DIGITAL TWIN DEVELOPMENT OF A HISTORICAL BUILDING

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Effective tools to characterize the structural response under operational conditions are critical to ensure the reliability of structural health monitoring (SHM) systems. The current structural condition as well as relevant historical data have to be taken into account to have an up-to-date representation of the actual physical system in operation. Digital twins can play a primary role in the evaluation of the current condition of the structure and in anomaly detection to support structural maintenance. Building Information Modelling (BIM) is currently showing a potential in this perspective thanks to the possibility of collecting miscellaneous data and information in a unified platform. So, an effective integration between the two is highly desirable. Relevant information coming from SHM systems can be integrated into a BIM model of a structure to make them available for interrogation and further analyses. The development of a digital twin of a historical structure combining SHM data, BIM, and finite element model updating is illustrated pointing out its promising applicative perspectives for structural maintenance.

Keywords: *digital twin, operational modal analysis, building information modelling, model updating*

1. Introduction

SHM is currently recognized as a key technology for structural assessment and maintenance of civil structures [1]. Remote and automated damage detection can take advantage of the integration of SHM with advanced numerical modelling and simulation tools to enhance its capabilities in the interpretation of data [2]. BIM is also increasingly applied in civil engineering because of its potential, recognized by recent codes [3, 4], in enhancing the exchange of information between the technicians involved in the design and con-struction process, and in optimizing construction time and costs. While the potential of BIM for newly built structures is currently well-established, its applicative perspectives in the field of management, maintenance and rehabilitation of existing structures are still under investigated. Taking into account that advanced SHM technologies can effectively support structural maintenance of existing structures and infrastructures, the integration of data and information from advanced SHM systems can further enhance the effectiveness of 6D BIM in the management of structures [5, 6, 7]. The present study focuses the attention on such SHM-BIM integration for the development of the digital twin (DT) of a historical structure, also exploiting the opportunities of model updating to obtain representative structural models in operational conditions.

2. Digital Twin development

The investigated case study is the Tower of the Nations, a historical building located in the area of the Mostra D'Oltremare urban park in Naples, Italy. The reinforced concrete structure is characterized by two blind and two completely see-through parallel façades, with elevator shafts and stairs located in the central part. Most of the levels are characterized by alternate floors, which cover just a half of the imprint area of the building. The structural system is very original because, in spite of consideration of gravity loads only in structural design, it shows several

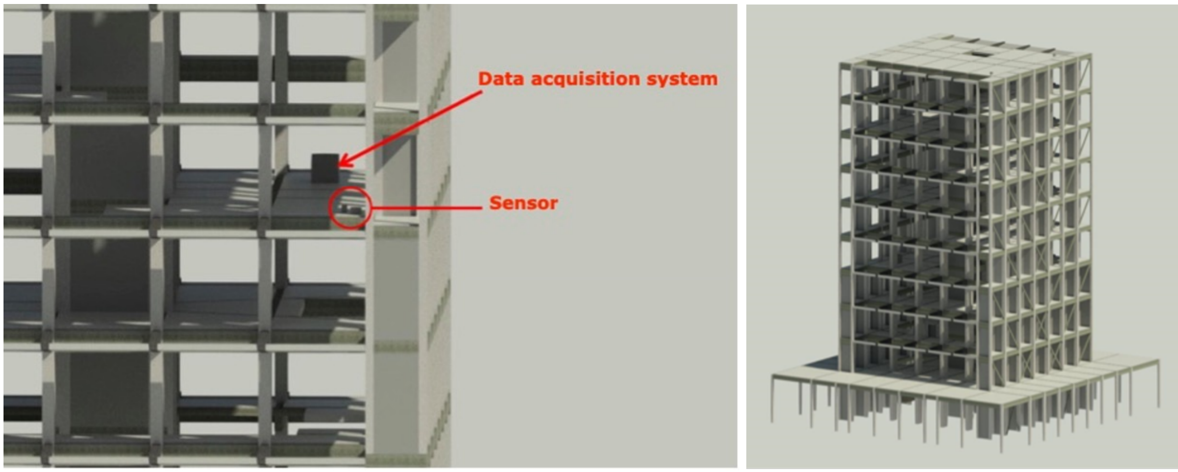

Figure 1: Families created in Revit for sensors and data acquisition system (a), BIM model (b).

elements (walls, braces) able to increase the lateral stiffness of the structure and to provide some capacity against horizontal actions. The mechanical characteristics of materials were obtained from drill cores and non-destructive tests, and the modal properties of the structure by OMA tests [8] have been considered in this application, together with original design drawings and results of geometric and structural surveys, for the development of the BIM model and the DT. For an effective integration between BIM and SHM and to provide the BIM model with some data processing capabilities, the open-source visual programming language Dynamo was used. The first step concerned the creation of new Revit Families allowing the insertion of new information of different nature in the same work environment; specifically, the newly created families contained technical information about the SHM equipment. This operation allows defining the positions of SHM equipment and assessing possible interferences with the ordinary activities. Families for sensors and data acquisition system have been created, and the corresponding elements (Fig. 1a) have been symbolically introduced into the BIM model (Fig. 1b) and coupled with the actual physical devices as described hereafter.

The data are transferred from the SHM system to the BIM model bidirectionally, by creating a direct correspondence between the database of the BIM and that of the SHM system collecting the experimental data. The database of the SHM system for the present application was a relational MySQL database collecting simulated data about the evolution of the natural frequencies of the fundamental modes of the structure over time. To assess

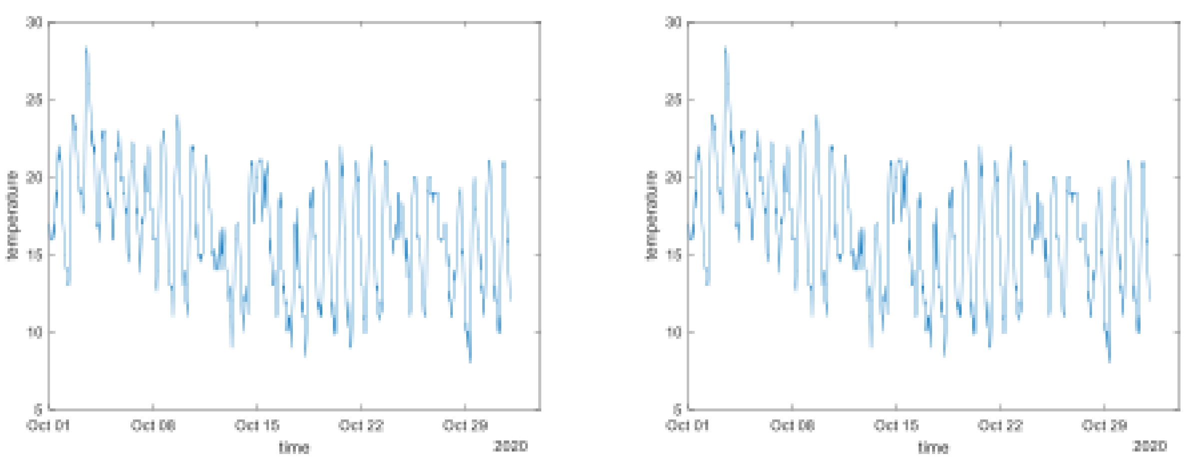

Figure 2: Temperature time series recorded in October 2020 in Naples (a), estimated Young's modulus of concrete by continuous model updating (b).

the effectiveness of the integrated solution for DT developed in the context of the present study, continuous modal parameter monitoring results have been simulated starting from the results of some OMA tests carried out on the structure in the past [9]. The simulated data were representative of the variability of the modal properties with temperature [9] (Fig. 2a). Random noise has been also added to the simulated data to make the time series as much realistic as possible. The opportunity of using SHM data for continuous model updating has been verified afterwards. A DT representative of the structural behavior in operation and able to replicate the structural response under varying environmental conditions was obtained (Fig. 2b).

3. Conclusions

The present study discussed how a DT of a historical structure can be effectively set by taking advantage of the integration of different technologies into a unified environment through the implementation of an appropriate code for continuous model updating based on SHM data. Encouraging results have been obtained in terms of capability of the DT to indirectly follow the evolution of material properties due to environmental effects.

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