Bridging Geometric Gaps between Digital Survey and BIM through Open-Source 3D Tiles - IFC Integration

Raphaël Vouilloz[1,2] Ken Percy[2], Nicolas Arellano Risopatron[2], Sabrina Liu[2], Philippe Marin[1], Stephen Fai[2]

[1] Université Grenoble-Alpes, ENSAG, MHA (Méthodes et Histoire de l’Architecture) - Grenoble, France
vouilloz.r@grenoble.archi.fr ; philippe.marin@grenoble.archi.fr
[2] Carleton University, CIMS (Carleton Immersive Media Studio) - Ottawa, Canada
kpercy@cims.carleton.ca ; narellano@cims.carleton.ca ; sliu@cims.carleton.ca ; sfai@cims.carleton.ca

Keywords: Digital survey, HBIM, Web viewer, Open source, IFC, 3D Tiles

Abstract

The adoption of innovative digital heritage workflows in the Architecture, Engineering, and Construction (AEC) sector faces significant challenges, particularly in integrating digital survey data with Building Information Modeling (BIM) into a unified model. This paper begins with a literature review that outlines the geometric and software-environment constraints complicating such integration and examines various proposed solutions, with particular attention to open-source tools and standard formats. Building on this foundation, the paper introduces an innovative two-stage method: (1) segmenting, classifying, and enriching digital survey data into a BIM model; and (2) developing a web viewer that hybridizes this BIM model with the original survey data. The proposed workflow relies exclusively on open-source tools and open standards, with Industry Foundation Classes (IFC) used as the native editing format. A seamless continuity is established between the Bonsai add-on for Blender, used as a BIM authoring environment, and the web library That Open Engine, which serves as a dissemination tool enabling interactive querying of BIM data within a web browser. This library shares a common dependency on Three.js with 3DTilesRendererJS, allowing the overlay of a tiled photomesh of the asset. This integration enables the combination of an accurate geometric and visual representation with structured metadata interaction within a unified web environment. Overall, the proposed approach provides a robust and flexible framework for supporting practical applications such as dissemination, documentation, and diagnostic studies of heritage assets.

1. Introduction

As digital surveying and Building Information Modeling (BIM) are increasingly adopted in the Architecture, Engineering, and Construction (AEC) sector, creating synergy between the two fields offers many potential applications in building maintenance, urban planning, heritage restoration, and archaeological studies. Digital surveying provides an accurate geometric and visual representation, while BIM embeds structured metadata within a digital model. However, interweaving both approaches raises significant geometric challenges.

This paper begins by identifying technical limitations through a literature review. These limitations encompass characteristics of heritage objects, the goals of the modeling process, and the technical details related to the computational specifics of the formats and tools utilized in various approaches. We explore strategies from previous studies to overcome these challenges, which can be categorized into two main phases. The first phase involves modeling, where methods are employed to convert data from digital surveys into BIM, addressing the inherent difficulties in these conversions. The second phase focuses on dissemination, integrating digital survey data and BIM through web-based viewers, for which we provide an overview of the primary libraries used in both areas. Based on this context, we suggest an alternative method that merges these two phases and can be applied to multiple use cases. Our case study examines a diagnostic study of the ashlar stone structure known as the horseshoe staircase at the Château de Fontainebleau in France, which can be seen in figures 1 and 5. This remarkable work of stereotomy—the art of cutting and assembling stone—derives its name from the sinusoidal lines of its two flights, which stage the king’s ascent to his apartments while simultaneously sheltering the arrival of carriages. Recently restored, it was built between 1632 and 1634 to replace an earlier monumental stair by Philibert de l’Orme. Its traditionnal attribution to Jacques Lemercier and/or Jean Androuet du Cerceau is now being questioned by historians (Ponsot, 2026).

The proposed method consists of two interconnected processes: 1) converting digital survey data into a BIM model, and 2) developing a web viewer for sharing a hybrid model. A notable innovation is the emphasis on open-source tools and open standards, in contrast to the proprietary software and closed file formats prevalent in the AEC digital landscape. The approach relies on two open standards: Industry Foundation Classes (IFC), the openBIM data schema, and 3D Tiles, a format designed for streaming and rendering large-scale, multi-resolution 3D content like photogrammetry. It employs alternatives to proprietary software, specifically: 1) the Bonsai add-on (formerly BlenderBIM) for the free and open-source 3D graphics software Blender, and 2) the JavaScript libraries That Open Engine (previously called IFC.js) and 3DTilesRendererJS, both built upon Three.js. IFC is central to integrating our methods: Bonsai and That Open Engine are leading open-source AEC projects that advocate for using IFC as an editing format, moving beyond its traditional role as merely an export format for archiving or interoperability. This novel approach is referred to as Native IFC (Postle, 2022). Our paper’s contributions include seamlessly combining both tools for creation and dissemination, as well as presenting a unified 3D web environment built on Three.js that converges multiple AEC datasets by integrating digital surveys into the workflow. The open nature of our approach makes it adaptable for various fields aiming to integrate digital survey data with BIM or other AEC data types.

This contribution has been peer-reviewed. The double-blind peer-review was conducted on the basis of the full paper.
https://doi.org/10.5194/isprs-annals-XI-4-2026-385-2026

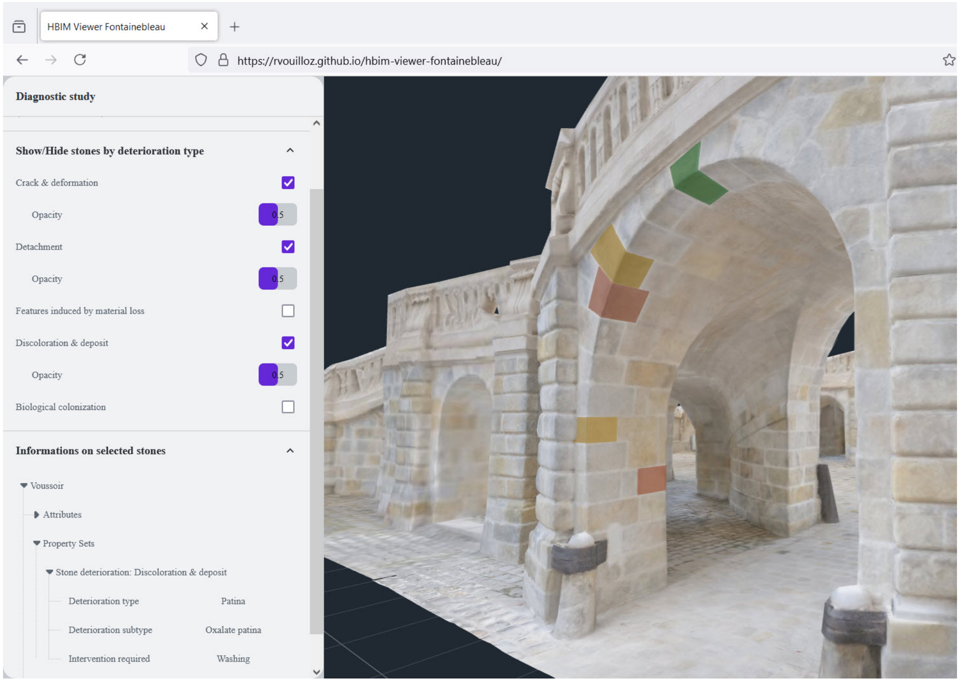

Figure 1. Hybridization of IFC and 3D Tiles in the HBIM web viewer.

The article is organized as follows. Section 2 provides background information through three subsections: the first addresses geometric challenges in integrating digital survey data with BIM; the second reviews prior research on this integration and introduces applicable open digital tools, including file formats, software, and libraries; the third subsection offers a deeper context for the tools used in our experimentation. Section 3 details the proposed methodology, exposing the case study along with the tools and libraries employed, which comprises two primary steps: conversion and dissemination. One subsection specifically covers the conversion process from a photogrammetric survey model to IFC using the Bonsai BIM add-on for Blender, while another details the web development phase, which merges That Open Engine with 3DTilesRenderer. Section 4 outlines the results and discusses their scientific contributions and limitations. Finally, Section 5 concludes the article and explores possibilities for future research.

2. Background

2.1 Geometric issues

BIM integrates metadata into a 3D model, facilitating information management throughout the entire lifecycle of a building. The specificity of cultural heritage has led to the concept of Historic or Heritage BIM (HBIM) (Lovell et al., 2023, Yang et al., 2020, Lopez et al., 2018, Pocobelli et al., 2018). Within an HBIM model, every building element has the potential to contain attributes or processes. As such, it can store information about heritage data, significant values, conservation policies, and the maintenance and conservation of its parts (Arayici et al., 2017). As BIM was intended originally for the modern AEC industry in regard both to semantic classification and modeling tools, previous research has tried to adapt both (Garcia-Gago et al., 2022, Simeone et al., 2021, Diara and Rinaudo, 2020). In this paper, we will focus on limitations in terms of modelisation, as a lot of time is spent on this phase—underlining the need for innovative approaches to architectural representation (Cotella, 2023, Murphy et al., 2021). Indeed, geometric modeling has been identified by (Lovell et al., 2023) as the initial challenge of HBIM and the most discussed topic through a comprehensive literature review. While presenting Mesh-to-BIM as the most accurate modeling approach to represent cultural heritage assets, it underlines limitations of compatibility between high-resolution mesh and BIM environments. In a previous literature review on the topic, (Yang et al., 2020) already identified a similar limitation, postulating that a unified HBIM platform could be generated by addressing the challenge of integrating complex and irregular geometries into workflows that translate survey data into BIM. Following this statement, we stress a number of geometric issues. Firstly, the geometry underlying heritage structures such as vaults often requires in-depth study; this knowledge may be necessary for use cases such as the fabrication of a part to be restored, but in a diagnostic study it would only inform the modelisation process, making it time-consuming. Secondly, traditional BIM software works with solid modelisation, which relies on exact geometry kernels. This industrial approach of conceiving 3D forms enables common usecases of BIM such as quantities extraction or automated hatching in drawing, but is less flexible than surface modeling or polygonal modeling software and is therefore more difficult to adapt to heritage assets. Lastly, this geometric rigidity is also problematic for integrating physical deformations, not negligible in heritage assets, which compromises overlay with a survey. Hence the need to model BIM directly from digital surveys data, which comes with further issues. Digital surveying employs laser-based scanning technology, photogrammetry, or a combination of the two. This process produces highly accurate 3D geometries in two forms: point clouds and texture-mapped models whose surfaces are defined by polygonal meshes, hereafter referred to as photomeshes. Both are data intensive, making them difficult to integrate into BIM software. Therefore, point clouds are used primarily as external links to guide the modelisation of geometry in BIM software in a process called Scan-to-BIM. Photomeshes, akin to large textured polygonal assets modeled for rendering, are difficult to import into traditional BIM software, at the cost of downgrading their quality at an unacceptable level. This integration becomes even more challenging in the case of tiled photomeshes—models organized as a collection of multiple submodels of varying precision that are dynamically selected according to viewing scale to enhance performance, as commonly implemented in map applications; this would enable maximum exploitation of the representation capabilities of large digital surveys. Textures are particularly valuable for HBIM as they contain information—difficult to perceive in point clouds—such as small joints or defects. Hence the need for innovative methods to hybridize digital survey data and BIM.

2.2 Interweaving digital survey data and BIM

2.2.1 Converting digital survey data to BIM Several approaches have been proposed for integrating data from digital surveys into BIM models in order to represent objects: (Krijnen and Beetz, 2017) have extended the IFC schema for integrating point clouds; (Moyano et al., 2022) have automatically recorded meshes from digital surveys in BIM models using traditional BIM software; and (Angeloni et al., 2023) have segmented and classified a mesh using Blender and the Bonsai add-on. Furthermore, in order to make textured meshes-workflows more productive when creating HBIM models, research on auto- segmentation of photogrammetric meshes has made significant improvements recently, leveraging deep learning techniques and advanced algorithms. Current state-of-the-art approaches often integrate 2D and 3D data for improved accuracy (Wang et al., 2023). Deep learning models, such as DiffusionNet (Sharp and Attaiki, 2022), are being employed for semantic segmentation tasks on 3D meshes, achieving high precision in landmark prediction and facial segmentation (Berends et al., 2024). Researchers are also exploring fully automated AI-based frameworks for raw 3D data segmentation, information extraction and object classification (Croce et al., 2023, Chen et al., 2019, Grilli and Remondino, 2019).

2.2.2 Embedding digital survey and BIM in web viewers Previous research has already resulted on pre-designed viewers for HBIM, such as Aïoli, a reality-based 3D annotation platform for the collaborative documentation of cultural heritage artefacts (Abergel et al., 2023). Yet, the focus of our paper is on adaptable methods, therefore this section rather presents tools for embedding digital survey data or BIM in a web development process, rather than end-user tools; these are mainly JavaScript libraries. One finding is that a majority of libraries related to AEC rely on a dependency to Three.js to operate with WebGL and handle common 3D computer graphics functions, such as creating a scene or setting a camera. This convergence is shown in figure 2; it facilitates the usage of multiple libraries as it allows to share elements such as cameras. Alternatives to Three.js include Babylon.js, which focuses on real-time 3D and virtual worlds, and SpiderGL, an academic project on which is based one AEC library that we will present here. A few AEC-related libraries build their own interactions with WebGL, such as Cesium.

Digital survey libraries. Cesium is a framework for creating 3D world-globes and maps, focused on a GIS (Geographic Information System) scale, with its own WebGL engine. 3DHOP (3D Heritage Online Presenter) and Nexus are a framework based on SpiderGL, by the Visual Computing Lab of ISTI-CNR, for streaming multi-resolution 3D models, oriented to the Cultural Heritage field. When it comes to Three.js related libraries, Potree is a renderer for large point clouds, developed at the Institute of Computer Graphics and Algorithms, TU Wien. Giro3D is a framework for visualizing and interacting with heterogeneous 2D, 2.5D and 3D data. Finally, the tool we will be using is NASA-AMMO 3DTilesRendererJS, developed by the Jet Propulsion Laboratory at California Institute of Technology, for integrating 3D Tiles into the Three.js library.

BIM libraries. Xeokit is a development kit from xeolabs and Creoox for BIM and AEC, with its own WebGL engine. IfcOpenShell is a toolkit and geometry engine to develop BIM platforms based on IFC—the Bonsai add-on, which will be discussed on section 2.3.2, is based on it. It could be brought to the web, but this is not its primary purpose. That Open Engine is a set of libraries to create custom 3D BIM software on the web, using IFC and based on Three.js, and is the tool we will use. Another framework is Speckle, a collaborative platform whose first goal is to connect AEC tools through open-source connectors. The viewer can be used either as end-user or as a library for custom web development, based on Three.js. Even if it supports IFC, the first aim of Speckle is to propose its own flexible data model.

2.3 Open tools for AEC used in the case study

Significant innovation of our approach is the exlusive use of open standards and open source; this section gives a context.

2.3.1 Open standards file formats IFC is the standardized data schema of BIM and a software agnostic file format. Traditionally, it is used as an export file format, for interoperability and as an archive or deposit document. While optimized for contemporary AEC, the value of using IFC for HBIM has been discussed in a number of articles. (Angeloni et al., 2023) highlighted the schema's robust relational data structure. (Diara and Rinaudo, 2020) proposed an extension method inside the open-source software Freecad, while (Oostwegel et al., 2022) increased its usability to store heritage information. (Moyano et al., 2022) have envisaged customized parameters. Finally, (Delpozzo and Balletti, 2023) connected IFC to external resources such as historical drawings. Though IFC supports meshes as tessellations, it is not intended to store high- and multi-resolutions models. This is why we propose a method for overlaying it with a tiled photomesh representation of the asset.

Textured meshes resulting from a digital survey are inherently photorealistic and geometrically exact. Standards as gltf allows for sharing small assets. At the scale of architecture, files tend to be very large. In order to disseminate them via a web viewer, it is necessary to tile them as multi-resolution models, as in the case of mapping applications (Fu, 2022). 3D Tiles is an open standard designed for streaming and rendering massive 3D geospatial content. It defines a hierarchical data structure and a set of tile formats of various types of 3D data. The computation and export are available directly in some commercial photogrammetry software such as Agisoft Metashape. It can also be converted from a basic photomesh through open-source tools (Kalberer and Dobias, 2026, Marnat et al., 2022).

2.3.2 Open-source software and libraries Proprietary software tends to lock the user's data in its native format and traditionaly uses IFC only as an exchange format, resulting in a loss of data at the time of conversion. As an alternative, Bonsai is a free and open-source tool for native IFC authoring, based on the

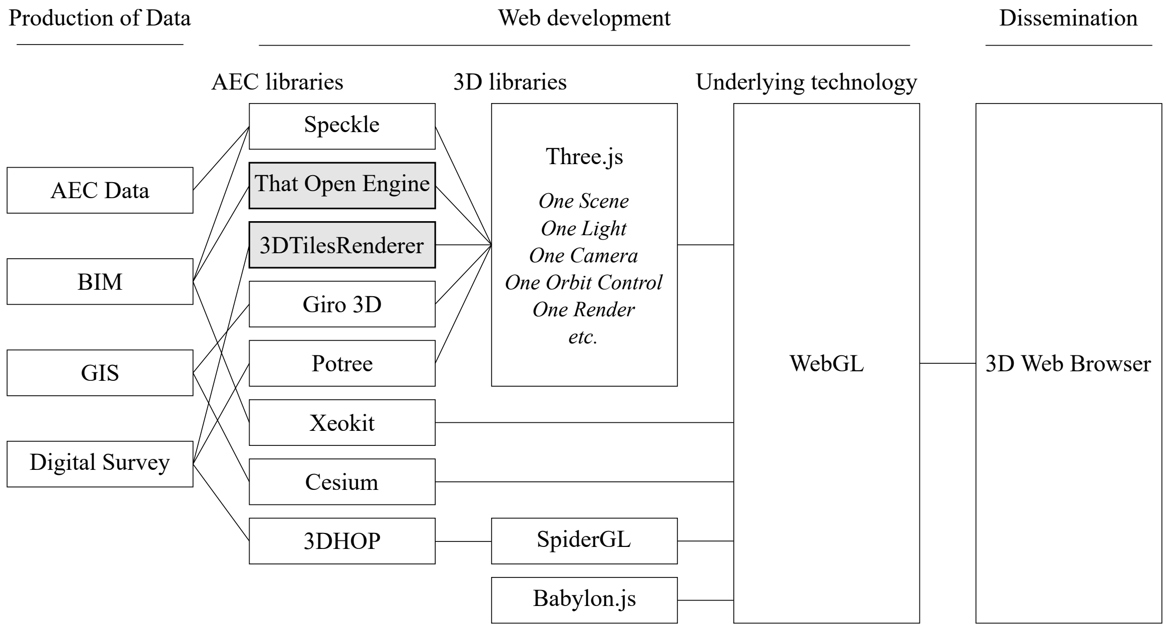

Figure 2. 3D web libraries for AEC and convergence to Three.js.

IfcOpenShell library. This new approach, defined by (Postle, 2022), allows for much more controlled handling of the data created. Furthermore, with the add-on being integrated into the open-source animation software Blender, it benefits from advanced polygonal modeling tools for segmenting photomesh, which traditional BIM software lacks. On the other side, the viewer is accessible from a web browser, which is important for adoption by diverse users (Rechichi et al., 2016, Agustín and Quintilla, 2019). It is based on two JavaScript libraries. Firstly, That Open Engine is used to load IFC files into the browser and interact with its metadata. It offers several libraries allowing a full customization of the user experience. Secondly, 3DTiles-RendererJS is used to load tiled photomesh into the browser and manage their progressive loading according to display. The main reason for choosing these two libraries is their shared dependency to Three.js library, a JavasScript library used to develop 3D computer graphics in a web browser. Three.js is based on Web Graphics Library (WebGL), the underlying technology that enables rendering 3D graphics in the browser, from which it removes much of the complexity. Three.js offers functions to quickly create 3D scenes, setting cameras or lighting parameters through a few lines of code, and these basic functions can be shared accross the various libraries built on top of Three.js. By contrast, trying to combine libraries that do not have this shared dependency is a difficult task as it requires, for example, superimposing scenes, coordinating cameras, etc.

3. Methods

This section details our proposed approach for interweaving digital survey data and BIM, illustrated in figure 3. First, it present the case study. Then, it details the methodology; the first step is a modeling process for segmenting, classifying, and enriching digital survey data into a BIM model, and the second step is a web viewer development to disseminate a hybridization of both models.

Case study The method is applied to a theoretical diagnostic study involving the horseshoe staircase of Château de Fontainebleau in France, which falls within the scope of Heritage BIM (HBIM). It uses the illustrated glossary on stone deterioration patterns released by the International Council on Monuments and Sites - International Scientific Committee for Stone (ICOMOS-ISCS, 2008). The scenario is based on a workflow traditionally resulting in a 2D graphic documentation. An architect carries out a diagnostic study, entering the deterioration observed and work required into the BIM model created from the digital survey data. The model is then shared via a website with craftsmen so that they can locate the operations to be carried out.

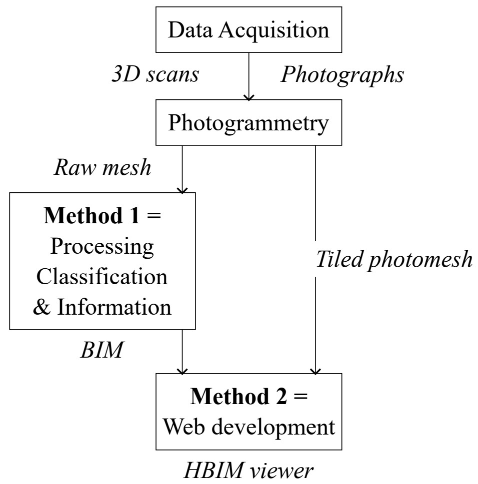

Figure 3. Photomesh to HBIM viewer workflow.

The digital survey is a combination of 3D scan and photogrammetry of the horseshoe-shaped staircase at Château de Fontainebleau. The point cloud is assembled from 34 scan stations, on top of which a photomesh is built from 1305 photographs. The model is assembled using the proprietary software Agisoft Metashape (previously known as Agisoft PhotoScan), version 2.0.1. It is then exported 1) in a standard mesh format such as obj or gltf 2) in 3D Tiles, which result is a folder of multiple b3dm files organized by a JSON file.

This contribution has been peer-reviewed. The double-blind peer-review was conducted on the basis of the full paper.
https://doi.org/10.5194/isprs-annals-XI-4-2026-385-2026 | © Author(s) 2026. CC BY 4.0 License.

3.1 Converting a textured mesh into IFC

This section describes the conversion of a textured mesh into BIM. The BIM model will not be used in the viewer to represent the whole asset, as it will be overlaid with the digital survey data. Therefore, only the voussoirs (the stone parts forming the assembly) receiving a diagnosis are integrated in the BIM model. Each voussoir is represented by its visible faces only, and the texture is not stored. The work is focused on the vault seen in figure 1. It follows three steps: first, the optimization of the survey mesh, then the segmentation and classification of the resulting mesh, finally the addition of information in the form of metadata.

In terms of optimization of the survey mesh, it is important to stress that an IFC file can store mesh representation of objects as tessellations, but the way it is encoded is not intended to store large meshes resulting from 3D surveys. Therefore, direct conversion of the model resulting from the survey is not recommended. By default the raw topology of the survey mesh is quite rough and it is advisable to process it to reduce the number of facets—as shown in figures 4 and 5. Once the photomesh is imported in Blender, it is retopologized using a quad draw modeling workflow.

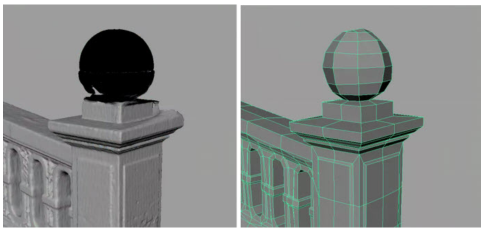

Figure 4. Detail of processed mesh.

Then, an IFC (version 4.3) is created through the Bonsai add-on (version 0.0.240602). The IFC is independent of the current Blender file in which it is displayed, each edition of the model from Bonsai tools being handled externally by IfcOpenShell. Each voussoir is segmented from the original mesh and is assigned an IFC Class in the Object Information menu. It is registered as an IfcElement of the generic class IfcBuildingElementProxy, and of the predefined type NOTDEFINED, as voussoirs are not defined in the current IFC schema. Also, a representation context is assigned in which the geometry will be used, which is set on Model/Body/MODEL_VIEW. In Bonsai's Geometry and Materials menu, under the Representations tab, the active representation is indeed a Tessellation, as shown in figure 6. Its geometry seen in the 3D viewport is no longer a native Blender object, but a visualization of the IFC element.

Once part of the IFC, the voussoir is sorted into the sub-collection of the relevant storey. It can be assigned any kind of IFC metadata, either standardized, such as a material or manufacturer, or created from scratch. To do this, custom IfcPropertySets, or Psets, are used. It is a container class that holds properties within a property tree. In the Project Overview menu, under Project Setup, Property Set Templates, new custom Psets are created from the Sample_Template file. They are renamed according to each deterioration category of the ICOMOS-ISCS glossary, e.g. “Stone deterioration: crack & deformation”. The chosen Template Type is Pset - IfcObject, as it will be applied to occurrences. The following Property Templates are added: Deterioration type, Deterioration subtype (if present in category), Intervention required and Other remarks. The IfcLabel and

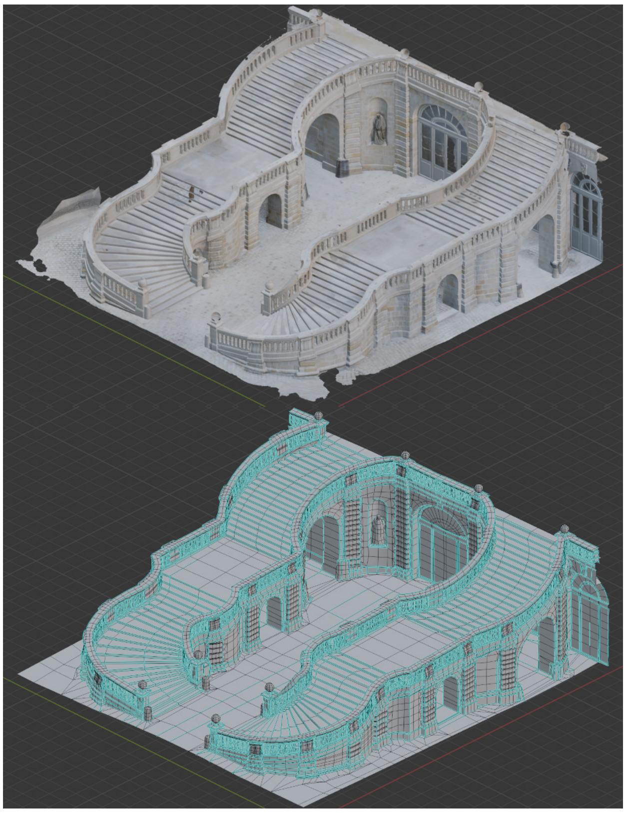

Figure 5. Raw photomesh processed to be converted as IFC.

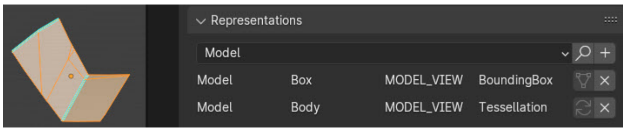

Figure 6. IFC tessellation displayed through Bonsai add-on for Blender.

P_SINGLEVALUE fields are retained for each of them, enabling these fields to be filled in with text for each voussoir. For a given voussoir, the Pset is then added in the Object Information menu, under Object Metadata, Property Sets. Fields are filled in for this occurrence, e.g. Crack, Fracture, Replace, as shown in figure 7.

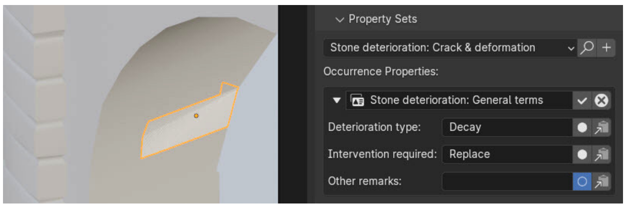

Figure 7. Adding metadata to a voussoir via a custom Pset.

3.2 Interweaving IFC and 3D Tiles in a web viewer

This section describes the web development process behind the web viewer illustrated in figure 1 (Vouilloz et al., 2026). The method benefits from the fact that both That Open Engine (version 2.1.0) and 3DTilesRendererJS (version 0.3.35) libraries are built on top of Three.js; therefore, both IFC and 3D Tiles are loaded into a common 3D environment. The first step is to set up Three.js basic assets as scene, light, or rendering. This can be done directly with That Open Engine, which offers the function OBC.World to speed up this process. The second step is to load the IFC into the scene via the OBC.IfcLoader function. To load the tiled photomesh via the 3DTilesRendererJS library, standard Three.js functions are extracted from That Open Engine with world.scene.three. To read the b3dm files, the DRACO decompression support is used. Once the two models overlaid, the next step is to make the IFC mesh transparent. To do this, we set up an OBC.Classifier, which groups parts of the BIM model according to various parameters. All the objects belonging to the IFC are retrieved via the function classifier.byModel and this classification's visibility is set to false via OBC.Hider. For interaction with the IFC metadata, a panel is set next to the 3D scene. The first section is a series of checkboxes related to the ICOMOS-ISCS classifications that add a color to diagnosed stones, for example, those bearing the custom property set "Stone deterioration: Discoloration & deposit". In addition, the opacity of the overlay color with the photomesh can be adjusted by the user. To achieve this in the code, further classifications are created with OBC.Classifier using the classifier.byIfcRel function. This is a particularly powerful tool that can be used on any relationship within IFC, such as IfcRelContainedInSpatialStructure, IfcRelAggregates, or in this case IfcRelDefinesByProperties. Next, each classification is traversed to assign a new material to the set of meshes contained in that classification. The second section of the panel displays the properties of a selected asset, developed through the function OBC.Highlighter. This colorizes preselected and selected elements, and returns metadata, in particular the diagnosis entered in Bonsai.

4. Results and Discussion

The result of the research is a new methodology to disseminate a photorealistic HBIM directly modeled from a 3D survey data, using open source tools and open standards. The scientific contribution is discussed from three perspectives.

4.1 Hybridization of digital survey data and BIM

The bakckground exposes the limitations of traditional Scan-to-BIM and Mesh-to-BIM approaches for heritage assets, particularly with regard to irregular geometries and photorealistic requirements. The focus on 'hybridisation rather than full conversion' seems therefore appropriate for diagnostic, documentation and dissemination use cases, as it allows to query IFC metadata while visualizing high-resolution photorealistic survey data in an unified web environment. Our prototype demonstrates that the geometry captured by a digital survey can be directly used as a representation in an IFC model, as a tessellation. This solve issues in terms of modeling and focus BIM in terms of documentation and information sharing, by combining its potential to contain diverse metadata with the exceptional metric and graphic fidelity of digital surveying. In our case study, we relied on the ICOMOS-ISCS Illustrated Glossary for basic stone repair categories because the glossary serves as a standardized guide for stone repair by providing a vocabulary and visual references for deterioration patterns. As it is based on open source and open standards, the method presented can be adapted or extended to any kind of classifications like the one of ICOMOS-ISCS, whether they are standardized or specific to a particular project or location. Interweaving digital survey data and BIM could also support the dissemination of archaeological studies, building maintenance or urban planning and design. The main limitation of the modeling approach is that objects are only represented by their visible faces. Quantitative data, traditionally extracted from geometry in BIM software, is not computable. It should also be noted that the exclusive use of tessellations circumvents the issue of interpreting more complex geometries embedded in IFC, such as solids, which are not always correctly transposed from the BIM authoring tool (Bonsai) to web libraries such as That Open Engine.

The unified web viewer demonstrates how multiple assets can converge into a shared 3D scene. Our research has shown that many AEC-related 3D web libraries use Three.js as a dependency, leveraging its core functionality. Examples were cited in section 2.2.2 and include: Speckle, Giro3D, Potree, That Open Engine or 3DTilesRendererJS, as shown in figure 2. This common foundation ensures compatibility and allows these libraries to share Three.js elements such as scenes, cameras, orbit controls and lights. This makes it much easier to superimpose elements supported by these different libraries, in our case the digital survey dat and BIM. It opens up numerous possibilities for future developments integrating one or other of these libraries.

4.2 Open source, open standards and Native IFC

The proposed workflow relies exclusively on open-source principles and open standards, with a seamless continuity between the BIM authoring environment and web-based dissemination. Storing and sharing architectural models through IFC has been common practice for decades, but IFC modeling in its native format has only become accessible with the launch of Bonsai. With these new editing capabilities, IFC has become more than a storage container. The potential of creating and sharing models that can be edited without proprietary software cannot be emphasized enough. Further, the integration of the IfcOpenShell library by the Bonsai add-on inside the well-established 3D software Blender enables hybridization between BIM and highly detailed polygonal models and takes advantage of advanced tools to process such geometries. Finally, thanks to open-source libraries like That Open Engine and 3DTilesRendererJs, this interweaving is also possible by layering models in the web browser, opening countless possibilities to visualize complex relationships between geometric and semantic data. IFC plays a key role in this respect by facilitating the structuring of metadata in a seamless pipeline from modeling to dissemination, while our strategy allows to overcome its limitations in terms of representation.

Our approach differs from similar processes achievable with other tools or libraries in several respects. Compared to off-the-shelf BIM viewer software such as BIMvision, our use of the That Open Engine library enables the customization of the interface and of interaction functionalities with IFC metadata, tailored to specific use cases and audiences. This also distinguishes our approach from the use of Cesium, which allows IFC models to be loaded into a 3D Tiles GIS-like environment, but offers only limited capabilities for interacting with IFC data. On the other hand, the use of the IFC standard itself can be debated. For instance, Speckle represents an alternative that seeks to move away from the IFC standard in order to promote case-by-case interoperability. While we acknowledge the technical limitations of using a standardized format, the perceived limitations of IFC are often also linked to how this open format is implemented in proprietary software and to the challenges associated with conversion processes. In this context, adopting IFC as a native format reinforces its relevance by enabling full control over its encoding, thereby avoiding reliance on conversion processes. Moreover, compliance with a standard enhances the long-term usability and interpretability of data within an ecosystem involving a wide range of stakeholders. As limitations, it should be noted that this paper has focused on geometry-related aspects and has not addressed the issue of IFC's semantic limitations, which nevertheless remains a major concern. No convention is currently widely accepted for precisely mapping cultural heritage assets to the IFC semantics. We adopted a pragmatic approach by using IfcBuildingElementProxy entities and custom property sets; however, this has implications for long-term interoperability, schema evolution, and compliance with the standard. Furthermore, the open-source tools used in the workflow are recent and still under development. There is little documentation available and their development is subject to rapid evolution, which may call into question the long-term viability of some of the functions used.

4.3 Model efficiency

Two contrasting IFC models (one consisting of stone fragments at 34Kb, and the second of the entire stair at 9.6MB) were tested in the viewer to compare loading times and usability for different scales of models. The results reveal a clear asymmetry between two phases of viewer performance: how long a model takes to load, and how smoothly it runs once it is on screen (figure 8). Decomposing several stones of the stair into individual IFC elements reduces the load time by approximately 77% compared to the monolithic assembly, yet once both models are fully loaded, they are rendered at nearly identical frame rates (57–58 FPS). This convergence suggests that the geometry presented to the renderer is effectively the same in both cases; the difference lies in how the IFC file is structured and parsed, not in how much the graphics hardware must ultimately draw. In other words, the choice of IFC representation matters most during the initial loading pipeline, not during sustained interactive use.

A secondary finding concerns perceived responsiveness during interaction. Even where average frame rates are comparable, the monolithic model shows slightly higher worst-case frame times and slower response to user input; effects that become more pronounced under constrained hardware, simulated here via CPU throttling. For heritage visualization contexts where users navigate a model to inspect individual elements, query construction phases, or compare spatial relationships, this interaction latency is more perceptible than a modest drop in frame rate. The practical implication for BIM authoring practice is that element-level decomposition, representing each stone as a discrete IFC entity rather than grouping the assembly, offers meaningful benefits for web delivery not by simplifying the rendered geometry, but by making the model easier and faster to ingest, enabling the viewer to reach an interactive state sooner and respond more fluidly to user actions.

5. Conclusion

The paper addresses a major issue in the field of HBIM: the persistent geometric discrepancy between high-fidelity digital surveys data and their implementation in BIM environments. In the first part, we identified challenges in integrating digital survey data with BIM. These issues stem from the complexity of heritage objects as well as the technical and geometric characteristics of the software and formats used in both fields. The literature review explored various strategies and highlighted libraries

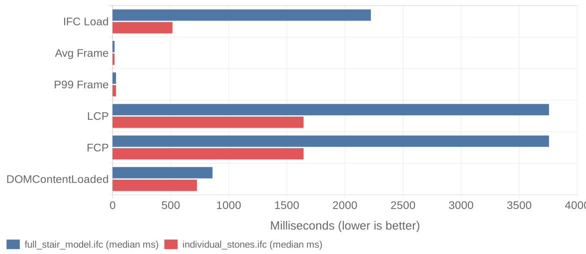

Figure 8. Model performance comparison in milliseconds

that can facilitate this integration. Building on these insights, our contribution details an innovative workflow, which applies open-source tools and standard formats for merging digital survey data with a BIM model in an unified model accessible in a web viewer. It uses the horseshoe staircase at Château de Fontainebleau as a case study. A textured mesh generated from the digital survey was processed, classified, and enhanced with custom information while being converted into an IFC format using Blender and the Bonsai add-on. This BIM model was then integrated with 3D Tiles from the same survey in a web viewer. The development employed 3DTilesRendererJS and That Open Engine, both JavaScript libraries based on Three.js, to provide photorealistic visualization and interactive access to metadata through a customized interface. This implementation logic notably utilizes IFC as a native format, establishing a dynamic data structure that supports both modeling and dissemination in a standardized language, while integrating the digital survey approach. Additionally, it demonstrates a convergence of various web libraries related to AEC into the Three.js environment. The open-source and open-standard nature of these methods creates a foundation for future innovation, including the potential integration of other file types such as maps or drawings for further exploration.

Acknowledgements

This research was funded in part by the Social Sciences and Humanities Research Council (SSHRC) of Canada, Partnership Talent Program (895-2015-1018).

References

Abergel, V., Manuel, A., Pamart, A., Cao, I., De Luca, L., 2023. Aïoli: A reality-based 3D annotation cloud platform for the collaborative documentation of cultural heritage artefacts. *Digital Applications in Archaeology and Cultural Heritage*, 30.

Agustín, L., Quintilla, M., 2019. Virtual reconstruction in BIM technology and digital inventories of heritage. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W15, 25–31.

Angeloni, R., Mariotti, C., Petetta, L., Coppetta, L., 2023. Enabling scan-to-bim workflow for heritage conservation and management process. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-2-2023, 79–86.

Arayici, Y., Counsell, J., Mahdjoubi, L., Nagy, G., Hawas, S., Dweidar, K. (eds), 2017. *Heritage Building Information Modelling*. Routledge, London.

Berends, B., Bielevelt, F., Schreurs, R., Vinayahalingam, S., Maal, T., de Jong, G., 2024. Fully automated landmarking and facial segmentation on 3D photographs. *Scientific Reports*, 14(1), 6463.

Chen, M., Feng, A., McCullough, K., Prasad, P., Mcalinden, R., Soibelman, L., Enloe, M., 2019. Fully automated photogrammetric data segmentation and object information extraction approach for creating simulation terrain. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC).

Cotella, V. A., 2023. From 3D point clouds to HBIM: Application of Artificial Intelligence in Cultural Heritage. *Automation in Construction*, 152.

Croce, V., Manuel, A., Caroti, G., Piemonte, A., De Luca, L., Véron, P., 2023. Semi-automatic classification of digital heritage on the Aïoli open source 2D/3D annotation platform via machine learning and deep learning. *Journal of Cultural Heritage*, 62, 187–197.

Delpozzo, E., Balletti, C., 2023. Bridging the gap: an open-source GIS+BIM system for archaeological data. the case study of Altinum, Italy. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-2-2023, 491–498.

Diara, F., Rinaudo, F., 2020. IFC classification for FOSS HBIM: open issues and a schema proposal for cultural heritage assets. *Applied sciences*, 10(23).

Fu, P., 2022. *Getting to Know Web GIS*. 5th edition edn, Esri Press.

Garcia-Gago, J., Sánchez-Aparicio, L. J., Soilán, M., González-Aguilera, D., 2022. HBIM for supporting the diagnosis of historical buildings: case study of the Master Gate of San Francisco in Portugal. *Automation in Construction*, 141.

Grilli, E., Remondino, F., 2019. Classification of 3D digital heritage. *Remote Sensing*, 11(7), 847. Number: 7.

ICOMOS-ISCS, 2008. *Illustrated glossary on stone deterioration patterns*. XV, Paris.

Kalberer, P., Dobias, M., 2026. pka/awesome-3d-tiles. https://github.com/pka/awesome-3d-tiles.

Krijnen, T., Beetz, J., 2017. An IFC schema extension and binary serialization format to efficiently integrate point cloud data into building models. *Advanced Engineering Informatics*, 33, 473–490.

Lopez, F. J., Lerones, P. M., Llamas, J., Gómez-García-Bermejo, J., Zalama, E., 2018. A review of heritage building information modeling (H-BIM). *Multimodal Technologies and Interaction*, 2(2), 21. Number: 2.

Lovell, L. J., Davies, R. J., Hunt, D. V. L., 2023. The application of historic building information modelling (HBIM) to cultural heritage: a review. *Heritage*, 6(10), 6691–6717. Number: 10.

Marnat, L., Gautier, C., Colin, C., Gesquière, G., 2022. Py3DTilers: an open source toolkit for creating and managing 2D/3D geospatial data. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, X-4-W3-2022, 165–172.

Moyano, J., Carreño, E., Nieto-Julián, J. E., Gil-Arizón, I., Bruno, S., 2022. Systematic approach to generate Historical Building Information Modelling (HBIM) in architectural restoration project. *Automation in Construction*, 143.

Murphy, M., Meegan, E., Keenaghan, G., Chenaux, A., Corns, A., Fai, S., Chow, L., Zheng, Y., Dore, C., Scandurra, S., Tierney, A., Diara, F., Rinaudo, F., Prizeman, O., 2021. Shape grammar libraries of European classical architectural elements for historic BIM. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVI-Mnumber 1-2021, Beijing, 479–486.

Oostwegel, L. J. N., Jaud, , Muhič, S., Malovrh Rebec, K., 2022. Digitalization of culturally significant buildings: ensuring high-quality data exchanges in the heritage domain using OpenBIM. *Heritage Science*, 10(1), 10.

Pocobelli, D. P., Boehm, J., Bryan, P., Still, J., Grau-Bové, J., 2018. BIM for heritage science: a review. *Heritage Science*, 6(1), 30.

Ponsot, P., 2026. Le "Grand degré" de la cour du Cheval-blanc et la transformation de la Maison royale de Fontainebleau sous Louis XIII. Preprint.

Postle, B., 2022. Native IFC. Technical report. https://github.com/brunopostle/ifcmerge/blob/main/docs/whitepaper.rst.

Rechichi, F., Mandelli, A., Achille, C., Fassi, F., 2016. Sharing high-resolution models and information on web: the web module of bim3dsg system. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLI-B5, 703–710.

Sharp, N., Attaiki, S., 2022. diffusion-net. https://github.com/nmwsharp/diffusion-net.

Simeone, D., Cursi, S., Fioravanti, A., Coraglia, U. M., 2021. Open-ArcH - An open knowledge-based system for architectural heritage representation. Novi Sad, 253–262.

Vouilloz, R., Percy, K., Arellano Risopatron, N., Liu, S., Fai, S., Marin, P., 2026. HBIM Viewer Fontainebleau. https://rvouilloz.github.io/hbim-viewer-fontainebleau/ code: https://github.com/rvouilloz/hbim-viewer-fontainebleau.

Wang, W., Zhong, G., Huang, J., Li, X., Xie, L., 2023. Instance segmentation of 3D mesh model by integrating 2D and 3D data. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-1/W2-2023, 1677–1684.

Yang, X., Grussenmeyer, P., Koehl, M., Macher, H., Murtiyoso, A., Landes, T., 2020. Review of built heritage modelling: integration of HBIM and other information techniques. *Journal of Cultural Heritage*, 46, 350–360.