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DESAROLLOS FUTUROS

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3D MODELING & BIM

DESAROLLOS FUTUROS

I volume raccoglie i contributi, dei relatori e degli studiosi, pervenuti in occasione del *Workshop 3DModeling&BIM. Desarrollos futuros*, che si è svolto a Cordoba (Argentina) in data 9 maggio 2025.
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Organizing Commitee

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A COMPUTATIONAL APPROACH TO ‘DRAWN’ ARCHITECTURE: A DRAWING ENCODING INITIATIVE (DEI)

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Abstract

Archives preserve thousands of architectural drawings that embody unbuilt visions and design reasoning. These documents represent a valuable but fragile category of heritage, drawn architecture, that exists only in representation, not in material form. This research introduces the Drawing Encoding Initiative (DEI), a methodology that employs Visual Programming Languages (VPL) and Heritage Building Information Modelling (HBIM) to encode the semantics of drawn architecture.

Introduction

Architectural archives and libraries safeguard vast collections of drawings, sketches, and plans that represent an overlooked form of heritage: projects conceived and designed but never built. This category, often referred to as unbuilt heritage, includes competition entries, visionary projects, utopian plans, and treatise illustrations. These works are more than visual documents. They embody the intellectual and cultural intentions of their authors and preserve fragments of design reasoning that never materialised in stone, brick, or mortar [Hollander, 1977].

Unlike built heritage, which endures as tangible artefacts, unbuilt heritage survives mainly through its representations. Plans, elevations, sections, and annotations provide evidence of stylistic experimentation and theoretical exploration. As scholarship increasingly acknowledges, the study of such documents reveals otherwise invisible processes of innovation.

The concept of drawn architecture emphasises the epistemological role of drawing. A drawing is not only an image; it is a codified language with its own grammar of proportions, conventions, and symbols that communicates complex ideas beyond the reach of words [Ching, 2023]. In architectural culture, the act of drawing has historically represented both an intellectual and a technical operation. Drawings combine multiple layers of representation: textual notes, orthographic projections, three-dimensional models, and, potentially, higher-order systems of structured knowledge [Giovannini, 2022].

Historically, treatises and competition entries preserved in archives constitute an extraordinary source of drawn architecture. From Renaissance codices and Baroque utopias to modernist projects that remained unbuilt due to political, economic, or technical constraints, these documents bear witness to the evolution of architectural thinking across the centuries. Vitruvian descriptions, Renaissance manuscripts, and Palladian treatises all exemplify how the medium of drawing structured architectural discourse. Each era introduced new modes of representation, shaping not only design practice but also the way knowledge was transmitted and interpreted.

The late twentieth century marked a decisive turning point in digital design. Computer-Aided Design (CAD) introduced precision and reproducibility to architectural practice, parametric design enabled flexibility and relational logics [Stiny & Gibs, 1978], and Building Information Modelling (BIM) incorporated semantics and structured knowledge into three-dimensional models [Carpo, 2012; Caetano & Leitão, 2020]. These technological shifts profoundly transformed the way architects represent, analyse, and communicate spatial ideas, moving from static drawings to dynamic and data-rich models. Since 2009 BIM approach was also used for documenting and representing historic buildings (HBIM) offering new perspectives for cultural heritage management and conservation [Murphy *et al.*, 2009; Lovell *et al.*, 2023].

A similar trajectory can be observed in the field of digital humanities, although with a different emphasis. Here, information technology has been primarily used to analyse documentary heritage through encoding systems, digital editions, and large-scale text or image corpora. Initiatives such as the Text Encoding Initiative (TEI) demonstrate how transcriptions and annotations can be structured into machine-readable resources that preserve and interpret cultural texts[1].

Architecture and the digital humanities thus share the same fundamental challenge—how to represent, organise, and interpret knowledge—but apply technological systems in different directions. While the humanities are primarily concerned with encoding and interpreting texts and images, with a focus on art history [Impett, 2024], architecture utilises computational frameworks to reconstruct and represent three-dimensional complexity.

Proposed solution

The Drawing Encoding Initiative (DEI) positions itself precisely at the intersection of these traditions. It extends the encoding logic of the digital humanities to architectural drawings, but simultaneously adopts architectural tools capable of representing spatial relationships and design grammars in 3D. In this way, DEI demonstrates how methodologies from distinct domains can converge to produce digital critical editions of architecture, combining the interpretive rigour of the humanities with the representational capacity of architectural practice.

By combining Visual Programming Languages and HBIM, DEI translates drawings into semantically enriched 3D models. Its novelty lies in its insistence on evidence-based encoding. Unlike artificial intelligence approaches, which may generate plausible but unverifiable forms, DEI builds reconstructions that are grounded in archival rules and proportions. This guarantees transparency, reproducibility, and accountability. Translating ‘drawn’ architecture into tangible and digitally accessible heritage offers new opportunities for the preservation and valorisation of documentary heritage and drawings.

In the digital age, digitising this fragile heritage poses unique challenges. Contemporary strategies for built heritage, such as laser scanning and photogrammetry, are effective in recording existing

1_ Text Encoding Initiative (TEI). Available at https://tei-c.org/

buildings but cannot capture projects that were never realised. In such cases, the building exists only on paper, requiring source-based methods that can extract and encode information directly from documentary evidence.

The Drawing Encoding Initiative (DEI) responds to this challenge. The method can be compared to the Text Encoding Initiative (TEI) in the humanities [Ciotti, 2018], which transforms manuscripts into digital critical editions. DEI extends this logic to architecture by linking graphic elements to semantic categories, thus ensuring that drawings are not only visualised but also interpreted and structured as data. In doing so, the initiative contributes to a broader vision of FAIR-compliant heritage digitisation [Wilkinson *et al.*, 2016], creating resources that are findable, accessible, interoperable, and reusable.

Finally, the DEI distinguishes itself from emerging AI-based generative imaging approaches, which can produce plausible but unverifiable reconstructions of unfinished architecture [Merino-Gómez *et al.*, 2023]. While AI tools generate statistical approximations and unverified errors, the DEI encodes architectural rules and archival evidence, delivering reconstructions that are transparent, reproducible, and critically accountable. In this regard, it signifies a methodological advancement in digital heritage: one that not only visualises the past but reconstitutes architectural thinking into structured, reusable knowledge.

The comparison in Fig. 1 highlights the unique contributions of the DEI methodology within the broader landscape of digital heritage modelling. Traditional 3D modelling, though valuable for visualisation, depends on manual interpretation and offers limited semantic enrichment, making it less reproducible and only partially FAIR-compliant. AI generative tools, such as GANs and diffusion models, have recently been explored for architectural applications, yet their outputs remain speculative, visually plausible, but methodologically unverifiable. Conversely, the DEI integrates VPL and HBIM to develop algorithmic, rule-based workflows that are transparent, reproducible, and semantically enriched. In this way, it represents not only a methodological improvement over existing practices but also an epistemological shift: from image-based visualisations to digital critical editions of architecture, ensuring the FAIR management of 'drawn' architecture and documentary heritage.

CRITERIA	GENERAL 3D MODELLING / VIRTUAL RECONSTRUCTION	DEI (DRAWING ENCODING INITIATIVE)	AI GENERATIVE TOOLS (GANS, DIFFUSION MODELS)	RADAR REPRESENTATION OF 3D MODELLING APPROACHES
SOURCE OF DATA	Drawings, photos, surveys (manual interpretation)	Archival drawings, historical documents	Large training datasets (images, texts, non-specific to heritage)	
PROCESS TYPE	Manual CAD / 3D modelling	Algorithmic, semi-automatic encoding with VPL + HBIM	Pattern recognition, probabilistic synthesis	
SEMANTIC ENRICHMENT	Low (geometry only, metadata rare)	High (typological, morphological, historical semantics)	Low (implicit, not rule-based)	
REPRODUCIBILITY	Limited (depends on modeller)	High (rule-based, computational workflow)	Low (stochastic, prompt-dependent)	
OUTPUT RELIABILITY	Variable (expertise dependent)	High (traceable, evidence-based)	Low-medium (plausible but unverifiable)	
FAIR COMPLIANCE	Low-medium (often not interoperable)	High (structured, FAIR-aligned data)	Low (opaque models, poor interoperability)	
SUITABILITY FOR 'DRAWN' ARCHITECTURE	Moderate (good for visualisation, weak for scholarship)	High (explicitly designed for 'drawn' architecture)	Low (speculative, not critical)	

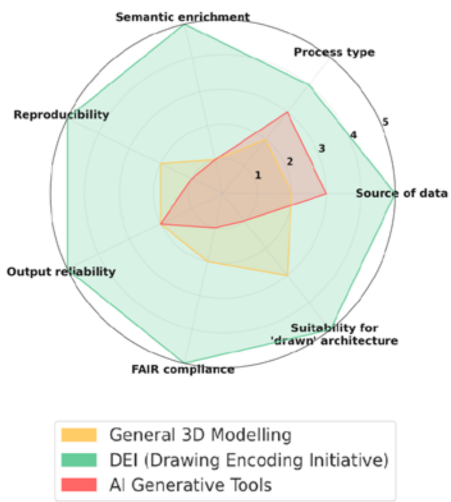

Fig. 1: Comparison of 3D Modelling Approaches

An integrated approach

Computational design tools such as Grasshopper (for Rhinoceros) and Dynamo (for Revit) have introduced new possibilities for algorithmic modelling. Within HBIM, these VPL environments allow architects and researchers to organise diverse data into structured workflows that can encode both geometry and semantics.

The DEI workflow integrates geometric modelling with semantic modelling. In the first phase, points, curves, and surfaces are extracted from digitised drawings through algorithms capable of reconstructing proportions and alignments. Once the geometric base is defined, it is enriched with meaning by classifying the elements into typological, constructive, and stylistic categories, thereby turning them into HBIM objects.

Archival drawings pose specific difficulties. Unlike modern technical plans, they often lack precise scales, may contain hand-written annotations, or suffer from distortions due to reproduction and ageing. Converting them directly from two dimensions to three, as in CAD workflows, risks introducing errors and inaccuracies [Feist *et al.*, 2024]. DEI addresses these issues through pre-processing techniques such as noise removal, rescaling based on historical units of measure, and proportion rectification. This ensures that both the graphical and textual content of the drawings are preserved and accurately reflected in the digital model.

The methodology also anticipates future integration with computer vision. Automated recognition of text and graphic components, coupled with semantic segmentation (Ahmed *et al.* 2011), could accelerate annotation and dimension checking. Such tools would not replace scholarly interpretation but rather provide support in verifying accuracy and consistency.

Experimental results

Andrea Palladio's Villa Sarego was chosen as a test case precisely because it exemplifies the challenges of unbuilt heritage. Designed in 1562, the project was only partially realised before construction was abandoned, and the remaining structures were later demolished.

Today, Palladio's drawings are the only evidence. His corpus has long served as a reference in computational research (Fig. 2), from Stiny and Mitchell's Palladian Grammar [1978] to Sass's experiments with digital fabrication [2007], facade's semantic analysis [Buthayna, 2008] and recent explorations of GANs for plan generation [Uzun *et al.*, 2020].

DEI builds on this tradition but shifts attention from generative approaches to the critical recovery of Palladio's design reasoning. Figures 3 and 4 illustrate the overall workflow of the Drawing Encoding Initiative (DEI) applied to Palladio's Villa Sarego (1562). The process begins with the digitisation and pre-processing of archival drawings, followed by image colour analysis, pixel-to-point conversion, and semantic labelling of architectural components. These data are then vectorised and anchored to HBIM elements, integrating plan and elevation information within a structured library of parametric entities. The outcome is a semantically enriched three-dimensional model, a 3D Digital Critical Edition, that transforms 'drawn' architecture into machine-readable, interoperable heritage knowledge.

Plan analysis

The initial stage focused on analysing the plan. The digitised image was cropped, resized, and normalised to ensure uniformity. Colour processing then converted it into a binary image, which facilitated the isolation of architectural lines and reduced background noise. From here, a pixel-to-point translation created a grid in which black pixels became active points representing architectural elements, while white spaces defined voids. These clusters of points were automatically grouped and interpreted according to their architectural role, such as walls, columns, or openings.

Vectorisation and anchoring

Once the drawing was cleaned and structured at the pixel level, the process advanced to vectorisation. The clusters were transformed into vector geometries that traced the centrelines of walls and the axes of columns. These geometries were then anchored to HBIM components drawn from a dedicated library. The transition to three dimensions was made possible by this step, which connected abstract vectors to parametric entities.

Elevation analysis

The workflow also relied on elevation drawings. These provided vertical references that were aligned with the plan data, ensuring that the three-dimensional reconstruction remained coherent across different representational systems. The integration of plan and elevation produced a model faithful not only to proportions but also to Palladio's compositional logic.

HBIM library of elements

Central to the methodology was the creation of an HBIM library (Fig. 5) tailored for Palladian architecture [Giovannini, 2023a, 2023b]. While generic components, such as walls and floors, exist in standard HBIM frameworks, features like classical columns, entablatures, and vaulted systems require custom, adaptive families. Their inclusion ensured that the resulting model captured the stylistic grammar specific

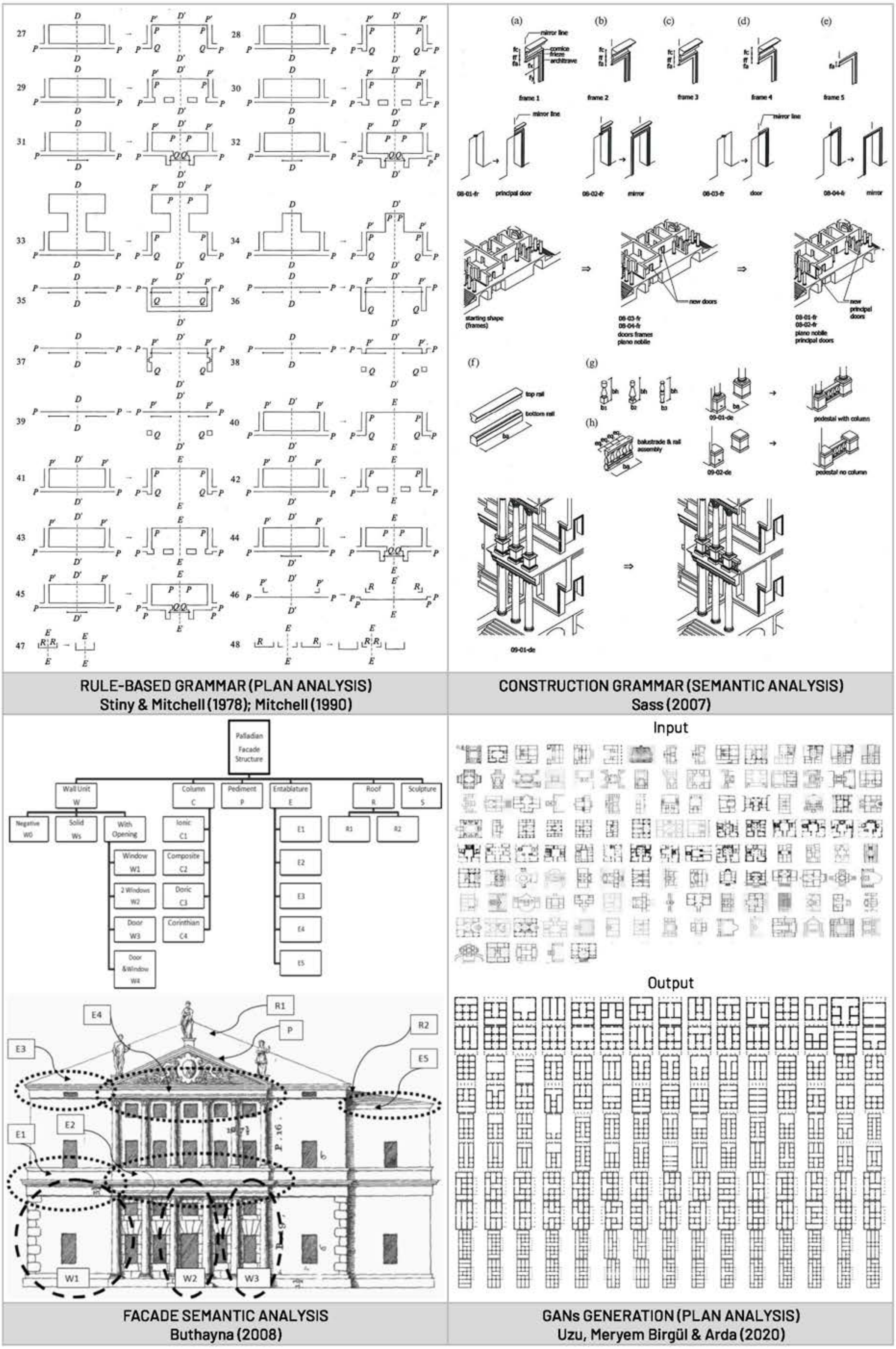

Fig. 2: Different computational approaches to Palladio's design

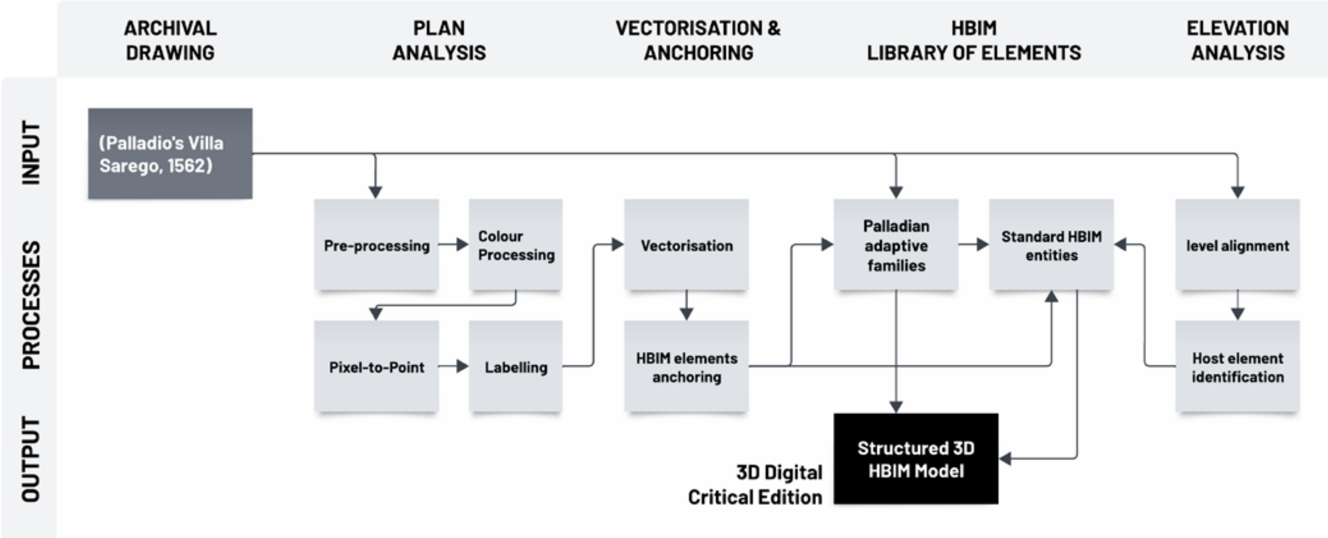

Fig. 3: Flowchart of the DEI workflow

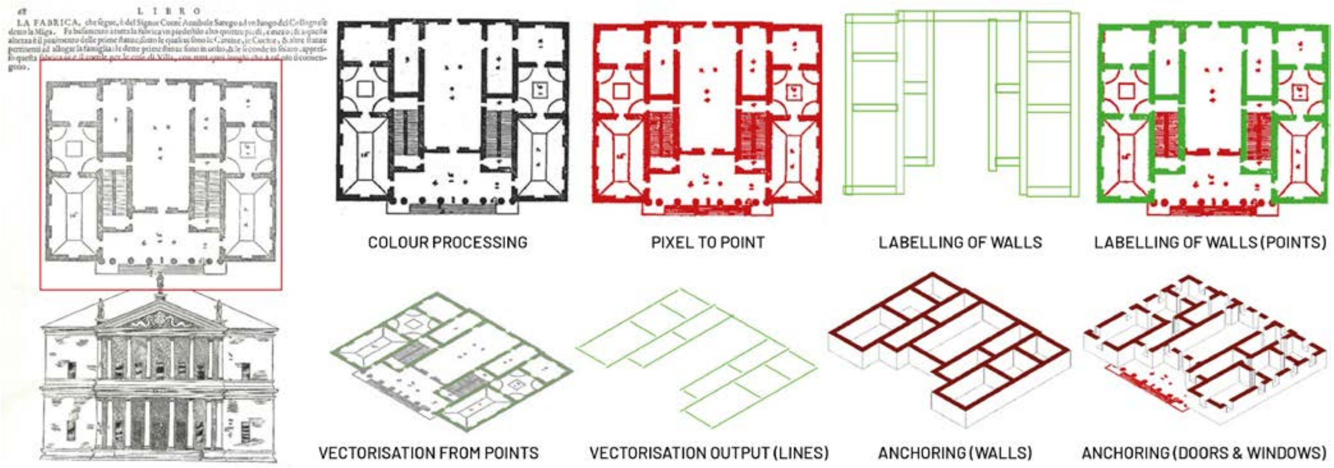

Fig. 4: DEI Workflow applied to Villa Sarego.

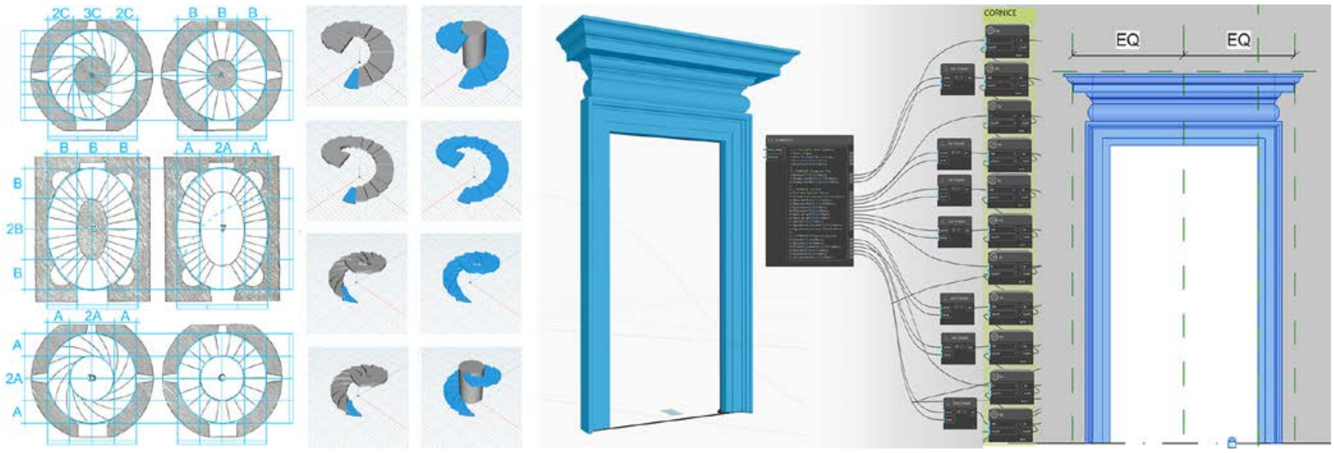

Fig. 5: A portion of HBIM library fpr Palladian Architecture. [Giovannini, 2023a,b]

to Palladio, extending beyond mere geometry to encode the cultural and formal essence of his design.

The outcome was a model that preserved both form and meaning. Rather than a static reproduction, it functioned as a digital critical edition: a structured artefact that both human scholars and computational tools could interrogate to reveal the underlying architectural grammar.

An HBIM open visualisation using dotbim format

At the beginning of 2022, a new file format was released for the BIM industry. It's called dotbim (extension: .bim), the project is 100% free and open[2]. This is a minimalist, simple, JSON-based file format for BIM developed by MIT in response to the perceived complexity of other OpenBIM initiatives, such as those of buildingSMART International (bSI)[3]. It supports only one representation (triangularization) and associates key-value pairs of data with it [Böhms *et al.*, 2023].

While Industry Foundation Classes (IFC), developed by bSI[4], remains the gold standard for contemporary construction workflows, its complexity and industry-specific semantics make it less suitable for the digitisation of unbuilt or documentary heritage (Fig. 6). In contrast, dotbim provides a lightweight, flexible, and FAIR-compliant format that is better aligned with the objectives of the DEI methodology, where the priority is not facility management but the encoding of architectural knowledge extracted from historical drawings into structured and reusable 3D digital critical editions (Fig. 7).

In this regard, semantic interoperability of complex cultural data could be integrated with the buildingSMART Data Dictionary (bSDD) platform[5] to enhance semantic interoperability for heritage assets [Argasiński & Tomczak, 2025].

By connecting bSDD shared definitions to virtual HBIM models, the DEI methodology ensures consistent, accurate, and interoperable 3D data across different software, supporting research and virtual reconstruction management by creating a more transparent and repeatable scientific process for unbuilt heritage.

2_ .bim - a new BIM file format, Bim Corner, 4 may 2022. Available at https://bimcorner.com/a-new-bim-file-format/

3_ buildingSMART International (bSI). Available at https://www.buildingsmart.org/

4_ Industry Foundation Classes (IFC). Available at https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/

5_ buildingSMART Data Dictionary (bSDD). Available at https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/

Conclusions

The Drawing Encoding Initiative illustrates how archival drawings can be reinterpreted and transformed into structured, semantically enriched digital models. By combining HBIM with algorithmic modelling, it establishes a workflow that is transparent, reproducible, and critically grounded in evidence.

The approach combines building typological shape grammars [Mamoli, 2020] with an encoded representation of architectural elements [De Luca *et al.*, 2007] using a semi-automatic algorithmic approach.

The Villa Sarego case study demonstrates the potential of this methodology. The process went beyond reproducing spatial configurations: it enabled the recovery of Palladio's design logic and reasoning. In this respect, DEI differs fundamentally from AI generative methods. While such tools may create visually convincing images, their speculative nature prevents them from serving as reliable resources for heritage research. DEI, on the other hand, emphasises accountability, ensuring that every step of the reconstruction can be traced back to archival evidence.

The initiative contributes to heritage studies by proposing a source-based framework for the digitisation of unbuilt architecture. It integrates geometry with semantics, produces resources that operate as critical digital editions, and adheres to the FAIR principles that guarantee reusability and interoperability.

The current limitations of the method lie in its semi-automatic character and the need for specialised HBIM libraries.

Currently, significant scholarly intervention remains necessary, and scalability to extensive archival collections remains challenging. However, the workflow points towards promising directions. Integration with computer vision may automate routine operations, while collaborations across disciplines could expand the semantic depth of HBIM libraries. Beyond academia, DEI also opens opportunities for museums, archives, and educational institutions, which could present unbuilt heritage through interactive and immersive visualisations.

Ultimately, DEI envisions a future in which drawings are not treated as static relics but as living digital resources. Through their transformation into structured models, they contribute to a renewed cultural memory, offering scholars, practitioners, and the public new insights into projects that were imagined but never realised.

6_ The Online 3D Viewer, allows visualisation of diverse types of 3D file formats, including .bim and IFC. Available at https://3dviewer.net/

CRITERIA	INDUSTRY FOUNDATION CLASSES (IFC)	DOTBIM (.BIM)
PURPOSE	Industry standard for construction and facility management	Lightweight format for exchanging 3D BIM-like models
COMPLEXITY	Very high (tens of thousands of entities)	Low (JSON-based, simple structure)
SEMANTIC STRUCTURE	Rigid, technical, oriented to contemporary construction	Minimal semantics, extensible with custom fields
FLEXIBILITY	Limited, requires strict classification	High, allows tailored metadata from historical sources
ACCESSIBILITY	Heavy viewers and libraries required	Lightweight, human- and machine-readable, browser-friendly
FAIR COMPLIANCE	Good, but complex to integrate with LOD/Linked Data	High, easy JSON integration with databases and FAIR workflows
SUITABILITY FOR 'DRAWN' ARCHITECTURE	Low: assumes complete, standardised building information	High: suitable for partial, interpretive data from archival drawings

Fig. 6: IFC vs dotBIM comparison

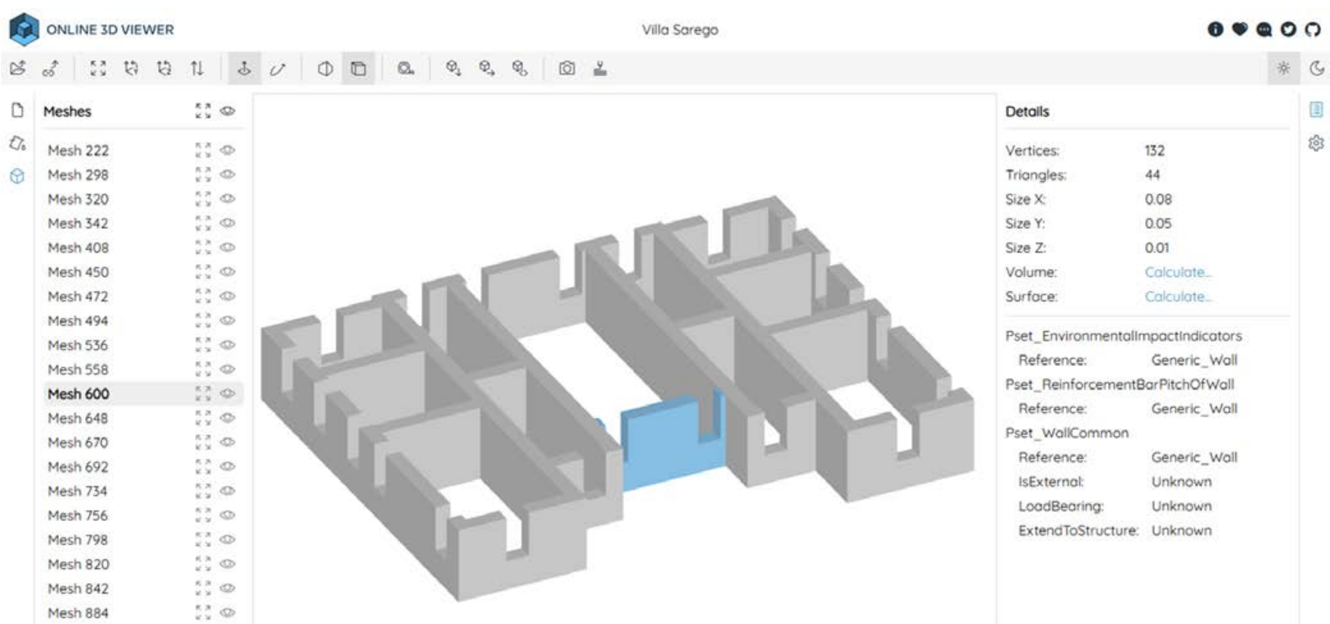

Fig.7: Web-based dotbim visualisation using Online 3D Viewer[6]

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