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Exploring Photogrammetry-Based Information Models within hBIM Contexts

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Abstract

BIM technologies and processes have finally become the state-of-the-art standard in digital design and are now widely adopted across the AEC industry worldwide. However, things become significantly more complex when shifting the focus from contemporary architecture to existing buildings—particularly historical or archaeological sites. In these contexts, we completely lack dedicated platforms, specific parametric tools, and even shared information standards. More importantly, we often stop acting like digital experts and start feeling like kids again, spending an overwhelming amount of time and effort manually retracing HBIM models from raw point clouds or photogrammetric data. But what if the building is already there—and so is its digital counterpart, right in front of our eyes? Why can't we simply use the survey model as-is and enrich it with information? When we get rid of our geeky parametric obsessions, survey scans reveal themselves as far more powerful and flexible than our tedious and outdated retracing routines. In a broader "BIMification" perspective, any geometric source becomes valuable—even non-parametric and unconventional ones such as planar shapes, textured meshes, NeRFs, or raw point clouds. The key lies in finding new ways to embed data and communicate these hybrid results. We ended up developing an experimental workflow combining photogrammetry, genAI, mesh-processing tools, BIM and visualisation platforms to create and interact with the Digital Twin of cultural artefacts. The resulting process turned out to be so distinct from traditional BIM or even HBIM workflows that we decided to call it PBIM in its own right: a new digital paradigm for managing historical and archaeological contexts through hybrid, Photogrammetry-Based Information Models. This innovative approach offers substantial benefits for both surface decay monitoring and conservation activities and led us to develop a cutting-edge AR visualization platform—paving the way for a truly immersive, inclusive, and information-rich cultural experience for visitors.

Keywords: HBIM, Photogrammetry, Digitalization

Introduction. Between Surveying and Information

Over the past two decades, the management of architectural heritage has been transformed by the advent of Building Information Modelling (BIM) and Heritage BIM (HBIM). These tools not only digitise building geometry but also promote interoperability, structured data archiving, and dynamic updates. Advances in digital surveying, particularly Structure from

Motion (SfM) photogrammetry and 3D laser scanning, allow the creation of highly accurate 3D models, revolutionizing how the built environment is measured. However, the integration between surveying and information modeling is still evolving. Currently, photogrammetry and laser scanning serve as preliminary phases in the HBIM process, providing point clouds from which a parametric model is manually created. While common, this approach presents challenges like data duplication, long modeling times, and loss of fidelity in geometry and information. The key question is: Is it necessary to manually create an HBIM model when photogrammetry already offers a complete and accurate 3D representation? This leads to the concept of a Photogrammetry-Based Information Model (PBIM), a new paradigm where the photogrammetric model is used directly as the informational base, without the need for parametric remodelling. In this framework, photogrammetry becomes not just a surveying tool, but an information container that can function like an HBIM model.

Photogrammetry as a Knowledge Process

Photogrammetry is a process, not a product. It involves extracting geometric and radiometric information from a set of images to create 3D models. Unlike other surveying techniques, photogrammetry produces visually rich models with textures and colors that represent not only form but also material and chromatic characteristics. The output is a textured mesh, a navigable 3D surface with both metric and visual data. From this perspective, photogrammetry becomes a core element in the knowledge process, where surveying and representation merge, and modelling evolves into informational enrichment rather than geometric reconstruction.

Limits and Potential of Traditional HBIM Workflow

The traditional HBIM workflow follows these stages: survey → point cloud → parametric modelling → data population → model management. While this process ensures interoperability, it has key limitations. Firstly, manual modelling of complex historical geometries leads to simplifications. BIM tools are designed for regular, standardised shapes, not the irregularities found in historical structures. Secondly, re-modelling the point cloud is time-consuming and involves arbitrary approximations. Finally, the resulting model often lacks a direct link to the original survey, losing its value for historical research and conservation. These issues call for a rethinking of the relationship between survey and model, allowing them to coexist more fluidly.

From Survey to Knowledge with the Photogrammetry-Based Information Model

PBIM addresses these issues by using photogrammetry as the foundation for the entire information process. The photogrammetric model becomes a data container that can be enriched with attributes, metadata, and links. This can be done through semantic segmentation, dividing the model into logical components (walls, roofs, arches), each of which can have descriptive data added. This step can be automated using machine learning or done manually in software like Blender or Metashape. In PBIM, the survey comes first, followed by interpretation. This approach maintains a closer relationship with reality than traditional HBIM workflows.

Methodological Implications of Additive and Subtractive Modelling

In PBIM, informational integration happens through additive modelling (adding layers of data such as materials, diagnostic information, and history) and subtractive modelling (fragmenting the model into independent, semantically rich components). This approach minimizes interpretative mediation, preserving the original complexity of forms. PBIM is well-suited for integration with augmented and virtual reality, enhancing applications in museums, education, and cultural dissemination. In conservation, it can assist in diagnosing damage, comparing interventions, and planning maintenance. In scientific research, it offers a tool for studying historical stratifications and understanding the relationship between form, material, and time. The ultimate goal is to create a cultural Digital Twin, a dynamic system that integrates surveying, monitoring, maintenance, and communication within a unified digital environment that updates in real time.

The Two Components of Architecture: Form and Content

The proposed research develops a structured workflow based on the assumption that architecture possesses a dual nature: form and content. According to this principle, the methodology addresses, on the one hand, the digital representation of the complex geometry of historical architecture and, on the other, the definition of rigorous methods for embedding non-geometric information (semantic enrichment) within digital components. To address the first aspect—the representation of complex form—the photogrammetric model is adopted as the primary means of describing the geometry of the architectural artefact. The objective is to produce a morphological configuration that is as faithful as possible to the real object. The use of textured mesh models is particularly advantageous in historical and, even more so, archaeological contexts. Moreover, since different parts of an architectural structure, whether intact or ruined, respond differently over time to decay processes, it is useful to identify units characterized by intrinsic homogeneity from typological, constructive, and stratigraphic perspectives. Through the segmentation of the photogrammetric model (Fig. 1), the digital portions composing the artifact can be clearly defined.

Following segmentation, each digital element is assigned a unique identification code and a classification (Fig. 2) to facilitate the recognition and management of distinct units. Once the geometric dimension has been established, attention shifts to the non-geometric content.

The reference framework adopted for organizing this information is the data sheet template

Fig. 1. Semantic segmentation according to homogeneous portions of masonry

developed by the Italian Ministry of Culture, specifically by the Istituto Centrale per la Catalogazione e la Documentazione (ICCD). Based on this framework, the non-geometric information required for a comprehensive understanding of an architectural unit can be

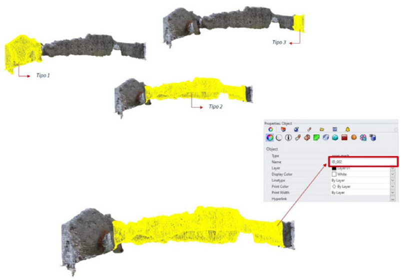

Fig. 2. Assigning ID codes to segmented portions of masonry

divided into three main categories: data related to historical knowledge; data related to technical and technological characteristics; and data related to the state of conservation. The evaluation of information across these three domains establishes an ordered semantic and ontological structure, facilitating the identification of masonry portions requiring priority intervention—whether for knowledge enhancement, conservation, restoration, or valorisation of the historical artefact.

The Role of Visual Programming Language

Following this phase, a dedicated strategy is defined for the indexing, correlation, and semantic enrichment of the segmented units of the photogrammetric model. One effective method for transferring non-geometric content is the development of a Visual Programming Language (VPL) script that maps data from the information sheets directly onto the digital objects. For this purpose, the potential of Grasshopper, a plugin for Rhinoceros, is leveraged, as it supports both textual and visual programming paradigms. The VPL code developed within this methodology is organized into several component sets, each fulfilling a specific function within the digital environment. The first set converts the textual information sheets into indexed data sequences organized according to parameter "macro-categories." The second set associates these data with the segmented portions of the digital model. Since Rhinoceros alone cannot manage complex information structures suitable for architectural components, this task is delegated to VisualARQ, a BIM-oriented plugin that provides dynamic documentation tools compatible with the proposed workflow. VisualARQ translates the categorized parameters into structured information linked to the architectural segments of the model. Simultaneously, a third set of components, implemented through eleFront, assigns metadata to each segment, designating it with an IfcWall index so that Rhinoceros recognizes it as a wall element. The fourth set links each parameter from the data sheets to the appropriate category of the architectural object, making the classification explicitly visible within the software interface. Finally, a fifth set assigns color gradients corresponding to the numerical values derived from the data sheets, allowing color to represent the level of information depth or the degree of degradation of each digital unit.

Analytical Visualization of the Model

Once this process is complete and the textured mesh model has been enriched with all relevant data, the information depth is directly transcribed onto the digital object. (Fig. 3) The use of color substitution, controlled by the VPL (fifth and final set) and calibrated according to predefined depth levels, enables clear and tangible analytical assessments.
The evaluation sheets translate qualitative observations into quantitative parameters by associating numerical ranges with specific color intensities. For example, after evaluating the technical and technological knowledge of two masonry segments (M1 and M2) belonging to the same artifact, M1 may exhibit a higher level of information than M2. As a result, M1 will display greater information depth and a more intense color. The same logic applies to the state of conservation: masonry portions exhibiting higher levels of criticality are represented with stronger color intensities.

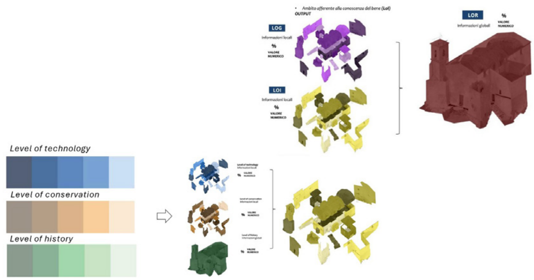

Fig. 3. Analytical visualization of the model

With regard to historical knowledge, this parameter often refers to the artifact as a whole; however, certain areas may be better documented than others. Consequently, better-understood portions of the structure are represented through more intense color gradations. Through these chromatic variations, the model visually communicates either conservation criticalities, indicating areas requiring urgent intervention, or knowledge density, highlighting portions of the architecture that require further investigation to enrich the model's informational content. From the most intense to the least intense, color substitution provides an immediate and intuitive visualization of information depth.

Delivering PBIM

It is now possible to implement a broader integrated process that shifts the photogrammetric model from a purely scientific and cognitive domain towards a design- and conservation-oriented dimension. Consequently, meshes must be integrated into authoring platforms to develop hybrid models, combining photogrammetric components (PBIM) with the parametric capabilities of conventional BIM/HBIM tools for new parts. A reverse approach appears disadvantageous; adapting parametric platforms to handle meshes is more efficient than incorporating information technologies into CGI tools. However, language interoperability remains a significant challenge. It requires a consultation platform capable of preserving the three pillars of an integrated PBIM model: geometric data (mesh and BREP), informational data (classifications and properties), and raster data (UV texture mapping), which is essential for delivering photogrammetry.

The IFC standard is currently unsuitable for such workflows, as its texture preservation features lack support in commercial platforms. Consequently, this study experimented with Graphisoft BIMx, a free and intuitive mobile platform ideal for broadening model accessibility. BIMx facilitates an immersive experience with multiple PBIM models tailored to diverse purposes and stakeholders (Fig. 4, Node A). It hosts various scans within a single semantic environment—including existing artefacts, reconstructions, and chromatic analyses—all enriched with specific datasets. By combining three distinct languages—self-compiling expressions, API instructions, and Markdown syntax—it is possible to embed advanced custom functionalities not natively available in the application. These include guided camera navigation to predefined viewpoints, AR viewport synchronisation, and URL linking to internal or external documentation with historical, photographic, and archival data. (Fig. 4, Node B)

Information Process

To clarify the process, it is more intuitive to retrace its stages in reverse order. This reflects the methodological approach used to design the PBIM flowchart in the first place: starting from the objectives and progressively identifying the tools and procedures required to achieve them effectively. The proprietary BIMx format requires Archicad, developed by the same software house. However, the original scan must be imported already segmented into parts to ensure object-referenced data population, mirroring the logic of native components. Archicad thus acts as an information collector for the recomposition and data enrichment of individual segments, performed either manually or via VPL-driven association algorithms. Finally, polygon and UV texturing optimisation for a non-mesh-oriented environment is automated through GDL programming. (Fig. 4, Node C)
The foundational core of this process must therefore occur outside the authoring platform, using open-source CGI mesh-processing tools. These enable topology optimisation, decimation, and segmentation of the photogrammetric continuum via a subtractive approach—the opposite of the additive method used in canonical BIM and HBIM workflows. (Fig. 4, Node D) Both the original mesh and high-resolution orthomosaics are

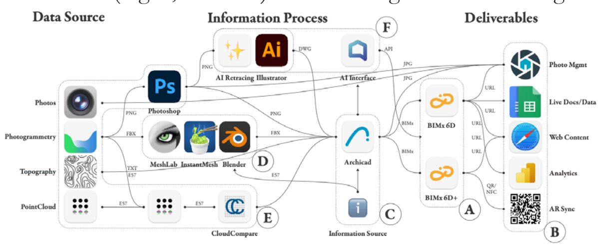

Fig. 4. PBIM general flowchart

previously generated in photogrammetric platforms and subsequently paired with BIM model projections; this hybrid approach ensures a level of quality for both types of content that would otherwise be unattainable. In parallel, other survey data sources converge within the authoring environment: topographic data for territorial restitution, point clouds for georeferenced recomposition, and photographic documentation for API integration with management platforms (Fig. 4, Node E).

Conclusions and Further Developments

Compared to canonical HBIM processes based on point cloud tracing, initial experiments on Roman and medieval artefacts yield encouraging results, demonstrating an overall efficiency gain of approximately 70% in the restitution workflow with proportional economic benefits. On average, this equates to three days of subtractive modelling and recomposition, compared to the ten days required by the traditional additive parametric approach. Moreover, qualitative metrics remain challenging to quantify. Given the typology of the historical and archaeological artefacts investigated, the results enable the continuous use of PBIM models for technical monitoring, conservation, and innovative digital dissemination. Early-stage applications yield promising results in terms of surface and decay QTO accuracy for intervention planning, data-driven decision-making regarding structural behaviour for reinforcement design, and predictive insights into long-term transformative phenomena for informed renovation and reuse planning. These outcomes are far superior to comparable parametric approximations—which are often unfeasible—and to the 2D vector representations that remains the standard in the archaeological field. Ultimately, information photogrammetry contributes significantly to optimising digital governance and data-driven conservation practices. It further promotes social benefits through dissemination models that enable authentic, immersive, and inclusive exploration, even in remote or restricted-access contexts. The open virtual consultation of PBIM models overcomes geographical and physical barriers, fostering a new digital dimension for the cultural community.

The PBIM process is still in its early stages of development, with several research areas undergoing continuous investigation and refinement. Three primary directions have been identified, each expected to significantly enhance the technological capacity and efficiency of PBIM workflows. Artificial Intelligence contributions are currently being explored along three main lines, two of which are already fully operational in ongoing experiments. (Fig. 4, Node F) These include: an AI-driven vector tracing process for the automatic extraction of CAD documentation from the original scan; a genAI conversational chatbot interface, specifically developed to facilitate API interaction during model exploration; and an automatic segmentation process for the photogrammetric continuum based on image recognition principles and enabled by recent advances in agentic AI. While point cloud–based studies have existed for over five years, applying these methods to meshes remains more complex, though notable progress is underway. Regarding acquisition techniques, promising opportunities arise from the paradigm shift introduced by Gaussian Splatting. This technology optimises previous NeRF methods by drastically reducing model size while enhancing visual quality, and it already demonstrates the potential to supersede traditional mesh-based photogrammetry. Concerning data durability and accessibility, a foreseeable transition involves the shift from generic commercial tools towards cloud-based environments designed as institutional repositories for PBIM content. This ensures the full preservation of the cognitive, analytical, and predictive potential of photogrammetry-based cultural Digital Twins.

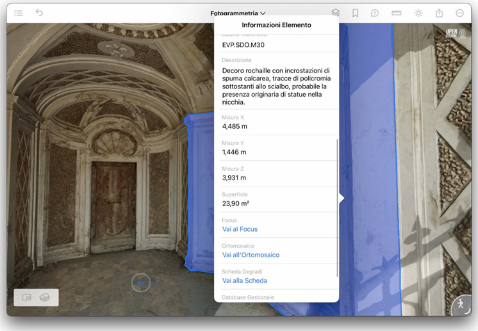

Fig. 5. PBIM segment with different kind of data

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