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Review

Historic Building Information Modelling: performance assessment for diagnosis-aided information modelling and management

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ABSTRACT

Building Information Modelling, new paradigm of digital design and management, shows great potential for the refurbishment process, as it represents a possible way out of criticalities that occur in documentation and preservation of existing assets, if connected to cognitive automation. The combination of BIM with automation systems improves the quality control during diagnosis, design and work execution, and the labour savings, which is particularly relevant for rapid intervention in case of hazardous conditions.

Therefore, the paper is going to address a methodological discussion concerning complete "as-built" parametric models of historical buildings, supporting the design of refurbishment and conservation interventions. Although some reviews of the state of the art exist on the topic of Historic Building Information Modelling, the present research introduces a different perspective on HBIM modelling, with diagnosis and performance assessment as key-aspects, in terms of automating performance assessment.

Specifically, from the data collection of contributions regarding HBIM/BIM, diagnostics and monitoring on existing buildings and infrastructures, a critical review by selected criteria is developed. Nevertheless, general methods and tools for information management and exchange tasks in BIM are briefly described as well, since they are considered useful for future developments of HBIM approach. The core of the critical analysis is focused on the scientific and technical relations among HBIM models, diagnosis and performance assessment features. In addition, the review identifies specific activities and relative tools and methods for knowledge acquisition and semantic enrichment.

Finally, gaps in knowledge of the current literature are outlined and discussed, with specific focus on performance assessment in HBIM. In this regard, a new methodology toward Diagnosis-Aided Historic Building Information Modelling and Management (DA-HBIMM) is proposed as a framework to be developed in order to address smart knowledge acquisition, collection and notification of assessed performances and eventual risks, by cognitive automation and artificial intelligence, in the near future.

Acronyms

AEC	Architecture, Engineering and Construction	HVAC	Heating, Ventilation and Air Conditioning
AIA	American Institute of Architects	ICP	Iterative Closest Point
API	Application Programming Interface	IE	Information Exchange
AR	Augmented Reality	IFC	Industry Foundation classes
BACnet	Building Automation and Control networks	IoT	Internet of Things
BAS/BA	Building Automation System	IR	Information Requirements
BCVTB	Building Control Virtual Test Bed	LCA	Life Cycle Assessment
BEMS/ BEM	Building Energy Management Systems	LEED	Leadership in Energy and Environmental Design
BHIMM	Built Heritage Information Modelling and Management	LiDAR	Light Detection and Ranging

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BIM	Building Information Modelling	LoD	Level of Detail
BrIM	Bridge Information Modelling	LOD	Level Of Development
BT	breakage-triggered	LVDT	Linear Variable Displacement Transducer
CAD	Computer Aided-Design	MCDM	Multiple Criteria Decision Making
CH	Cultural Heritage	mesh-OBIM	mesh to BIM objects
CHIM	Cultural Heritage Information Management	MVD	Model View Definition
CMMS	Computerised Maintenance Management System	NoSQL	Not Only SQL
COBie	Construction Operations Building information exchange	NURBS	non-Uniform Rational Basis-Spline
CPS	Cyber Physical Systems	ODBC	Open Database Connectivity
DA-HBI-MM	Diagnosis-Aided Historic Building Information Modelling and Management	pointclouds-OBIM	point clouds to BIM objects
DB	DataBase	RANSAC	RANdom SAmple Consensus
DBMS	DataBase Management System	RFID	Radio Frequency Identification
EDMS	Electronic Document Management System	RGB-D sensors	RGB colours and Depth sensors
FDD	Fault Diagnostic and Detection	RPVs	Remotely Piloted Vehicles
FEM	Finite Elements Model	SCADA	Supervisory Control and Data Acquisition
FM	Facility Management	SfM	Structure for Motion
GBI	Green Building Index	SHM	Structural Health Monitoring
gbXML	Green Building extensible mark-up language	SOA	service-oriented architecture
GPR	Ground Penetrating Radar	SQL	Structured Query Language
GPS	Global Positioning System	TMH	Traditional Malay House
HBIM [1]/ H-BIM	Historic Building Information Modelling	UAVs	Unmanned Aerial Vehicles
HBIM [2]	Heritage Building Information Modelling	VR	Virtual Reality
HBIMM	Historic Building Information Modelling and Management	WSN	Wireless Sensors Networks
HBRP	Housing Building Refurbishment Plan	XML	Extensible Markup Language

1. Introduction

Building Information Modelling, new paradigm of digital design and management, shows great potential for the refurbishment process [1], as it represents a possible way out of criticalities that occur in documentation and preservation of existing assets, especially if connected to cognitive automation. For instance, BIM can be very attractive for the management of the comprehensive and incremental knowledge of the built heritage, fundamental activity for an accurate assessment of the residual building performances to be recovered by refurbishment and retrofit. The approach can also ensure the effective involvement of all the technicians with multidisciplinary skills and the successful information sharing. The integration of BIM with automation systems would positively support the quality control during diagnosis, design and work execution as well as the labour savings.

Therefore, Building Information Modelling can be a guide tool for work and information flows as long as it stands on the concept of integrated digital archive that collects geometric, semantic and topological data, in different formats and contents, within parametric objects [1]. BIM proprietary or customised tools can manage and analyse the multiplicity of variables due to query operations and specific programmed automation algorithms.

The application of BIM in the built heritage was initially identified as Historic Building Information Modelling (HBIM) [2]. However, according to the previous definition, the concept of information management - complementary to the modelling one - is excluded; thus, an evolution has occurred toward the approach of Built Heritage Information Modelling and Management (BHIMM) [3]. Reviews of the state-of-the-art exist on the topic of “Historic Building Information Modelling” for building refurbishment (both in general terms [4], and specifically related to existing buildings [5]). However, some guidelines are still needed to achieve a complete “as-built” model of historical buildings, especially featured with irregular and complex morphology, toward the design of refurbishment and conservation interventions [6].

A critical activity, which the authors are dealing with, is the integration of a variety of information through independent and structured methods. Such information comes from historically archived documentation, analytical investigations, surveys, diagnostics and monitoring and requires continuous updating during performance assessment, design and execution.

BIM tools are software programs (more or less interoperable) and databases that support the organisation and the collection of information, which is disconnected and sometimes unavailable, and reported in separate sources.

Ultimately, the scientific community must invest resources in the development of HBIMM methodology in order to improve its ability to contain both tangible and intangible information inherent to the existing buildings [7].

In this way, the information could be available to all the stakeholders for management of building operation and maintenance throughout the life cycle. Furthermore, real-time updates and notifications of centralised models are expected by installing integrated monitoring systems [8].

In this context, this revision of the state-of-the-art is drawn up for the following purposes: 1) analysing criticalities and potentialities of HBIMM, as emerged in refereed publications; 2) formalising the first attempts of HBIMM application; 3) proposing a methodological flow to be consolidated; 4) suggesting future developments toward a diagnosis-aided HBIMM (DA-HBIMM) within an automation-based framework.

2. Research methodology

The aim of this state of the art is to identify gaps in knowledge and to provide insights for future development on methods and tools of Historic Building Information Modelling for the refurbishment project, toward the automated diagnosis of the residual performances and design of coherent structural reinforcement and energy retrofitting. In addition, relevant issues, investigated within this work, concern knowledge acquisition and management of the diagnosis, with the future perspective of automatic performance assessment within the BIM approach, in order to achieve accurate and precise performance