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Integration and Development of Common Data Environment Platforms for the Hybrid Visualization of Quantitative and Qualitative Data

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Abstract

The digitalization of architectural heritage requires the integration of interoperable tools for the documentation, modeling, and sharing of cultural assets. This study proposes a methodology applied to the case of the Monastery of San Nicolò del Lido in Venice, aimed at HBIM modeling, collaborative management through open-source platforms, and immersive visualization. Based on an integrated photogrammetric and laser scanner survey, a BIM model was created in Revit, exported in IFC format, and uploaded to BIMData, an open-source Common Data Environment platform. The infrastructure was enhanced through the integration of the ARKBIM plug-in within a Vue.js environment, enabling semantic navigation of the model. In parallel, realistic visualization was explored using Mark Kellogg’s 3D Gaussian Splatting Viewer, integrated within the same framework, to offer a photorealistic and immersive experience of the current state of conservation of the architectural artifact. The result is a scalable, accessible, and replicable workflow that combines interoperability, information management, and rendering for the enhancement of cultural heritage. The methodology highlights the potential of 3D Gaussian Splatting as an effective complement to BIM models, expanding the modes of engagement and communication for a diverse audience.

1. Introduction

The digitalization of cultural heritage represents a strategic research domain in which diverse disciplinary competencies and rapidly evolving technologies converge. The need to document, preserve, and enhance complex historical artifacts requires tools capable of capturing not only the accurate geometry of buildings but also the semantic structure of the information that describes their identity, history, and state of conservation. Within this framework, Heritage Building Information Modeling (HBIM) emerges as an operational paradigm capable of integrating metric survey, parametric modeling, and collaborative data management in coherent digital environments. However, despite the significant advances achieved in recent years, several critical issues persist, including fragmented workflows, difficulties in ensuring semantic interoperability across different platforms, and the ongoing challenge of balancing geometric accuracy with meaningful information content. The research presented here situates itself within this context by proposing an integrated digital framework for the information modeling, shared management, and immersive visualization of a historically significant architectural complex: the Monastery of San Nicolò del Lido in Venice. The case study provides an opportunity to systematize a set of tools and methods aimed at constructing an interoperable digital environment for stratified documentation and informed access to built heritage. The process began with an integrated survey that combined terrestrial laser scanning from fixed stations, terrestrial photogrammetry, and drone-based aerial photogrammetry. This synergy of technologies enabled the acquisition of a high-density dataset essential for subsequent HBIM modeling and the development of a multilayered information system. The modeling phase involved the use of open-source software and BIM environments focused on data semanticization, while project management was structured within a cloud-based Common Data Environment (CDE). Particular attention was given to the semantic organization of the model, its adaptability across different software ecosystems, and the ability to experience its content immersively. In this sense, the adoption of advanced rendering techniques, such as 3D Gaussian Splatting (Kerbl et al., 2023), allows for fluid and realistic visualization, serving both communicative and technical-analytical purposes.
The aim of the research is to define a replicable methodology for the information-based documentation of complex cultural assets, capable of integrating metric data, descriptive content, and collaborative logic. The proposed approach seeks to overcome the dichotomy between geometric representation and historical meaning, offering a versatile tool for the conservation, management, and valorization of architectural heritage in line with contemporary demands for multidisciplinarity and interoperability (Bernardello and Merlo, 2021; Agazzi, 2013; Guidarelli, 2021; Guidotto, 1948; Pilutti Namer et al., 2023; Fabbiani, 1989; Silberman, 2007).

1.1 The Case Study

The case study at the core of this research concerns the significant monastic complex of San Nicolò, located in the northern area of the Lido of Venice, currently housing the International School of the Global Campus of Human Rights. Its location—near one of the main lagoon inlets connecting the sea with the Venetian Lagoon—grants the site a strategic role from both historical and territorial perspectives.
The origins of the complex date back to the 11th century, with the foundation of a Benedictine abbey that underwent continuous architectural evolution over time. Between the 14th and 17th centuries, the site experienced major transformations, leading to the expansion and reorganization of its spaces, including the replacement of original medieval structures and the construction of a new sacred building. In the late 18th century, following the suppression of religious orders by the Republic of Venice, the complex was decommissioned and repurposed for military use—a function it retained under

subsequent regimes. Only in the 20th century, particularly between the 1930s and 1940s, was the area returned to religious use and entrusted to Franciscan friars, eventually becoming, in the 21st century, the headquarters of the Global Campus of Human Rights. Due to its layered historical and architectural development, the complex constitutes an emblematic case study for the analysis of transformations in religious heritage and for understanding the relationship between architecture, urban space, and the dynamics of the lagoon environment.

Figure 1. Drone photograph of the monastery and church of San Nicolò del Lido.

2. Survey and HBIM reconstruction

2.1 Survey

The survey of the monastic complex of San Nicolò al Lido was structured in multiple phases, each aimed at producing an integrated, high-information-density three-dimensional model. The first phase focused on the photogrammetric acquisition of the exterior surfaces, carried out using a Fujifilm X-T50 mirrorless camera for ground-based captures and a DJI Mini 2 drone for roof documentation. Data processing was conducted with Agisoft Metashape, organizing the project into two separate chunks—one for terrestrial images and one for aerial images—in order to optimize alignment and the density of the resulting point cloud. In parallel, a terrestrial laser scanning survey was conducted using the BLK360 device, particularly targeting the interior spaces of the complex. This operation proved crucial for the correct scaling of the photogrammetric model and for ensuring coherent integration between interior and exterior spaces during the final point cloud merging phase. The point cloud resulting from the integration of the two surveys was cleaned of unnecessary points for 3D reconstruction using Autodesk Recap and linked to the BIM project in Autodesk Revit as a dimensional reference. Concurrently, a drone-based video survey was conducted, specifically designed for processing within the Gaussian Splatting framework. The video sequences were processed using PostShot, a software developed by Jawset, which enabled the generation of a radiance field from extracted frames. From this, a Gaussian point cloud in PLY format was generated and subsequently integrated into the Common Data Environment (CDE) platform, with the aim of enriching the digital model of the complex and testing advanced solutions for immersive representation and information management of architectural heritage (Borin and Pedron, 2014; Bertocci, Bigongiari, Della Bartola, 2024).

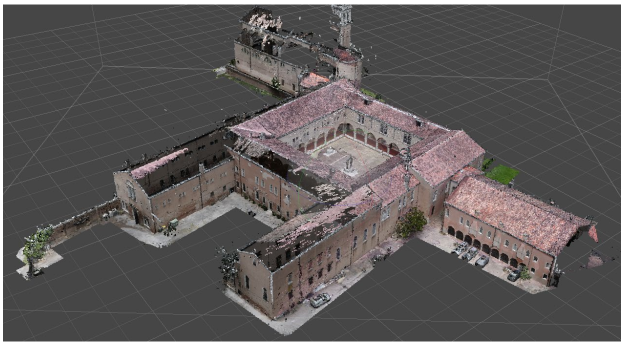

Figure 2. Dense point cloud from photogrammetry.

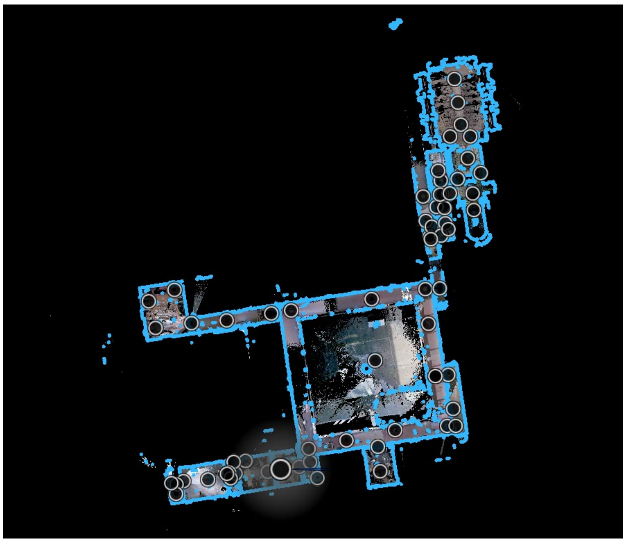

Figure 3. Point cloud from BLK360 laser scanner.

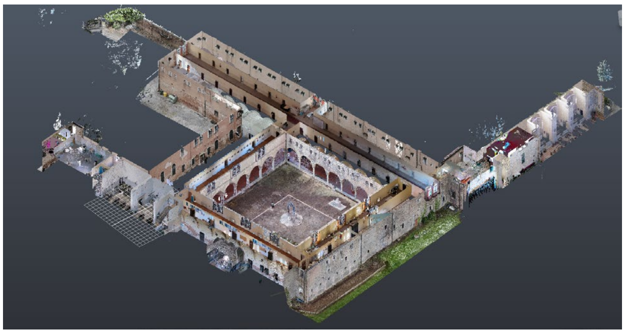

Figure 4. Merged point cloud.

2.2 HBIM

In the context of historic buildings, information modeling is strongly influenced by the nature and variety of data derived from the survey, making the adoption of standardized schemas complex both in terms of semantic classification and in defining the most appropriate Level of Detail (LOD) for representation. To address these challenges, a flexible, multilayered methodological approach was adopted, capable of capturing the complexity of the collected information and adapting to the morphological and evolutionary specificities of the building.

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The semantic classification was structured on two distinct levels: the first, general in nature, involved annotating the main historical phases of the architectural organism, the documented interventions, and the transformations undergone over time; the second was focused on organizing the modeled entities into families, each representing a typological category consistent with the building’s specific characteristics. The construction of families took into account the uniqueness of numerous elements, often singular in shape, size, or function, which is why the level of parametrization was intentionally limited. In the presence of repeated but non-identical components, adaptive families were developed, able to vary their instances based on dimensional or geometric parameters. In some cases, in-place modeling was necessary, especially for elements exhibiting irregular geometries, deformations, or morphological relationships not reducible to standard patterns. Concurrently, starting from the BIM model and the point clouds derived from the survey, graphic deliverables such as plans, elevations, and sections were produced with the goal of ensuring a coherent, reliable, and technically sound representation grounded in metric evidence. These deliverables constitute an indispensable support for the analysis, documentation, and interpretation of the architectural organism.
The resulting model allows consultation of heterogeneous data associated with objects, making them accessible in a multiplatform environment through the Common Data Environment (CDE), where contents are organized as textual metadata, graphic documentation, linked images, or hyperlinks. An essential aspect of this process was the inclusion of historical and archaeological data that contributed to the hypothetical reconstruction of the ancient medieval basilica, thus integrating the representational aspect with the interpretative one (Borin and Pedron, 2014; Bertocci and Cioli, 2024).

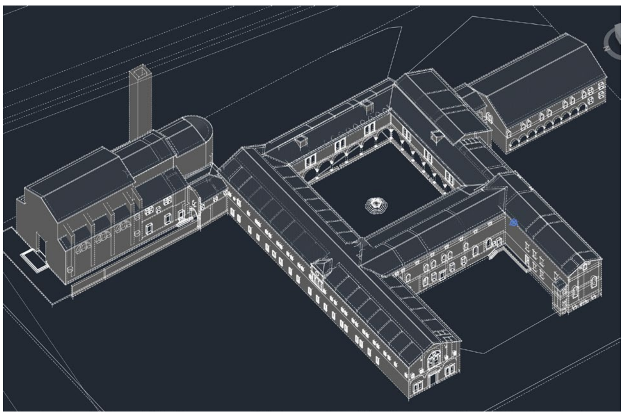

Figure 5. Axonometric view of the monastery within Revit software.

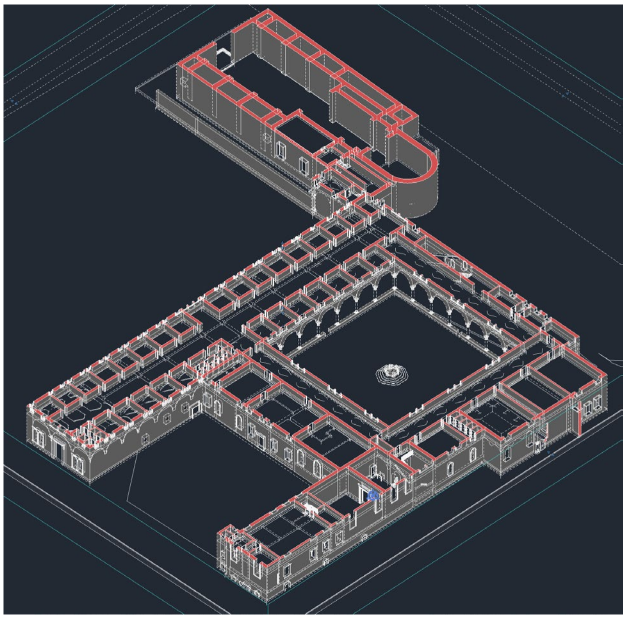

Figure 6. Axonometric section of the monastery within Revit software.

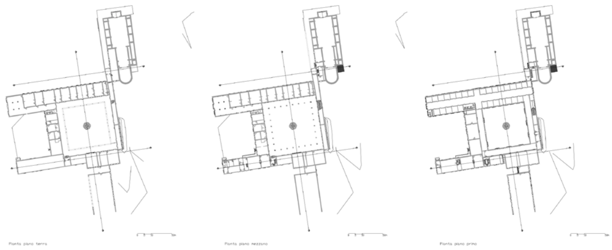

Figure 7. Plans exported from Revit.

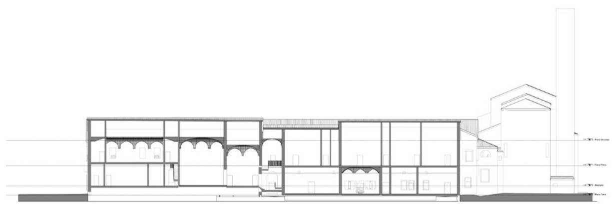

Figure 8. Longitudinal section of the monastery’s refectory wing exported from Revit.

Figure 9. Cross section of the monastery cloister exported from Revit

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3. OpenBIM platform and CDE

3.1 BIMData

To ensure the sharing and structured management of information within a collaborative environment, the HBIM model was exported in IFC format, thus guaranteeing its interoperability and readability across heterogeneous tools and work environments. Among the available solutions for managing and visualizing IFC models, BIMData was selected; it is an open-source project founded in 2015 as a spin-off of a research initiative funded by Ademe (Agence de la transition écologique). BIMData provides an infrastructure accessible via a web interface and, importantly, offers a public API that enables direct integration with customized development environments, making it particularly suitable for experimentation in academic and cultural contexts. Within this framework, two distinct approaches were developed. The first involved creating a simple static HTML page, useful for verifying the correct loading of the IFC model, exploring its hierarchical structure, and testing the main visualization functionalities offered by the integrated viewer.
The second, more advanced approach was based on adopting the Vue.js framework within a Node.js environment, with the goal of building a modular interface capable of adapting to the specific needs of the project. The use of the framework allowed not only for more advanced API call management but also for the integration of plugins designed to extend the native functionalities of the visualization library. Additionally, experimentation was initiated with ArkBIM, a plugin developed specifically for the BIMData environment, which enables the application of semantic filters, visualization, and querying of metadata associated with IFC objects, as well as integration with external documentary resources. This supports historical, material, and construction analysis of the architectural artifact. This strategy overcame the limitations imposed by preconfigured web interfaces, offering a flexible working environment oriented towards customization of the information workflow. The integration with BIMData, conceived not as a definitive platform but as an open and interoperable service infrastructure, represented an opportunity to experiment with innovative modes of interaction with the model, useful to support documentation, conservation, and valorization activities of architectural heritage within a distributed digital context (Diara, Rinaudo, 2021).

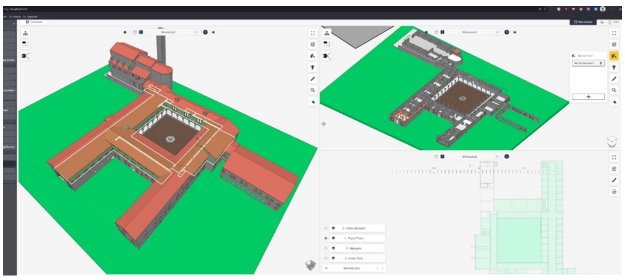

Figure 10. BIMData – perspective view, axonometric section, and plan of one of the monastery's levels.

3.2 ArkBIM

The initial operation involved the integration and updating of the ARK-BIM plugin to ensure full compatibility with the latest version of the BIMData viewer. This activity required a revision of the source code and an adjustment of the semantic filtering logic according to the updated API specifications. The extension enabled a significant improvement in usability and efficiency in data management, allowing users to query, filter, and visualize IFC models enriched with information more smoothly and clearly. Particular attention was given to the interactive visualization phase, during which the implementation of the HBIM model was tested within a custom web viewer based on Three.js, a JavaScript library for real-time 3D rendering. The integration leverages WebGL technology, enabling hardware acceleration through the GPU within modern browsers, thereby ensuring high-performance graphic rendering directly online without the need for additional plugins or software.
This approach facilitates smooth and detailed exploration of architectural elements, even in the presence of complex geometries and articulated information structures, increasing accessibility and interoperability in the digital dissemination of built heritage (Diara, Rinaudo, 2021).

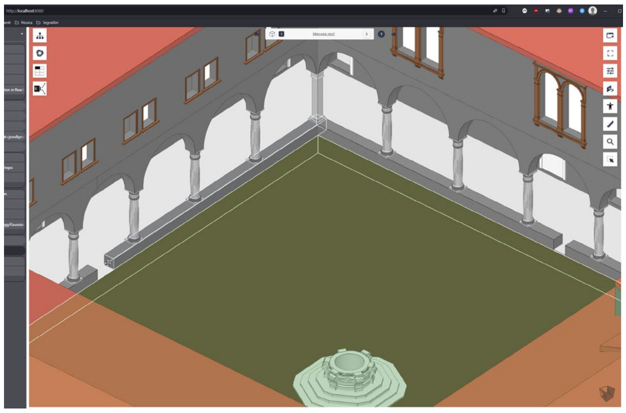

Figure 11. View of the cloister within BIMData.

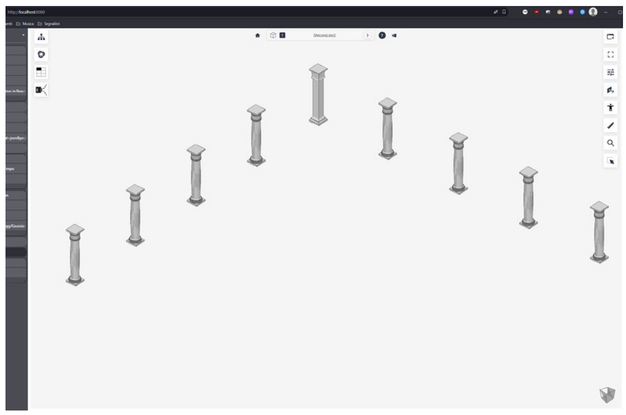

Figure 12. "Isolate objects" command of the ArkBIM plugin within BIMData – Cloister columns.

4. Gaussian Splatting Integration

To enrich the user experience and expand the communicative potential of the digital model, the study envisages the integration of the 3D Gaussian Splatting Viewer developed by Mark Kellogg within the Vue.js framework-based project (Rüter et al., 2024; Ye et al., 2025; Kellogg, 2025). This viewer enables a photorealistic, interactive, and immersive representation of the current state of the monastic complex, offering an innovative mode of fruition and understanding of the architectural space, both materially and perceptually.

The adoption of this technology allows for smooth navigation within the splatted model, with the possibility to focus attention on specific areas of interest—such as portions subject to degradation or recent conservation interventions—while maintaining a high radiometric fidelity of surfaces. The degree of realism achieved in material rendering provides a more natural visual perception compared to traditional mesh-based models. The visualization of the .ply file derived from the Gaussian Splatting process occurs through a custom-developed plugin. This component adds a dedicated button within the main viewer interface, enabling a direct link to a static HTML page hosting the real-time visualization of the splatted model.

Through this methodology, the research proposes a scalable, open, and replicable workflow for the documentation, dissemination, and enhancement of architectural heritage, integrating open-source tools, state-of-the-art rendering algorithms, and a user-interaction-oriented interface. The system thus contributes to the participatory and collaborative management of the digital model within a Common Data Environment (CDE) context.

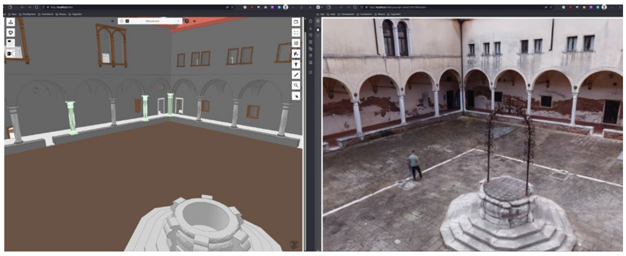

Figure 13. Button integrated into the BIMData interface linking to the HTML page for Gaussian Splatting visualization.

5. Repository e divulgazione

The sharing of the code and developed resources constitutes a fundamental phase of the research process, especially in projects aimed at experimentation and replicability within academic and cultural contexts. To this end, a public repository has been prepared on GitHub, structured according to criteria of clarity and reusability, which documents in detail the entire process of development, configuration, and integration of the visualization system.

The repository includes:

– Vue.js project configuration files with updated dependencies for the Node.js environment;

– integration with the BIMData viewer;

– update and integration of one of the ArKBIM plugins;

– a module linking to Mark Kellogg's Gaussian Splatting viewer, including the code for generating the interactive link and managing the visualization of the .ply file within a dedicated HTML page;

– detailed instructions for deploying the system on a personal or institutional web space, ensuring full accessibility and sharing of the content with the scientific community and stakeholders.

Link: https://github.com/fabrizioiacobucci/snicolo-lido

The choice of GitHub (Fig. 00) responds to the need to ensure transparency, version control, and collaboration. The repository is accompanied by an explanatory README.md file, illustrating the project context, the technologies employed, and the usage modalities of the available modules. The setup of a shareable web platform is conceivable, hosted on Node.js environments (e.g., DigitalOcean) or on any static hosting services, allowing project visualization. This interface enables users to explore the artifact through two synergistic modalities: on one hand, a semantic and structured reading of the HBIM model and its metadata; on the other hand, an immersive and photorealistic experience of the built space via the radiance field generated by Gaussian Splatting. The system thus proves scalable and adaptable, not bound to proprietary solutions, and facilitates the dissemination of results also in educational, museum, or participatory research contexts.

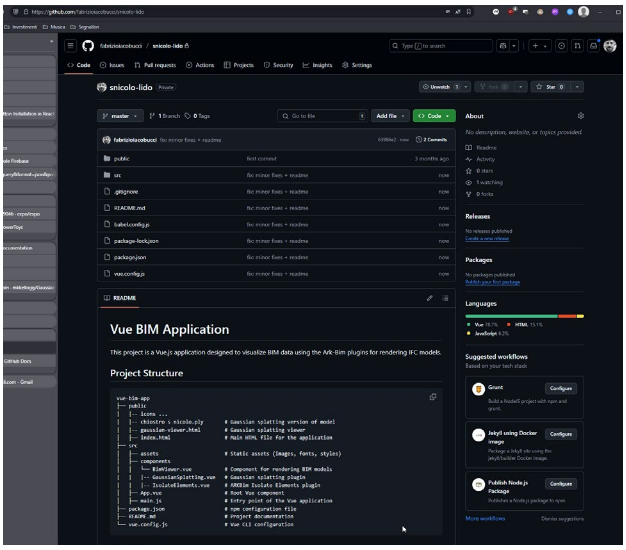

Figure 14. GitHub repository.

6. Conclusions

The methodological approach adopted for the modeling, management, and visualization of the San Nicolò del Lido complex demonstrates how the integration of open-source tools, interoperable HBIM models, and advanced rendering techniques can provide a solid foundation for the documentation and enhancement of architectural heritage. The strengths of this workflow lie in its modularity, which allows the adaptation of levels of detail according to the morphological and evolutionary characteristics of the building, and in its interoperability, ensured by the use of the IFC format and integration with external environments via public APIs. The use of BIMData, not only as an online viewer but as an adaptable infrastructure through external frameworks such as Vue.js, has enabled the extension of traditional CDE functionalities by implementing custom components, including plugins for semantic filtering (ARK-BIM) and advanced viewers for Gaussian Splatting content. Moreover, the combination of HBIM modeling and immersive visualization allows for a more natural and intuitive reading of the architectural object, rendering its materiality through realistic and navigable rendering accessible directly via the web and usable by a wide range of users. Among the identified weaknesses is the requirement for high technical expertise in plugin development and adaptation, which is not always accessible in non-specialist contexts. Furthermore, the integration of heterogeneous tools entails the management of complex workflows that can become difficult to scale without an adequate supporting digital infrastructure. Despite these challenges, the tested approach represents a flexible and replicable solution capable of combining scientific rigor, operational sustainability, and accessibility, positioning itself as a reference for future digitalization and participatory management interventions of architectural and cultural heritage. In this direction, the publication of the code on GitHub, organized into reusable modules and accompanied by technical documentation, constitutes a further element of openness and transparency. The repository offers users the possibility to explore, modify, and adapt the developed platform. The potential creation of a publicly accessible web version ultimately enables immediate dissemination of the results, facilitating sharing among researchers, cultural operators, and non-specialist audiences, and promoting participatory digital use for the protection and enhancement of historic built heritage.

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