

DIGITAL LANDSCAPES

PAESAGGI DIGITALI

**DIGITAL PROCESSES FOR THE REPRESENTATION
OF CITY, ARCHITECTURE, PRODUCT**

**PROCESSI DIGITALI PER LA RAPPRESENTAZIONE
DELLA CITTÀ, L'ARCHITETTURA, IL PRODOTTO**

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La collana adotta un sistema di valutazione dei testi basato sulla revisione paritaria e anonima (*peer-review*). I criteri di valutazione adottati riguardano: l'originalità e la significatività del tema proposto; la coerenza teorica e la pertinenza dei riferimenti rispetto agli ambiti tematici propri della collana; l'assetto metodologico e il rigore scientifico degli strumenti utilizzati; la chiarezza dell'esposizione e la completezza d'analisi. Per temi specifici la revisione anonima è effettuata da esperti esterni scelti dal comitato scientifico.

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Digital landscapes / Paesaggi digitali

Digital processes for the representation of city, architecture, product

Processi digitali per la rappresentazione della città, l'architettura, il prodotto

Landscape is not scenery, it is not a political unit; it is really no more than a collection, a system of man-made spaces on the surface of the earth. Whatever its shape or size it is never simply a natural space, a feature of the natural environment; it is always artificial, always synthetic, always subject to sudden or unpredictable change.

J.B. JACKSON

La collana mette in luce il ruolo della rappresentazione digitale come metodo di prefigurazione del progetto e come strumento di indagine per la conoscenza. Le rappresentazioni, che siano rivolte al pensiero, alla comunicazione o alla costruzione, sono generalmente improntate su processi impliciti che scaturiscono nella mente del progettista. La digitalizzazione impone la necessaria esplicitazione delle azioni per la costruzione dei modelli. Gli ambiti indagati sono il paesaggio, la città, l'architettura e il prodotto. Attraverso esperienze teoriche e casi studio si dimostra quanto le scelte insite nei processi siano foriere di creatività e invenzione. L'interesse verso le procedure per disegnare prevede l'utilizzo di processi aperti e condivisi anche per agevolare il dialogo tra le discipline, rendendo il modello informato e creando un nuovo legame tra modello concettuale e modello costruttivo.

The book series highlights the role of digital representation as a method of foreshadowing the project and as an investigative tool for knowledge. The representations, whether they are aimed at thought, communication or construction, are generally based on implicit processes that flow into the mind of the designer. Digitisation imposes the necessary explicitation of actions for the construction of models. The areas investigated are the landscape, the city, the architecture and the product. Through theoretical experiences and case studies it is shown how much the choices embedded in the processes are the harbingers of creativity and invention. The interest in procedures for designing involves the use of open and shared processes also to facilitate dialogue between disciplines, making the model informed and creating a new link between conceptual model and construction model.

Classificazione Decimale Dewey:

720.285 (23.) ARCHITETTURA. APPLICAZIONI DEL COMPUTER

VALERIA CROCE

H-BIM, SEMANTICS AND ARTIFICIAL INTELLIGENCE

SEMANTIC ANNOTATIONS FOR HERITAGE DOCUMENTATION

Preface by

LIVIO DE LUCA

Afterword by

MARCO GIORGIO BEVILACQUA



ar@cne



ISBN
979-12-218-1799-7

FIRST EDITION
ROME 24 MARCH 2025

To my family



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Publication of this work was entirely funded by the Prix UIF/UFI
from Università Italo-Francese / Université Franco-Italienne.

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PREFACE

In the ever-evolving landscape of heritage sciences, digital technologies have progressively reshaped the ways in which we document, analyze, and interpret our cultural heritage. The integration of artificial intelligence, semantic annotations, and Building Information Modeling (BIM) into this domain is not merely a technical evolution; it represents a profound shift in our epistemological frameworks, enabling a more interconnected, structured, and intelligent approach to cultural heritage documentation.

The rapid advancement of digital technologies has led to paradigm shifts in data production, enrichment, analysis, and interpretation, creating a complex and multifaceted landscape that incorporates contributions from diverse fields such as spatial information sensing, computer vision, computational geometry, information systems, and knowledge engineering.

To fully grasp the transformative impact of digital methodologies on heritage documentation, one must develop an

ability to navigate this fragmented landscape, integrating its dispersed elements into a cohesive vision. This requires transcending disciplinary boundaries, embracing multiple dimensions of representation, and projecting these insights toward a redefinition of methodological approaches in heritage analysis, conservation, and restoration.

Valeria Croce's work, *H-BIM, Semantics and Artificial Intelligence, Semantic Annotations for Heritage Documentation*, is a significant contribution to this transformation.

It offers an in-depth exploration of the methodologies and tools that bridge computational sciences with heritage studies, proposing a comprehensive approach to structuring and managing digital heritage data. Through a rigorous methodological framework, this book addresses one of the most pressing challenges in the field: ensuring that the vast and heterogeneous datasets we generate are not only preserved but also enriched with meaningful, interoperable, and reusable semantic information.

In a period of such profound transformation, engaging with the question of semantics fundamentally entails redefining the relationship between human, collective, and artificial intelligence. This dynamic interplay is at the core of the methodological renewal that is reshaping heritage sciences and professions, fostering a new paradigm where human expertise is augmented by machine intelligence, and knowledge structures evolve through collaborative digital ecosystems.

By bridging these dimensions, we are not only ensuring a more coherent and structured documentation process but also setting the stage for a more adaptive, inclusive, and intelligent approach to cultural heritage preservation.

At the heart of this work lies a vision that resonates strongly with my own research in digital heritage: the necessity of developing open, structured, and sustainable digital ecosystems that foster collaboration among historians, architects, conservation scientists, and computer scientists.

The author systematically demonstrates how semantic annotations, combined with AI-driven methodologies, can enhance our ability to link, retrieve, and propagate knowledge across multiple representations—be they images, point clouds, meshes, parametric models, or historical documents.

During her doctoral research, she was able to immerse herself in the scientific concerns of our laboratory, gaining an acute understanding of how semantic annotation serves as a fundamental building block, capable of traversing multiple representations and dimensions to convey and preserve knowledge derived from human expertise within this vast technological landscape.

This approach not only facilitates a more nuanced understanding of heritage assets but also supports long-term conservation strategies and multidisciplinary research, ensuring that structured knowledge remains at the core of digital heritage methodologies.

A particularly compelling aspect of this monograph is its application to real-world case studies, including studies on significant Italian heritage sites such as the Calci Charterhouse, the Cathedral, the Chapel of Sant'Agata and the Museum of San Matteo in Pisa, as well as some experiments carried out within the digital data working group of the Notre-Dame de Paris scientific action. This last scientific framework, which I have had the privilege to coordinate within the CNRS, epitomizes the challenges

and opportunities of integrating digital methods into heritage preservation.

By focusing on how semantic information can be embedded within digital twins and H-BIM environments, this book goes beyond these popular concepts, encouraging a deeper reflection on their implications. While digital twins and H-BIM have become widely discussed trends in heritage science, this work allows us to look beyond the buzzwords, revealing the pivotal role of structured knowledge representation in contemporary heritage science. It demonstrates that the true challenge lies not merely in the creation of digital replicas, but in structuring, contextualizing, and interlinking knowledge in ways that foster meaningful interdisciplinary collaboration strategies. The ability to represent, retrieve, and evolve heritage information through structured digital frameworks is what ultimately ensures the relevance and sustainability of these technological advancements in the service of cultural heritage.

Beyond its methodological rigour, this work invites us to reconsider the very nature of digital heritage documentation. The concept of *digital continuity*, a recurring theme in this book, highlights the critical importance of ensuring that heritage-related data remains accessible, interoperable, and adaptable over time.

As cultural heritage continues to face threats from environmental, social, and political factors, the ability to maintain a living digital record of our past becomes an ethical as well as a scientific imperative.

Through its meticulous research and forward-thinking approach, this book serves as a vital reference for scholars, practitioners, and policymakers engaged in the digital preservation of cultural heritage.

It challenges us to embrace new technologies not as mere tools, but as catalysts for a more profound and collaborative understanding of our built heritage.

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CHAPTER I

INTRODUCTION

As digital technologies have been increasingly permeating our lives, artificial intelligence (AI) has gradually made it onto the scene too, but without much fanfare. This once daunting prospect has become a part of our lives even in domains that do not seem to belong to a futurist world, such as cultural heritage and museums. The results are both promising and surprising: reconstructing a piece of art, completing an unfinished composition of a great musician, identifying the author of an ancient text, or providing architectural details for a potential reconstruction of the Notre-Dame de Paris cathedral would have seemed like science fiction just a few years ago.

In the 2023 briefing on *Artificial Intelligence in the context of cultural heritage and museums* (© European Union, Pasikowska-Schnass & Lim, 2023), the European Parliament Research Service highlights the crucial role that artificial intelligence might play today in advancing

Cultural Heritage preservation. Reflection on the rapidly evolving AI technology in the Cultural Heritage domain is a key priority and considerations on its related benefits, risks, resources and potential legal implications are more and more raised (Münster et al., 2023).

Additionally, the growing development of digital acquisition, graphic restitution, and modeling systems is offering a new approach to conservators, architects, engineers, restorers, and other experts involved in the analysis, preservation, documentation, and dissemination of heritage assets.

What is the role of AI in the design discipline today? Can we harness new technologies like AI to better preserve our historic buildings and monuments? Could such evolving technologies support the restoration and conservation work of landmarks such as Notre-Dame Cathedral in Paris or the Pisa Charterhouse? By leveraging machine learning for 3D digitalization, could AI potentially act as a *catalyst* (Schönfelder et al., 2023) for the digital transformation and automation of the documentation process?

To address these concerns, this monograph aims at creating detailed digital models of historic buildings by linking historical information, photos, documents, and restoration guidelines, utilizing AI and, in particular, machine learning, to support restoration and conservation efforts. The idea is to define a methodology that, through hierarchical access keys based on user type and trust credentials, allows access, insertion, modification, storage, extraction, and processing of all available information on a monument, so as to track its evolution over time, even in view of future conservation, restoration, maintenance, repair, and consolidation works. Such a method would enable the