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Doctoral Dissertation
Doctoral Program in Architectural and Landscape Heritage (37th Cycle)

Digitization in conservation process: An integrated approach in Scan-to-BIM modelling using 3D semi-automated and AI-based strategies

By

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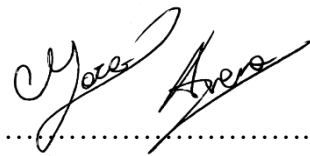
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A handwritten signature in black ink, appearing to read 'Marco Avena', written over a horizontal dotted line.

Marco Avena
Turin, May 12, 2025

Abstract

The documentation of Cultural Heritage (CH) through 3D metric surveys and digitization processes is essential for the conservation, management, and enhancement of these valuable assets. Utilizing 3D surveying technologies, heritage conservation efforts increasingly rely on reality-based methods, incorporating both image- and range-based techniques to produce accurate and detailed models of CH environments. Due to the diversity and complexity of data associated with CH, it is vital to structure this information effectively. This enables the creation of workflows that can efficiently analyze and extract all necessary features for developing informative 3D models with multidisciplinary content, supporting experts in heritage conservation.

A major challenge in CH documentation is the digital 3D modelling of complex shapes, which is traditionally a manual and time-consuming task. Addressing this, the research proposes an innovative methodology to automate and enhance Historic Building Information Modelling (HBIM) processes, using 3D metric survey data to generate reality-based models enriched with both semantic and geometric information. This approach bridges the gap between efficient data acquisition and labor-intensive modelling processes. The methodology leverages Visual Programming Languages (VPL), Artificial Intelligence (AI), and Generative AI (GenAI) techniques to automate repetitive tasks, minimizing manual effort and expediting the generation of enriched HBIM models. This type of approach allows the investigation of leveraging such a workflow to integrate 3D models classified – through established ML or DL techniques – or predicted – using GenAI techniques – into the parametric environment as appropriately categorized BIM elements. This approach facilitates the creation of comprehensive 3D databases, significantly enhancing heritage asset study, conservation and management. The proposed semi-automated workflow allows for integrating and categorizing 3D models directly within the parametric environment as structured HBIM elements. This method not only optimizes the modelling process but also facilitates semantic enrichment, enhancing the informational value of CH models. By harnessing the power of VPL, AI, and GenAI, the approach aims to overcome documentation challenges in CH, fostering sustainable digital preservation practices and improving the interdisciplinary management of heritage assets. This research establishes best practices in CH digitization, supporting the ongoing maintenance and appreciation of cultural assets