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The Architecture, Engineering and Construction (AEC) industry is experiencing an unprecedented transformation from conventional labor-intensive activities to automation using innovative digital technologies and processes. This new paradigm also requires systemic changes focused on social, economic and sustainability aspects. Within the scope of Industry 4.0, digital technologies are a key factor in interconnecting information between the physical built environment and the digital virtual ecosystem. The most advanced virtual ecosystems allow to simulate the built to enable a real-time data-driven decision-making. This Book Series promotes and expedites the dissemination of recent research, advances, and applications in the field of digital innovations in the AEC industry. Topics of interest include but are not limited to:

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Digital Restoration and Virtual Reconstructions

Case Studies and Compared Experiences for Cultural Heritage

Springer

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Foreword

Virtual reconstruction and restoration is gaining momentum at a surprising pace and this is only partially due to the availability of powerful information and computational technologies. Indeed, virtualization has proved to be a multidisciplinary subject whose applications can go beyond what initially expected. Virtual representation of archeological sites and architectural artefacts, as well as digital exhibitions and installations involving virtual, augmented, or mixed reality have already made their path in the framework of cultural heritage and new techniques and solutions appear at daily frequency.

From the perspective of the preservation and use of cultural built heritage, however, the digital restoration has still some exciting steps to take. In countries like Italy, where the built heritage is extraordinarily large and in the vast majority of cases still used for public and private purposes, one of major challenge is to manage the "trade off balance" between philological restoration and modernization of ancient, but still "alive" constructions.

Aside from museums and other cultural buildings, there are in Italy thousands of constructed facilities belonging to the monumental built heritage hosting various crucial activities like hospitals, schools, universities, banks, and public offices. Furthermore, a significant part of the road and railways bridges are centuries old and built in masonry, therefore in many case it has the "right" to belong to our built heritage. In such cases, in order to keep these facilities running for their functions, a specific maintenance is needed to reach satisfactory safety levels in terms of structural behavior and sufficient service levels in terms of comfort performance. This, in turn, means the need for the adoption of structural measures and for the installations of plants (i.e., HVAC systems, energy production or transformation elements, etc.) in a complex and tight path where unavailable constraints of restoration should meet the need for new or upgraded structural and plant elements.

From this point of view, thus, the exploitation of digital restoration techniques and technologies can be looked at as a tremendously powerful tool for evaluating advantages and drawbacks of any single maintenance operation on the built heritage. The articles included in this issue yield the seeds of this powerful application of Virtual reconstruction and restoration.

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Preface

The digital technologies currently in use for the virtual representation of archaeological sites, and architectural artefacts offer researchers and scholars a wider range of possibilities than a few decades ago. The rapid evolution of ICT applied to the Cultural Heritage field has greatly advantaged the archaeological interpretation process; the latter, thanks to the development of three-dimensional acquisition, analysis, and visualization methodologies, is now able to extract previously unthinkable information and advance reconstructive hypotheses for landscapes, sites, and artefacts. Simultaneously, in the architectural domain, ICTs have made clear the interpretation process by integrating data resulting from the field survey with those relating to the state of surface degradation, finally making them readable directly on the virtual models, thanks to accurate ontologies. This has made it possible to create virtual restoration and simulations or, when possible, three-dimensional reconstructions based on analytical interpretation obtained by crossing the documentary sources with the material evidence that can be read directly on the artefacts.

Within this framework, archaeology, architecture, and conservation have often operated independently by referring to their theoretical background, operational needs, and fields of application. Although with extensive cross-contamination, each discipline has adapted or developed its methodologies, processes, and terminologies based on its own operational needs and aims.

According to scientific literature, Digital (or Virtual) Restoration (DR) consists in applying digital techniques in the field of restoration. Given that, DR is limited to the digital domain without any intervention on the physical artefacts. This definition is rather fuzzy, vague and it is used with different connotations according to the contexts and field of applications (architecture, sculpture, artworks, paintings, etc). Some of the most widespread meanings in academia are presented below.

DR can be intended as a digital intervention to simulate the result of physical restoration. Most often this is a digital reassembling or anastylosis where digitised fragments of artworks are digitally manipulated to find matches. In this case, digital restoration tools allow restorers to perform actions, in a virtual environment, that would be difficult or impossible to do in a physical context. Indeed, in many cases, the size or weight of fragments or their fragility limits the possibility of physical

intervention. An example is the case of the restoration of Madonna di Pietranico (L'Aquila, Italy). An earthquake struck L'Aquila in 2009, damaged the city and the terracotta masterpiece was destroyed. The recomposition of the fragments was assisted by computer simulation: after complete digitisation of the fragile fragments, the researchers analyzed the matches among the fragments in a virtual environment, preventing damages, and allowing to simulate different reassembly alternatives.

In other cases, the term refers to digital actions to support the physical restoration, such as the recreation of missing parts of a broken artefact using automatic algorithms or manual photo retouching and 3D modelling techniques. An example is the case of the ancient funerary busts, dated between the 2nd and the 3rd century A.D., rescued from Palmyra (Syria). Firstly, the researchers designed the missing portions using 3D modelling and subsequently printed them using synthetic nylon powder and rapid prototyping technologies.

DR is also used to describe the digital rehabilitation of lost heritage, destroyed by natural or human-caused catastrophic events, in its former state of preservation and beauty. The recent cases of destruction of cultural heritage caused by war, as in the case of the ancient city of Palmyra (2016) and the Buddha of Bamiyan in Afghanistan (2011), or by accidental events, as in the case of the fire which caused severe damage to the Notre Dame cathedral (2019), has led international communities to an unprecedented need for digital preservation through projects of virtual restoration. In the first two cases, physical restoration is not always possible and the only way to restore these sites to their former beauty and make them accessible is only through 3D modelling and virtual reality technologies.

In some areas, like music, photography, or cinematography—related to visual or acoustic assets—DR is, de facto, the only restoration possible especially when the matter of the work of art cannot be restored or when the restoration to the tangible support (films, vinyl records) is limited. For instance, in film restoration, there are procedures of colour correction for recovering and enhancing the detail, look, and tone of the films that can be done only on the digital copies without endangering the original materials. When the restoration was performed only on analogue films, the operations were limited by the state of conservation of the product, but nowadays, this kind of digital procedure makes it possible to scan, edit and reconstruct images for which the advanced level of degradation precludes any physical interventions.

Finally, DR is also defined as the process used to reconstruct the unity of style or, in other words, the hypothetical original aspect of an artefact. The main goal of this digital edition is to provide an undisturbed reading of the whole artefacts in its integrity and improve better legibility for interpretation and dissemination purposes.

DR is then used to remove alteration from the digital copy of a painting and bridge the gaps in a mimetic way gathering the missing information from analogous elements present on the surface of the artwork. This stylistic restoration is carried on many fields, from paintings and mosaics restoration to written work and sculpture, especially when the gaps are small and easy to fill through unassailable evidence. When the evidence is not enough to complete the reconstruction, then "traditional" approaches from the physical restoration are commonly used to complete the work (neutral retouching, chromatic dampening, etc).

A complete stylistic restoration of large gaps, on the other hand, can be carried out under certain conditions. However, in this case, we are dealing with Virtual Reconstruction (VRC) rather than restoration. According to literature, stylistic restoration is sometimes used as synonymous with virtual reconstruction, especially in the field of historical architecture and building archaeology where the artefactsts are often preserved as ruins. Both terms refer to processes of simulation of the past aimed at restoring the unity of style of an artefact, however, in VRC the concepts of "hypothesis" and "conjecture" play an important role and specific precautions must be evaluated to ensure the reliability and consistency of the work.

According to the Principles of Seville, VRC is a digital process that uses "a virtual model to visually recover a building or object made by humans at a given moment in the past from available physical evidence of these buildings or objects, scientifically reasonable comparative inferences, and in general, all studies carried out by archaeologists and other experts in relation to archaeological and historical science". Given that, when the gaps exceed what is preserved and the evidence is not sufficient to complete the reconstructive model and guarantee the legibility of the artefact, it is necessary to push the critical hypothesis beyond the context and rely on sources and comparisons.

The most criticized issue regarding VRC stands on authenticity. Advantages and drawbacks of the simulation models of the past have been widely discussed in academia, leading to the development of guidelines and best practices, particularly for what concerns the issues related to the philologic study, authenticity, and scientific transparency which are the fundamental background to guarantee the reliability of the work and avoid arbitrary interpretations and reconstructions. Especially in the field of archaeology and ancient architecture, the debates have led to the creation of international documents such as the London Charter and the Principles of Seville.

As noted above, the case studies presented within this volume cover a variety of chronological contexts with methodologies specific to archaeology, architecture, and conservation. Thus, there are some elements that unify the various approaches. In almost all cases the authors present, albeit sometimes in a sketchy way, the use of the reconstructive model for valorization purposes. It is worth noting that the first wave of virtual reconstructions in the 1990s and 2000s was strongly aimed at a visualization for enhancement while in the last decade, thanks to increased methodological awareness, the visualization approach is becoming more widespread to increase scientific understanding of the cultural context. Given this premise, the addition of a valorization step, even where it is merely a sketch or a forecast of future development, seems to indicate a still-living link between reconstruction and valorization. This link, although on the one hand, it remains legitimate for the natural development of project analysis and synthesis, on the other hand, it seems to demonstrate a widespread expectation of the public (including the "academic" public) towards "compulsory" reuse of reconstruction for valorization and educational purposes. This, in our opinion, can be seen as a sign of not complete autonomy of the scientific reconstructive process from the needs of musealization and valorization, which, although absolutely legitimate and important, represent only a part of the purposes of the reconstructive process and should not be considered "obligatory" within the

study project. In other words, virtual reconstruction is still struggling to be distinguished from valorization, probably because it is still not fully considered an integral part of the analytical and study aspect of the monument or archaeological context.

Given this premise, in this volume, we would like to focus on the current application of virtual restoration and reconstruction in different Cultural Heritage domains by comparing and discussing several case studies. The book can provide a representative state of the art for archaeologists, architects, restorers and experts in the representation, enhancement and protection of cultural heritage.

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Contents

Virtual Reconstructions

Interpreting and Visualizing the Past Through Virtual Archaeology: From Site to Museum Experience 3
Daniele Ferdani, Emanuel Demetrescu, and Marco Cavalieri

"Sources of Research" for the Virtual Reconstruction of Ancient Monuments: The Case of Architectural Models 19
Massimo Limoncelli

The Virtual Reconstruction of the *Cine-teatro Olympia* in Catania for the Documentation and Memory of Places 39
Carmela Rizzo, Mariateresa Galizia, and Cettina Santagati

From Design to Construction: Digital Reconstruction of the Convent's Kitchen Area in the Monastery of El Escorial 57
Pilar Chías, Tomás Abad, and Lucas Fernández-Trapa

De RE Virtual RES. The Virtual Reconstruction of Rocca Janula in Cassino for a Meaningful "Reading" of the Historical Stratification 73
Assunta Pelliccio, Marco Saccucci, and Virginia Miele

Digital Heritage: Before, During and After COVID-19: The Aurelian Walls as a Case Study 85
Marco Canciani

The "Amiternum Project" on Archaeological Site Valorisation 105
Stefano Brusaporci, Alfonso Forgione, Fabio Graziosi, Fabio Franchi, Silvia Mantini, Pamela Maiezza, Alessandra Tata, and Luca Vespasiano

Castellaccio of Monreale: From the Survey to the Visualisation of Virtual Reconstructions 117
Vincenza Garofalo, Enrico Lepre, and Cristian Antonino Mancino

Images of the Disappeared Puerta Real in Seville 131
Antonio Gámiz-Gordo and Pedro Barrero-Ortega

Digital Reconstruction for the Analysis of Conservation State: The Transmission of Historical Memory of St. George and the Dragon Tile in San Michele Basilica Facade 151
Elisabetta Doria, Hangjun Fu, and Francesca Picchio

Architecture and Archeology. Virtual Reconstruction of Ipi's Tomb TT315 in Deir-el-Bahari, Theban, Egypt 169
Ernesto Echeverria Valiente, Flavio Celis D'Amico, and Fernando da Casa Martín

Diachronic 3D Reconstruction of a Roman Bridge: A Multidisciplinary Approach 185
Germano Germanó

Digital Restoration

Multidisciplinary Approach for the Knowledge of Historical Built: Digital Tools for the Virtual Restoration 205
Adriana Marra, Ilaria Trizio, and Francesca Savini

Virtual Restoration and Persuasive Storytelling for a Virtual Visit to Palazzo Rosso, Genoa 225
Francesco Gabellone

Methodological Practice for the Physical and Virtual Reconstruction of "Absent" Museum Goods: Hypotheses for Their Protection, Valorization and Inclusive Dissemination 237
Rita Valenti, Fernanda Cantone, and Emanuela Paternò

Structural Investigation on 3D Reality Based Models for Cultural Heritage Conservation and Virtual Restoration 253
Sara Gonizzi Barsanti

Digital Enjoyment and Virtual Musification

Roman Theatre Experience the Making of Digital Reconstruction 275
G. Amoruso and C. Carioni

Archaeology of the Present: Knowledge as a Strategy for Claiming the Value of Contemporary Authorial Architecture 299
Paolo Belardi and Valeria Menchetelli

Visual Journalism Applications: 3D Modeling for Cultural Heritage Sites Visualization 321
Amedeo Ganciu, Marta Pileri, Andrea Sias, and Michele Valentino