

Data Modelling in Architecture: Digital Architectural Representations

Original

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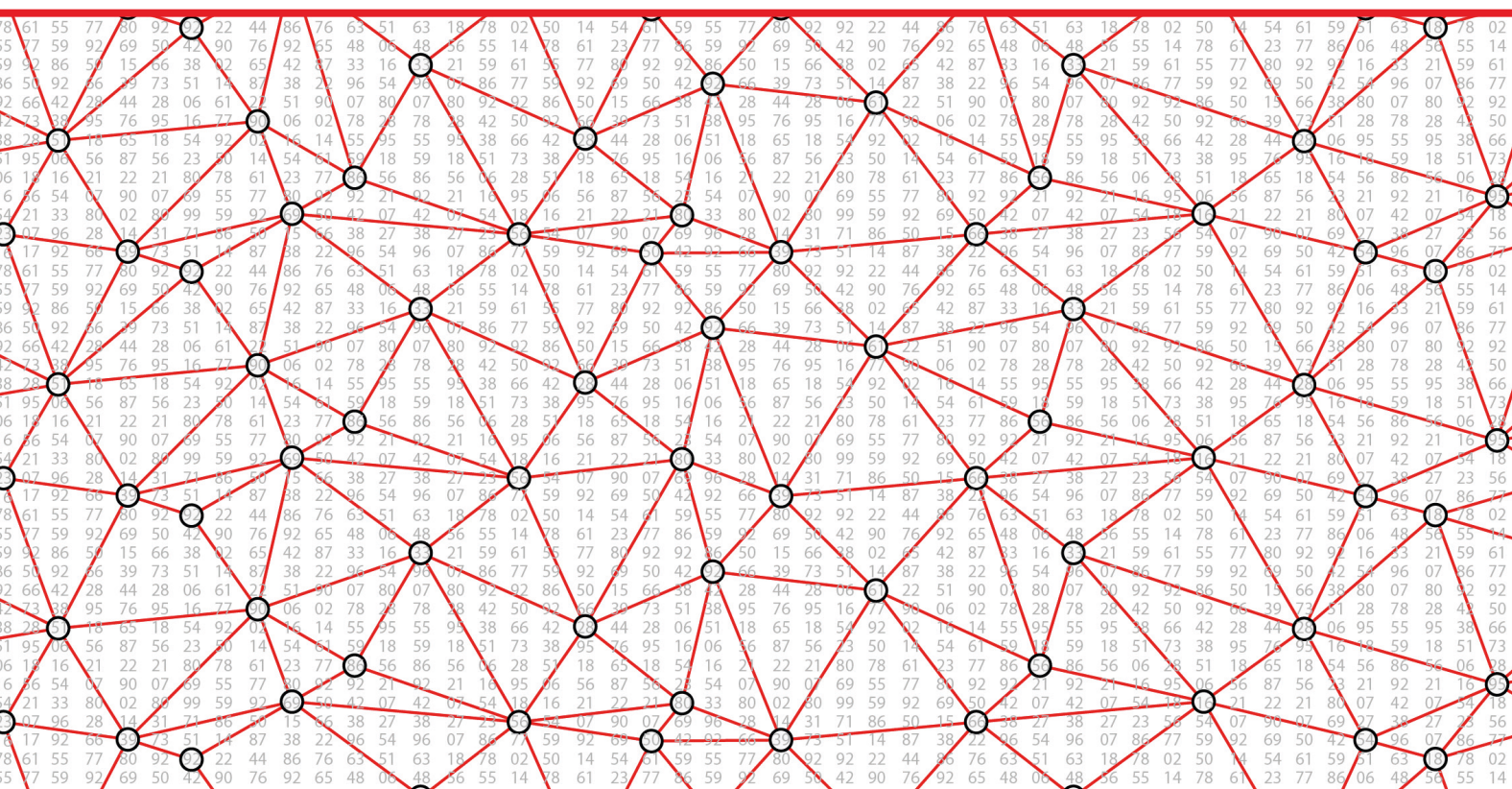
Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain

edited by

Andrea Giordano

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7

Francesca Fatta
Preface

9

Andrea Giordano, Michele Russo, Roberta Spallone
Representation Challenges: The Reasons of the Research

AR&AI theoretical concepts

23

Francesco Bergamo
The Role of Drawing in Data Analysis and Data Representation

29

Giorgio Buratti, Sara Conte, Michela Rossi
Artificial Intelligency, Big Data and Cultural Heritage

35

Marco Ferrari, Lodovica Valetti
Virtual Tours and Representations of Cultural Heritage: Ethical Issues

41

Claudio Marchese, Antonino Nastasi
The Magnificent AI & AR Combinations: Limits? Gorgeous Imperfections!

47

Valerio Palma
Data, Models and Computer Vision: Three Hands—on Projects

53

Alberto Sdegno
Drawing Automata

59

Marco Vitali, Giulia Bertola, Fabrizio Natta, Francesca Ronco
AI+AR: Cultural Heritage, Museum Institutions, Plastic Models and Prototyping. A State of Art

AR&AI virtual reconstruction

67

Alessio Bortot
Physical and Digital Pop—Ups. An AR Application in the Treatises on Stereotomy

73

Maurizio Marco Bocconcino, Mariapaola Vozzola
The Value of a Dynamic Memory: from Heritage Conservation in Turin

79

Antonio Calandriello
Augmented Reality and the Enhancement of Cultural Heritage: the Case of Palazzo Mocenigo in Padua

85

Cristina C ndita, Andrea Quartara, Alessandro Meloni
The Appearance of Keplerian Polyhedra in an Illusory Architecture

91

Maria Grazia Gianci, Daniele Calisi, Sara Colaceci, Francesca Paola Mondelli
Digital Tools at the Service of Public Administrations

97

Riccardo Florio, Raffaele Catuogno, Teresa Della Corte, Veronica Marino
Studies for the Virtual Reconstruction of the Terme del Foro of Cumae

103

Maurizio Perticarini, Chiara Callegaro
Making the Invisible Visible: Virtual/Interactive Itineraries in Roman Padua

AR&AI heritage routes

111

Marinella Arena, Gianluca Lax
Saint Nicholas of Myra. Cataloguing, Identification, and Recognition Through AI

117

Stefano Brusaporci, Pamela Maiezza, Alessandra Tata, Fabio Graziosi, Fabio Franchi
Prosthetic Visualizations for a Smart Heritage

123

Gerardo Maria Cennamo
Advanced Practices of Augmented Reality: the Open Air Museum Systems for the Valorisation and Dissemination of Cultural Heritage

129

Serena Fumero, Benedetta Frezzotti
The Use of AR Illustration in the Promotion of Heritage Sites

135

Alessandro Luigini, Stefano Brusaporci, Alessandro Basso, Pamela Maiezza
The Sanctuary BVMA in Pescara: AR Fruition of the Pre—Conciliar Layout

141

Alessandra Pagliano, Greta Attadema, Anna Lisa Pecora
Phygitalarcheology for the Phlegraean Fields

147

Andrea Rolando, Domenico D'Uva, Alessandro Scandiffio
A Technique to Measure the Spatial Quality of Slow Routes in Fragile Territories Using Image Segmentation

153

Giorgio Verdiani, Ylenia Ricci, Andrea Pasquali, St phane Giraudeau
When the Real Really Means: VR and AR Experiences in Real Environments

159

Ornella Zerlenga, Vincenzo Cirillo, Massimiliano Masullo, Aniello Pascale, Luigi Maffei
Drawing, Visualization and Augmented Reality of the 1791 Celebration in Naples

AR&AI classification and 3D analysis

167

Marco Giorgio Bevilacqua, Anthony Fedeli, Federico Caprioli, Antonella Gioli, Cosimo Monteleone, Andrea Piemonte
Immersive Technologies for the Museum of the Charterhouse of Calci

173

Massimiliano Campi, Valeria Cera, Francesco Cutugno, Antonella di Luggo, Domenico Iovane, Antonio Origlia
CHROME Project: Representation and Survey for AI Development

179

Paolo Clini, Roberto Pierdicca, Ramona Quattrini, Emanuele Frontoni, Romina Nespeca
Deep Learning for Point Clouds Classification in the Ducal Palace at Urbino

185

Pierpaolo D'Agostino, Federico Minelli
Automated Modelling of Masonry Walls: a ML and AR Approach

191

Elisabetta Caterina Giovannini
Data Modelling in Architecture: Digital Architectural Representations

197

Marco Limongiello, Lucas Matias Gujski

Image-Based Modelling Restitution: Pipeline for Accuracy Optimisation

203

Federica Maietti, Marco Medici, Ernesto Iadanza

From AI to H-BIM: New Interpretative Scenarios in Data Processing

209

Michele Russo, Eleonora Grilli, Fabio Remondino, Simone Teruggi, Francesco Fassi

Machine Learning for Cultural Heritage Classification

215

Andrea Tomalini, Edoardo Pristeri, Letizia Bergamasco

Photogrammetric Survey for a Fast Construction of Synthetic Dataset

AR&AI urban enhancement

223

Giuseppe Amoruso, Polina Mironenko, Valentina Demarchi

Rebuilding Amatrice. Representation, Experience and Digital Artifice

229

Paolo Belardi, Valeria Menchetelli, Giovanna Ramaccini, Margherita Maria Ristori,

Camilla Sorignani

AR+AI = Augmented (Retail + Identity) for Historical Retail Heritage

235

Fabio Bianconi, Marco Filippucci, Marco Seccaroni

New Interpretative Models for the Study of Urban Space

241

Marco Canciani, Giovanna Spadafora, Mauro Saccone, Antonio Camassa

Augmented Reality as a Research Tool, for the Knowledge and Enhancement of Cultural Heritage

247

Alessandra Pagliano

Augmenting Anghi: Murals in AR for Urban Regeneration and Historical Memory

253

Caterina Palestini, Alessandro Basso

Evolutionary Time Lines, Hypothesis of an AI+AR-Based Virtual Museum

259

Daniele Rossi, Federico O. Oppedisano

Marche in Tavola. Augmented Board Game for Enogastronomic Promotion

AR&AI museum heritage

267

Massimo Barilla, Daniele Colistra

An Immersive Room Between Scylla and Charybdis

273

Francesco Borella, Isabella Friso, Ludovica Galeazzo, Cosimo Monteleone, Elena Svaldiz

New Cultural Interfaces on the Gallerie dell'Accademia in Venice

279

Laura Carlevaris, Marco Fasolo, Flavia Camagni

Wood Inlays and AR: Considerations Regarding Perspective

285

Giuseppe D'Acunto

Augmented Reality and Museum Exhibition. The Case of the Tribuna of Palazzo Grimani in Venice

291

Giuseppe Di Gregorio

The Rock Church of San Micidiano of the Pantalica Site and 3DLAB VR/AR-Project

297

Elena Ippoliti

Understanding to Enhance, Between the Technical and Humanist Approaches

303

Gabriella Liva, Massimiliano Ciammaichella

Illusory Scene and Immersive Space in Tintoretto's Theatre

309

Franco Prampolini, Dina Porpiglia, Antonio Gambino

Medma Touch, Feel, Think: Survey, Catalog and Sensory Limitations

315

Paola Puma, Giuseppe Nicastro

The Emotion Detection Tools in the Museum Education EmoDeM Project

321

Leopoldo Repola, Nicola Scotto di Carlo, Andrea Maioli, Matteo Martignoni

MareXperience. AI/AR for the Recognition and Enhancement of Reality

AR&AI building information modeling and monitoring

329

Vincenzo Bagnolo, Raffaele Argiolas, Nicola Paba

Communicating Architecture. An AR Application in Scan-to-BIM Processes

335

Marcello Balzani, Fabiana Raco, Manlio Montuori

Integrated Technologies for Smart Buildings and PREdictive Maintenance

341

Fabrizio Banfi

Extended Reality (XR) and Cloud-Based BIM Platform Development

347

Carlo Biagini, Ylenia Ricci, Irene Villorosi

H-Bim to Virtual Reality: a New Tool for Historical Heritage

353

Fabio Bianconi, Marco Filippucci, Giulia Pelliccia

Experimental Value of Representative Models in Wooden Constructions

359

Devid Campagnolo, Paolo Borin

Automatic Recognition Through Deep Learning of Standard Forms in Executive Projects

365

Matteo Del Giudice, Daniela De Luca, Anna Osello

Interactive Information Models and Augmented Reality in the Digital Age

371

Marco Filippucci, Fabio Bianconi, Michela Meschini

Survey and BIM for Energy Upgrading. Two Case Study

377

Raissa Garozzo

A Proposal for Masonry Bridge Health Assessment Using AI and Semantics

383

Federico Mario La Russa

AI for AEC: Open Data and VPL Approach for Urban Seismic Vulnerability

389

Assunta Pelliccio, Marco Saccucci

V.A.I. Reality. A Holistic Approach for Industrial Heritage Enhancement

AR&AI education and shape representation

397

Maria Linda Falcidieno, Maria Elisabetta Ruggiero, Ruggero Torti

Visual Languages: On-Board Communication as a Perception of Customer caring

403

Emanuela Lanzara, Mara Capone

Genetic Algorithms for Polycentric Curves Interpretation

409

Anna Lisa Pecora

The Drawn Space for Inclusion and Communicating Space

415

Marta Salvatore, Leonardo Baglioni, Graziano Mario Valenti, Alessandro Martinelli

Forms in Space. AR Experiences for Geometries of Architectural Form

421

Roberta Spallone, Valerio Palma

AR&AI in the Didactics of the Representation Disciplines

427

Alberto Tono, Meher Shashwat Nigam, Stasya Fedorova, Amirhossein Ahmadian,

Cecilia Bolognesi

Limitations and Review of Geometric Deep Learning Algorithms for Monocular 3D Reconstruction in Architecture

Data Modelling in Architecture: Digital Architectural Representations

Elisabetta Caterina Giovannini

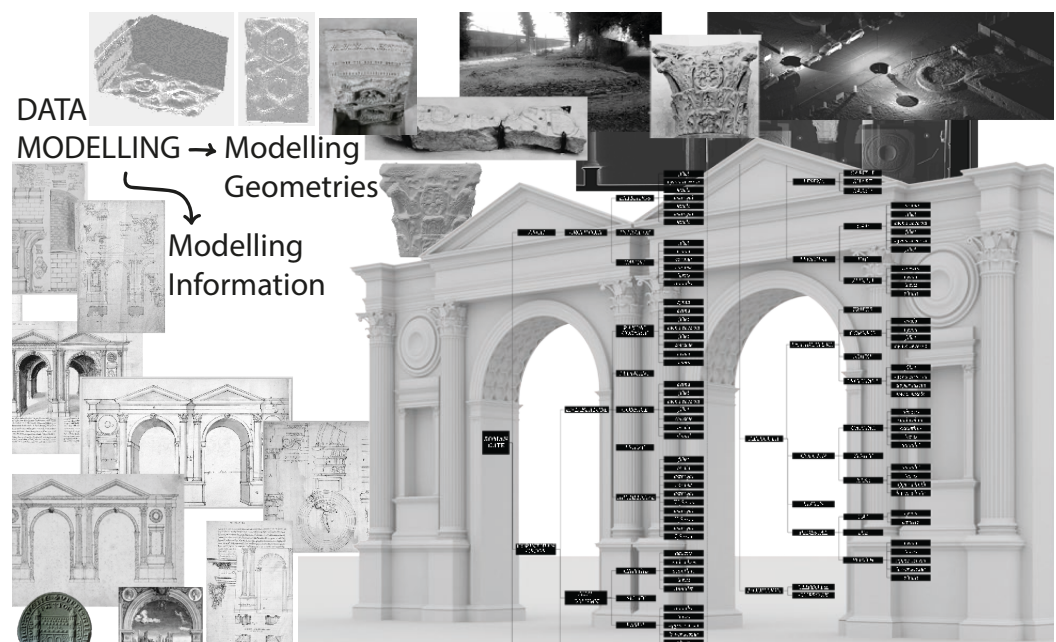
Abstract

Digital Architectural Representations represent the most fruitful field of research of the last decade. Digital technologies and the use of internet in architectural representation shows how 3D visualization combined with storytelling can help to spread scientific knowledge over the web. These new technologies also affect the way of thinking 3D models, how to design them and how to build their related knowledge with the purpose of future reuse of information and data.

The paper is focused on the analysis of current methodologies and workflows for data modelling in Architecture to better understand the potential of using standards in the 3D modelling sector with a focus on cultural and architectural heritage.

Keywords

3D models, semantics, data models, standards, ontologies.



The Complexity of Digital Architectural Representations

Since the '90s of the last century, with the advent of computers, information technologies and computer-aided design (CAD) systems have seen the beginning of the use of digital models in archaeology and architecture [Boccon-Gibod, Golvin 1990; Frischer 2006; Reilly 1991]. The use of these three-dimensional models, which I like to define as digital representations of architecture, poses nowadays, unlike in the past, some questions about the meaning and the scientific value [Borra 2004; Borghini, Cariani 2011; Dell'Unto et al. 2013] that they assume for diverse target audiences.

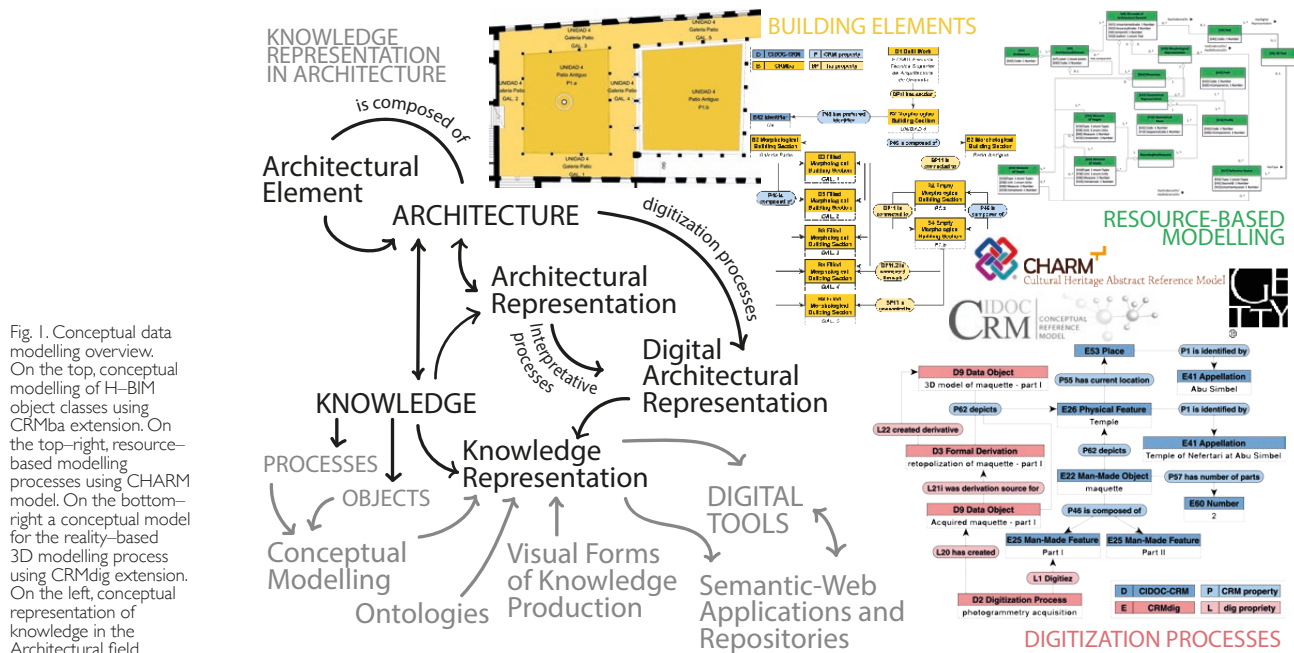
In the field of architectural heritage and more specifically in the field of virtual reconstructions, starting from historical documentation, it seems evident that alongside geometric modelling, the presence of diverse data and documents prefigure the need for the definition of an informative model that should assist the geometric modelling and that should make explicit the series of processes related to the critical interpretation of data and information available [McCurdy 2010; Apollonio, Giovannini 2015; Brunke 2017]. Different interpretative and cognitive processes can be considered similar to algorithms "a procedure used to return a solution to a question through a set of well-defined instructions" [Tedeschi, Andreani 2014]. The difference from the mathematical algorithm definition is that, in this case, the set of instructions are generally not stated and that the interpretative algorithm can generate several outputs (diverse hypothetical reconstructions) starting from the same series of input (knowledge available).

A Three-dimensional model became then, a digital architectural representation of the n digital representations that can be generated by human processes of interpretation. Analyzing the type of input of the three-dimensional reconstruction process, we can see how these interpretative processes are linked to the qualitative and quantitative values of the available documentation. This type of data and information support both geometric and informative modelling, considered as two indivisible and inter-related components of the same process. An example of that is the common practice of using the semantic architectural structure to digitally create the parts of a 3D model according to logics proper of the architectural field and to use digital architectural elements as reference objects to connect additional information [De Luca 2013; Giovannini 2017; Quattrini, Battini, Mammoli 2018]. A digital architectural representation can be, then, considered as a visual and graphical expression of an interpretative activity and a constitutive element of knowledge production. This assumption is valid not only for 3D models but also for all human objects of production that can be manuscripts, sketches, drawings, maquettes, etc. These pre-existing data can then be used for information modelling and three-dimensional modelling enriching diverse Levels of Knowledge (LoK).

Knowledge Representation in Architecture

Applications of Artificial Intelligence (AI) to Cultural Heritage (CH) have been developed with a varying fortune to produce innovative tools for documenting, managing, and visiting cultural heritage. From the representation of cultural history, digital semantic archives, tools to support visitor's interpretation, augmented reality and robotics, the application of AI has been applied to the whole humanistic area. In the Architectural Heritage field, AI is commonly used for storytelling, restoration analysis and 3D model classification. AI is also used to develop ontologies [1] to allow computers to perform automated reasoning about data and information all over the world. Software Engineering, on the other hand, started to use conceptual modelling as a representation of a system to describe concepts. Tools for designing and creation of online visualization of data, according to the rules that govern the web in the past, and more recently the semantic-web cannot avoid the use of Information modelling to manage and structure data and information. In the case of digital architectural representations, the text analysis and the source where architecture is represented in a bi-dimensional way are enriched by three-dimensional information derived from the digital acquisition or three-dimensional modelling. The recent need

for interoperable processes that characterize most of the research on documentation and representation of architectural heritage has emphasized the occurrence of various approaches. Some studies analyze conceptual modelling to define and reorganize the information and material available for the comprehensive use of a digital asset. The theme of processes in digital modelling is useful to trace choices, decisions on three-dimensional models using visualization codes [De Kramer 2020; Giovannini 2020; Apollonio, Gaiani, Sun 2013]. Declaring the accuracy or reliability of 3D models [Apollonio et al. 2017; Bianchini, Nicastro 2018] including those obtained using tools and algorithms (for example in the case of digital survey or photogrammetric acquisition) is a practice mostly used in approaches for geomatics and Building Information Modelling applied to Heritage (H-BIM) [Maiezza 2019; Garagnani 2013; Quattrini, Pierdicca, Morbidoni 2017]. Resource-based 3D modelling considered as interpretative process, differs from digital acquisition where reality-based data can be considered as formal derivation of the original object. Both modelling processes are in relation since the 3D reality-based data, if present, affects the modelling and validation process of the derived resource-based model. Standards and models for information modelling including conceptual ones have long been in use in the cultural heritage sector: the CIDOC Conceptual Reference Model (CRM) standard [2], the ISO 21127:2014 also known as CIDOC-CRM, often associated with the controlled vocabulary of the Getty Institute (AAT) [3], is the most used ones. Recent trends demonstrate that ontologies and conceptual models are not that different,



and that combined can allow standardising the documentation of cultural heritage. In the archaeological field the Cultural Heritage Abstract Reference Model (CHARM) [4] is an ontology for cultural heritage expressed in Conceptual Modelling Language (ConML) [Gonzalez-Perez et al. 2012]. The Extended Matrix (EM) [5] is a visual language of knowledge representation in the field of virtual reconstructions with a stratigraphic approach [Demetrescu 2015]. In the architecture, engineering and construction (AEC) industry, the reference standard is the Industry Foundation Classes (IFC) data model [6], a metadata schema capable of describing architectural semantics and making Building Information Modelling (BIM) models interoperable between different software solutions. The IFC guarantees the management of geometry but it does not allow the addition of customized information outside the context of the construction industry. Nevertheless, some emerging research proposes an IFC classification for architectural heritage asset

[Diara, Rinaudo 2020] or an architectural heritage semantic 3D documentation for the reusability of 3D city models [Noardo 2018]. To establish a dialogue between the architectural field and the cultural heritage assets a recent study proposes a conceptual model based on the CIDOC–CRM standard to describe a building in its parts, as encoded by a BIM software using the CIDOC–CRMba extension [7], developed to describe built archaeology [Parisi, Lo Turco, Giovannini 2019]. With that model, it was possible to describe the morphological elements that characterize a building but it fails in describing the link between the geometric parts and their spatial coordinates. The conclusion was partially acceptable if we think that the CIDOC–CRM was born to describe assets about museum collections and not about architecture.

Conclusions

Considering the diverse research conducted, the possibility of creating conceptual models capable of managing three-dimensional data and descriptive metadata on the documentation of architectural heritage is still missing. The CRM–dig [8], a CIDOC–CRM extension, is a model capable to manage the complexity of the reality-based data acquisition, but it does not clarify and explain the relationships between the source used, the data extracted from it and its use for geometrical modelling. The IFC, on the other hand, can be used to describe geometric information of BIM or H–BIM models. The challenge is to create an efficient data model that allows semantic traceability of data. A novel semantic organization of data is necessary for the development, of platforms, analysis tools and algorithms able to manage structured data, make queries for different purposes in complementary disciplinary domains emphasising their combined potential. There is a need for a common conceptual model that reflects the complexity of the three-dimensional modelling process. Conceptual modelling should focus on the representation of architecture in all its forms (drawings, surveys, digital models) and should represent both digital and physical properties. A conceptual reference model for the digital representation of architecture (fig. 1) should first identify the architectural evidence, built, or only represented ones, the parts of which it can be composed and how these can be digitally represented. The knowledge about an architectural asset is also composed of a set of resources that also need to be digitized and that contribute to the creation of the “architectural” digital asset. Then the relationship between digitized resources and three-dimensional modelling can take place by mapping diverse interpretative and modelling processes creating different levels of knowledge. The knowledge produced, can then be used by digital tools able to read the conceptual grammar of the asset: an information system in which three-dimensional models and historical documentation is collected and organized. To reuse data, data models are necessary and even if they do not follow standards, they must at least be stated because this is how computational technologies and machine can see the human world.

Notes

[1] Ontology is the theory and the Information Model is the application. Information modelling is here intended as “a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse. The advantage of using an information model is that it can provide sharable, stable, and organized structure of information requirements for the domain context.” [Lee 1999]

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