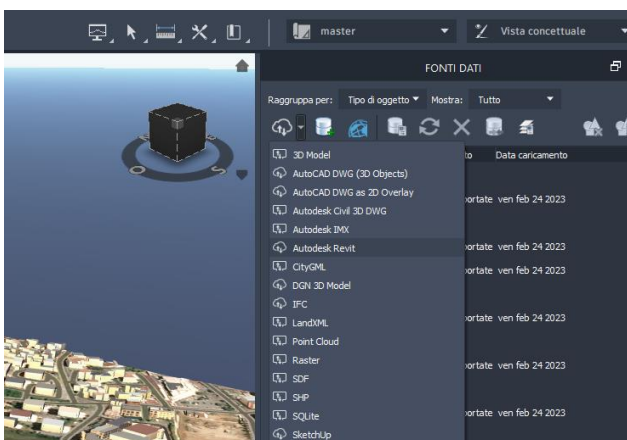


Figure 6. Infraworks Environment: screenshot of the possible data format.

For environment modeling in Infraworks, the process began by importing the DEM (Digital Elevation Model) of the study area as raster data, together with the shapefile of contour lines and the shapefiles of buildings and roads obtained from pre-existing GIS projects and by the QGIS plugin "QuickOSM" used to extract data from OpenStreetMap, as shown in Figure 7.

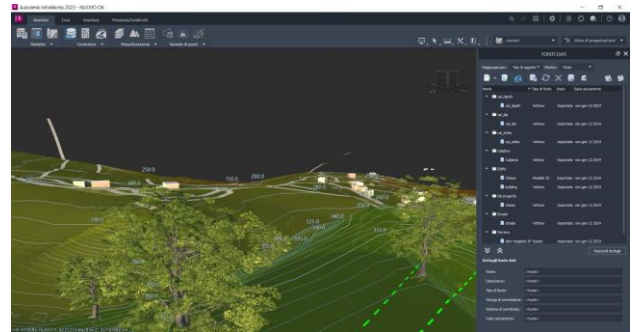


Figure 7. Infraworks Environment: modeling of the study area by adding DEM, streets and buildings shapefiles.

After reconstructing the study area, the Revit model of the Precacore Church was imported. Infraworks allows the geolocalization of the Revit model in a specific reference system; for this reason, when importing the model, the same reference system used in the BIM model, namely WGS84-UTM 33 N, was set and once the model was configured, the church was correctly georeferenced in Infraworks.

In attempt to overcome some limitations of the Infraworks environment, a virtual/augmented and mixed reality app, already created by the authors (Fotia and Barrile, 2023) was also used, which offers an immersive and one-of-a-kind experience. The latter was created using Unity 3D and the Microsoft HoloLens augmented reality device. In particular, the app allows the visualization and analysis of the different project phases, guaranteeing the control and dissemination of cultural heritage.

Finally, to achieve complete integration between the two environments, the Cesium platform was used.

In fact, one possible way to combine the potential of the two methods and overcome their limitations is to use the Cesium platform, an open-source platform for web-based 3D interactive map visualization. It supports a variety of features, including terrain visualization, 3D models, satellite imagery, lines of sight, tags and more. It can also integrate with data from various sources, such as map services, sensors, GIS data and temporal data, configuring itself as a GIS-like platform capable of managing 3D geospatial data. Within this platform, it is possible to integrate customizable libraries that Cesium optimizes in 3D tiles and allows to view on any device.

The libraries available in Cesium are numerous and allow the import of BIM data, CAD, point clouds or photorealistic 3D files, and much more.

In this specific case, Cesium ion was initially configured and, once the Access Token (the identifier of each user who uses the platform) was obtained, the BIM model file was uploaded into the "Assets". In particular, the supported files for the library that allows the import of BIM files include Wavefront OBJ (.obj), Digital Asset Exchange (.dae) and .glTF. In this case study, we imported and converted the 3D model from .rvt to .obj format. In this way, Cesium will preserve some characteristics of the

model imported from Revit and allow it to be identified in a way typical of the GIS-like environment. Cesium also allows the addition of various types of models and point clouds, enabling the visualization and interactive classification of portions of the point clouds in a manner typical of GIS environments.

3. RESULTS

The methodology described was applied in Precacore Complex situated in the South Calabria. In order to connect the information concerning the HBIM and the geospatial information of the GIS environment, the Autodesk Infracore software is initially used. With Infracore, which possesses the capability to communicate and dynamically transfer data, it is possible to create three-dimensional models of a portion of territory, extending up to 200 km². The models, visually realistic and complete in every detail, are built using all available GIS data and if the information is not available, Infracore lets to pull map data from various cloud services, allowing to import the model created in Revit by positioning it and specifying the coordinates, the system, the scale and the rotation. Infracore 3D capabilities and the ability to georeference digital information provide a unique multi-scale environment linking HBIM and GIS.

In particular, Figure 9 and Figure 10 show the BIM model of the Church of Precacore correctly georeferenced within the Infracore environment, where layers containing the raster data and the various shapefiles mentioned in Section 2 have previously been inserted.

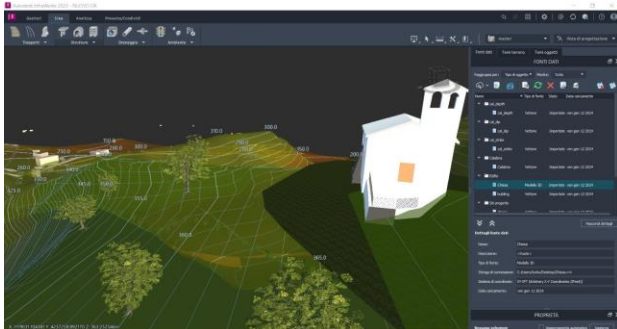


Figure 9. Infracore Environment: Precacore Church.

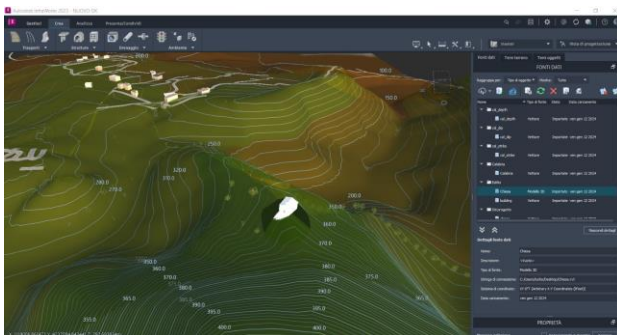


Figure 10. Infracore Environment: view of Precacore Church and part of Ferruzzano Municipality.

For ancient villages management and dissemination, Infracore is an environment that allows important advantages: in fact, it allows for more efficient planning and more intelligent management of resources, allowing detailed information to be

included on structural elements, materials but also elements of the surrounding environment, such as underground services, connection networks and proximity to resources.

Even if this methodology has huge potential regarding the planning of possible restoration interventions, as regards the Cultural Heritage, it can present limitations regarding the dissemination of the information among the tourists and above all from the perspective of BIM-GIS integration there is a loss of some information regarding the HBIM model. In fact, if on the one hand Infracore can be useful for planning maintenance interventions or designing new transport infrastructures, it is not easy to use for non-experts and may not be suitable for dissemination among tourists. The app of Virtual/Augmented and Mixed Reality could help to overcome some of these issues, even if only from a virtual point view. When it comes to building apps, there are several tools and frameworks available, with their own characteristics and benefits. In the case in question, it was decided to use the Unity 3D platform. To make the experience immersive and interactive, it was decided to combine the use of the app with the Microsoft HoloLens viewer. The latter is a mixed reality device developed and manufactured by Microsoft. It is a kind of wearable viewer that mixes the real world with interactive virtual elements, allowing users to interact with three-dimensional digital content within their physical environment. In fact, it allows to see and interact with 3D models as if they were physically present in the environment. The app has been implemented to display the 3D model of the Cultural Heritage as a hologram superimposed on the field of view whether the user is not in situ or whether the device on which the app is installed is near the Cultural Heritage in question and whether the device recognizes the identifier of the building in question within a GIS map. Figure 11 shows the point cloud of the Precacore complex on the GIS map. Figures 12 and 13, instead, illustrate the possibility of analyzing and interacting with the 3D model and the BIM of the church, both on site and remotely, allowing effective interaction. This offers the possibility of collaborating with a team in any location to plan maintenance interventions or using the model in schools for interactive and engaging lessons. It could also be very useful among tourists to allow an immersive visit with the possibility of accessing metadata on the structure under consideration. In fact, together with the HBIM, it is possible to add the 3D model and all the historical information on the complex under examination for better understanding and visualization.



Figure 11. Example of VR/AR/MR App use: Dense point cloud available on the map.

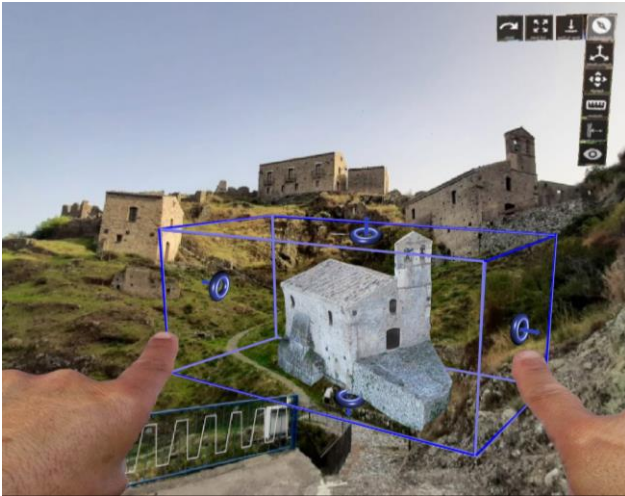


Figure 12. Example of App utilization for an immersive and interactive experience: 3D model available for in situ interaction.

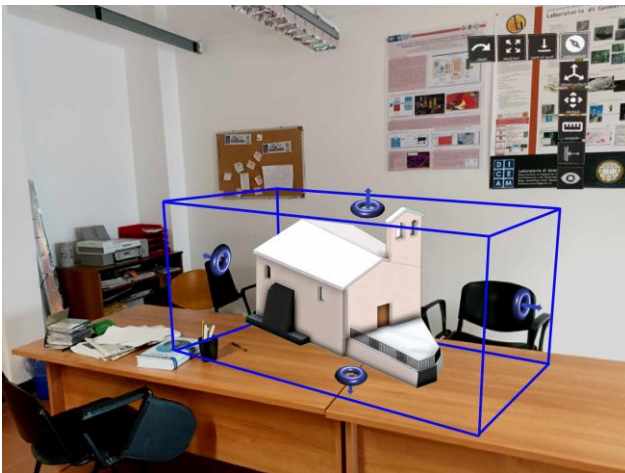


Figure 13. Example of App utilization for an immersive and interactive experience: BIM model available for remote interaction.

Although the virtual/augmented reality application certainly shows an immersive and interactive vision of the model, including interaction with the surrounding environment, with a view to resolve the limitations of BIM-GIS integration, it presents problems, remaining an exclusively virtual solution.

For this reason, the authors are currently studying and analyzing possibilities to overcome these limitations, in order to obtain not only a holistic view of the places under study, form a virtual point of view. A possible solution is the use of Cesium. The authors' proposal focuses on the creation of a software module integrated into Cesium's customizable libraries. Such a module would have the ability to automatically convert files in the .rvt or .ifc formats to a format supported by Cesium, without the need to use intermediate software or files. The basic idea is to develop a database that includes BIM and GIS schemas, and the introduction of a BIM-GIS schema for jointly saving data from IFC (Industry Foundation Classes) and CityGML. This would facilitate conversion between BIM and GIS and data

sharing, with all three schemes implemented within a single database.

The term "schema" is used in this context with two meanings: as a data structure and as a place to store tables and procedures in the database, while the stored procedure consists of a set of SQL (Structured Query Language) statements stored in the system database management as a block.

We intend to implement a model based on dynamic data conversion, with the data saved exclusively in the new BIM-GIS schema. Schemas dedicated to individual BIM and GIS applications, as well as others, will be created as views and stored procedures within the database. The BIM application-specific schema will be generated dynamically, based on stored procedures that convert data from the new BIM-GIS schema. A similar situation would occur for the CityGML schema.

The main benefit of this solution lies in the elimination of data duplication. Each object is stored in the database only once but can be viewed using CityGML and IFC views. The authors are working on the creation of both the new schema and the structured database to accommodate the three schemas.

The idea, therefore, is to equip Cesium with this software module for the joint use of BIM and GIS data.

In this context, the authors have examined solutions to customize Cesium libraries. This study phase concerns the import of the Revit model in .obj format into Cesium and the identify process, typical of the GIS environment, from which it was possible to obtain information on the material, the height of the building and other significant details. Moreover, a declarative web form has been developed that assists in the georeferencing of the data uploaded to map.

The advantages of this solution offered by Cesium are multiple. Cesium is available for different devices and offers an immersive and complete vision. It also allows customization of libraries and the development of classification features (such as point clouds and terrain models).

Figure 14 a, b, c, d show the use of the platform for viewing the Precacore complex and the BIM model of the Church. Part of the script for importing the Revit model as .obj file is also shown.



Figure 14a. Cesium Platform: visualization of Precacore Complex and part of Ferruzzano Municipality.



Figure 14b. Cesium Platform: example of library used and exported. Detail of study area.

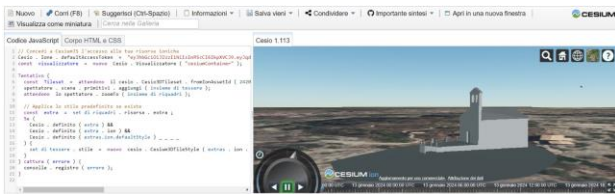


Figure 14c. Example of using the Cesium Platform for visualizing and interacting with a detail of Precacore Church BIM model (Ferruzzano, Italy)

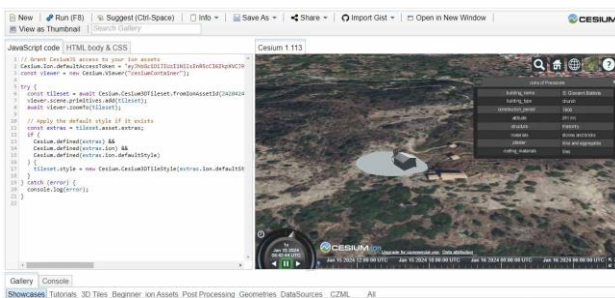


Figure 14d. Cesium Platform: visualization of Precacore Church BIM model (Ferruzzano, Italy)

In particular, Figure 14b shows one of the numerous libraries that allow 3D and realistic visualization of the surrounding environment, on which it is possible to import and display models or build possible scenarios. This capability allows for continuous monitoring of the structure over time and planning of interventions, allowing stakeholders to make decisions based on concrete data.

Figures 14c and 14d show the Cesium interface for viewing 3D Tiles within the platform. On the left, the figure shows part of the script for configuring the data source, including the Access Token number and Church's Asset ID. Furthermore, Figure 14d shows the identify tool through which it is possible to obtain information on the investigated object. In this case, the information inherited from the BIM model is still limited, but it can be optimized through the actual implementation of the methodology described above.

As said, future developments in this field will include the customization of libraries with a software module that automatically converts the standard HBIM format into a format

compatible with the Cesium environment. Furthermore, the authors are investigating the possibility of creating dynamic 3D geospatial visualizations using this platform, where it's possible to track the evolution of a Cultural Heritage site over time. In fact, by utilizing 4D modeling in Cesium, it becomes feasible to create a virtual representation of the site, showcasing how it has evolved over time. This visualization can highlight structural changes, the addition of new elements, and the state of degradation. In this way, the authors hope to make a contribution to solving BIM-GIS integration issues.

REFERENCES

- Antoniou, V., Panousis, D., Nikoli, E., Katsigera, A., Vlasopoulos, O., Nomikou, P. 2023: The Geo-Cultural Heritage of Kos Revisited: Web-GIS Applications and Storytelling Promoting the Well-Known Island of Dodecanese, Greece. *Resources*, 12(7), 74.
- Barrile, V., Bernardo, E., Fotia, A., Bilotta, G., 2022: Integration of Laser Scanner, Ground-Penetrating Radar, 3D Models and Mixed Reality for Artistic, Archaeological and Cultural Heritage Dissemination. *Heritage*, 5(3), 1529-1550. <https://doi.org/10.3390/heritage5030080>
- Barrile, V., Genovese, E., Favasuli, F., 2023: Development and application of an integrated BIM-GIS system for the energy management of buildings. *WSEAS Transactions on Power Systems*, 18, 232-240.
- Baik, A., Yaagoubi, R., Boehm, J., 2015: Integration of Jeddah historical BIM and 3D GIS for documentation and restoration of historical monument. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40, 29-34.
- Boboc, R. G., Băutu, E., Gîrbacia, F., Popovici, N., Popovici, D. M., 2022: Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications. *Applied Sciences*, 12(19), 9859. <https://doi.org/10.3390/app12199859>
- Fotia, A., Barrile, V., 2023: Viaduct and Bridge Structural Analysis and Inspection through an App for Immersive Remote Learning. *Electronics*, 12(5), 1220.
- Guo, T., Boonyarutkalin, T., 2023: Using digital technology to protect the traditional cultural heritage of Laosicheng Village. *Res Militaris*, 13(2), 1352-1361.
- Kantaros, A., Ganetsos, T., Petrescu, F. I. T., 2023: Three-Dimensional Printing and 3D Scanning: Emerging Technologies Exhibiting High Potential in the Field of Cultural Heritage. *Applied Sciences*, 13(8), 4777.
- Mendoza, M. A. D., De La Hoz Franco, E., Gómez, J. E. G., 2023: Technologies for the Preservation of Cultural Heritage—A Systematic Review of the Literature. *Sustainability*, 15(2), 1059.
- Nieto-Julian, J. E., Farratell, J., Bouzas Cavada, M., Moyano, J., 2023: Collaborative workflow in an HBIM project for the restoration and conservation of cultural heritage. *International Journal of Architectural Heritage*, 17(11), 1813-1832.
- Nishanbaev, I., 2020: A web repository for geo-located 3D digital cultural heritage models. *Digital Applications in Archaeology and Cultural Heritage*, 16, e00139.7

Ortiz Villarejo, A. J., Delgado Barrado, J. M., 2023: DIGITALESCAPE Project—Aerial Remote Sensing, HBIM, and Archaeology for the Preservation and Dissemination of the Cultural Heritage at Risk in the Sierra Sur and Sierra Morena Regions. *Remote Sensing*, 15(13), 3315.

Rahaman, H., Champion, E., Bekele, M., 2019: From photo to 3D to mixed reality: A complete workflow for cultural heritage visualisation and experience. *Digital Applications in Archaeology and Cultural Heritage*, 13, e00102.

Yan, W. J., Li, K. R., 2023: Sustainable Cultural Innovation Practice: Heritage Education in Universities and Creative Inheritance of Intangible Cultural Heritage Craft. *Sustainability*, 15(2), 1194.