Chapter 13
Impact of Industry 4.0 in Architecture and Cultural Heritage:
Artificial Intelligence and Semantic Web Technologies to Empower Interoperability and Data Usage

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ABSTRACT

Building Information Modelling (BIM) is recognized as the central mean in the digitalization process of the construction sector affecting both the technological and the organizational levels. The use of information models can empower communication capabilities thus addressing one of the main development directions of industry 4.0. However, several issues can be highlighted in the representation of objects through information models especially in the case of existing and/or historical buildings. This chapter proposes an extensive analysis of the use of BIM for existing assets exploring the recent development in the area of machine learning and in the use of ontologies to overcome the existing issues. It will provide a structured presentation of existing works and of perspectives in the use of ontologies, expert systems, and machine learning application in architecture and cultural heritage focusing on communication and data use in digital environments along the industry 4.0 paradigm.

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INTRODUCTION

The industry 4.0 paradigm born in the manufacturing and is slowly entering in the construction sector producing deep changes in this industry. Product Lifecycle Management (PLM), Internet of Things, Cloud Computing, Big Data, 3D printing, Cyber Physical Systems, Augmented Reality, Virtual Reality, Human Computer Interaction are only some examples of technologies and principles that are highly impacting in the construction industry.

Nevertheless, in general terms, industry 4.0 refers to both the increasing digitalization and automation of the manufacturing environments and the creation of digital value chains to enable communication between products, their environment and business partners (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). Hence, industry 4.0 implies the progressive digitalization of an industrial sector focused on improved automation and communication capabilities, including in these last all the interested parties as well as the products (buildings, infrastructures, etc.). Building Information Modelling (BIM) is recognized as the central mean in the digitalization process of the construction sector affecting both the technological and the organizational levels. The use of information models can empower communication capabilities thus addressing one of the main development directions of industry 4.0. In fact, information models are characterised by the aggregation of both geometrical and non-geometrical information in composing objects (Eastman, Teicholz, Sacks, & Liston, 2011) defined according to a shared semantic structure (Pauwels, Zhang, & Lee, 2017). However, the complexity of the construction products (buildings, infrastructures, etc.) as well as their uniqueness can limit the communication processes due to the difficulties in defining a standard semantic structure able to embrace all these peculiarities. This issue is intensified by the lack of geographical and organisational proximity that characterise the construction supply chain (Dallasega, Rauch, & Linder, 2018). In this context, the concept of interoperability, i.e. the process to exchange and use information between two or more systems (IEEE, 1990) represents a crucial aspect.

Since 1995, the BuildingSmart consortium (formerly known as International Alliance for Interoperability until 2008) is working on the Industry Foundation Classes (IFC), a common data model to represent and describe building processes (Laakso & Kiviniemi, 2012). Nowadays, IFC represents the reference standard to share information models in the construction sector. However, several studies demonstrated its limits and highlighted practical issues in its application in the industry. Moreover, due to the above-mentioned product complexity, the semantic structure defined in IFC models is limited and is not able to comprehend all the elements and all the information required during both the development and the maintenance of a real estate. Some researchers explored the use of expert systems and machine learning technologies applied to IFC models to augment the organisation proximity pushing a standardised communication supported by the machine (Bloch & Sacks, 2018). However, these studies are bounded to the IFC semantic structure and can address the underlined issues only partially.

The difficulties in representing the semantics of buildings is highlighted in the case of existing buildings and in particular with reference to the historical ones. The development of BIM applications in the maintenance of historical buildings has demonstrated an increasing interest in last years (Logothetis, Delinasiou, & Stylianidis, 2015; Megahed, 2015; Volk, Stengel, & Schultmann, 2014). The experimentations developed on the Albergo dei Poveri in Genova (Musso & Franco, 2014), the Basilica of S. Maria di Collemmaggio in l'Acquila (Oreni, Brumana, Cuca, & Gergopoulos, 2013), the Masegra-castle in Sondrio (Barazzetti et al., 2015) and the Dome in Milan (Fassi, Achille, Mandelli, Rechichi, & Parri, 2015) are only some examples. These studies underline the difficulties in the semantic representation of historical elements in building information models. For example, the representation of complex

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