Interactive Information Models and Augmented Reality in the Digital Age

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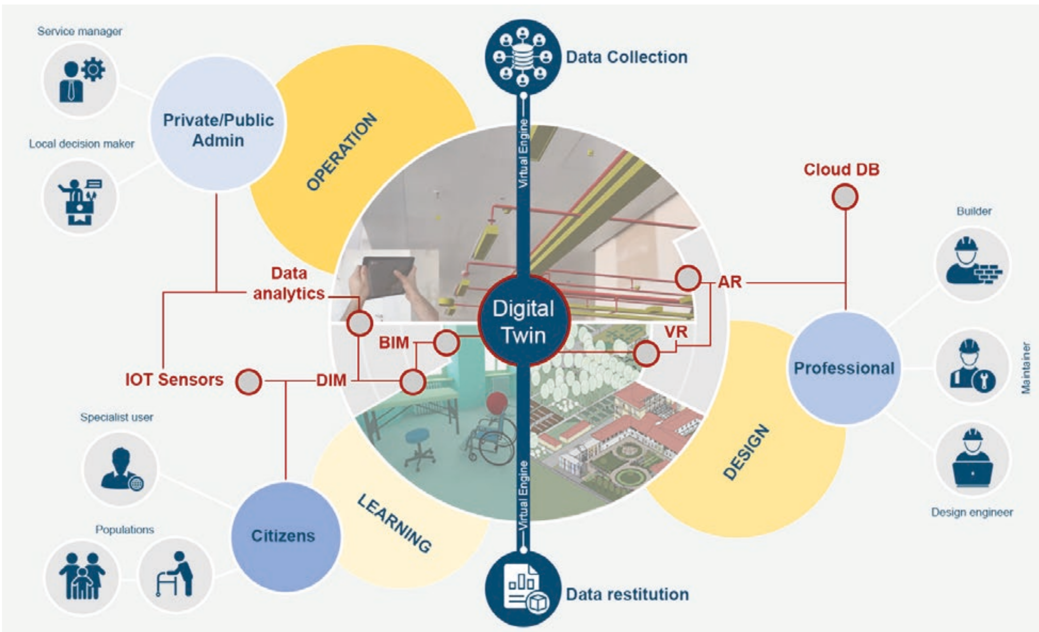
Abstract

The construction industry in the digital era has seen significant changes in design, construction, and spatial process learning through new technological systems. These processes influence management and how data is collected, cataloged, and monitored using sensors and connected users. The real challenge that the digital era imposes on the society of the future is to define new secure and resilient digital models coupled with interoperable methods that minimize the impacts of our built heritage throughout its lifecycle. For these reasons, new models are being investigated to educate, gain detailed knowledge of places, design inclusive spaces that meet users' needs and finally manage and maintain the built heritage. New technologies of Augmented and Virtual Reality support principals and users to define stable and interoperable relational processes. Although the challenge is ambitious, it is essential to find efficient solutions in governance policies for the city's future.

Keywords
augmented and virtual reality, digital twin, construction digital twin, participatory digital model.



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Introduction

In recent years, the spread of innovative tools that increase communication between users has highlighted the adoption of new tools and methods for managing built heritage data.
Within this technological evolution, the building artifact becomes a digital model in which the rapidity of data exchange highlights new awareness and limits expressed within a society in continuous change [Salgues 2018]. Digitization of the construction industry involves the management of various data domains brought into the system to meet the needs of the involved actors. In this sense, Information and Communication Technologies (ICTs) transform citizens' lifestyles in buildings and cities, developing new dynamic characteristics, going beyond the static nature of social relations.
Cities and their systems need solutions that optimize the information that governs the smart society by cataloging the progress highlighted during the digitization process [van Dinh 2020]. This transformation's efficiency is based on a network composed of nodes, real databases, and virtual environments. The new technological borders of information exchange between users and virtual systems are artificial intelligence (AI), Internet of Things (IoT), Machine Learning (ML), Deep Learning (DL), cognitive computing, and big data analytics that define the boundaries beyond which reality is pushed by virtuality [Sharma 2018]. Smart and digital services, Augmented (AR), and Virtual Reality (VR) tools are emerging to facilitate the integration between the physical environment and cyberspace, enabling the adoption of these innovative methods to process, manage, and compute real–world processes [Baheti 2011].
The contribution examines the optimization of the information process through digital models and related virtual interfaces aimed at education, in–depth knowledge of the places, the design of appropriate spaces, and finally, the management and maintenance of the artifact.
The development of these information–rich models and the proper use of enabling technologies to transform parametric digital models into true Digital Twins (DTs) in which data transmission is characterized by information bi–directionality with cyber–physical systems.
Besides, DT's definition can be integrated with the concept of Construction Digital Twin (CDT), as the ability of a system to adapt to complex social flows that regulate the management of the building life cycle [Boje 2020].

Methodology

The ability to develop a digital model capable of relating to the physical environment has to be compared with the need to use graphical interfaces connected to various databases, providing information content to different users. For this reason, the development of a DT, a virtual replica of reality [Grieves 2015], plays a key role in this digital transition phase. The starting point for this action is to identify specific objectives of the information model and their different uses that differ according to the user. Therefore, depending on the user–virtual environment interaction, the adoption of specific technologies based on desktop and mobile applications facilitates the various selected databases' connection.
From a methodological point of view (fig. 1), it is possible to describe the relationship between the involved representation scale involved, the employed strategies, and the adopted tools for developing specific graphical interfaces. Consequently, from selecting the specific field from building to urban scale, various representation strategies can be considered starting from hand–made drawing to informative modeling based on Building Information Modelling (BIM) with different levels of maturity. Moreover, the useful tools can be more or less immersive depending on the type of interaction required. Therefore, the importance of users viewing this information according to their needs is emphasized according to the project's specific purposes. For this contribution, three experiences have been examined (fig. 2) that apply in a multi–disciplinary way what has been described above, starting from the generation of BIM models using the Autodesk Revit platform.
The first selected case study focuses on the Santissima Trinità hospital in Fossano (Cuneo). The hospital complex is located within a historical building of the eighteenth century.

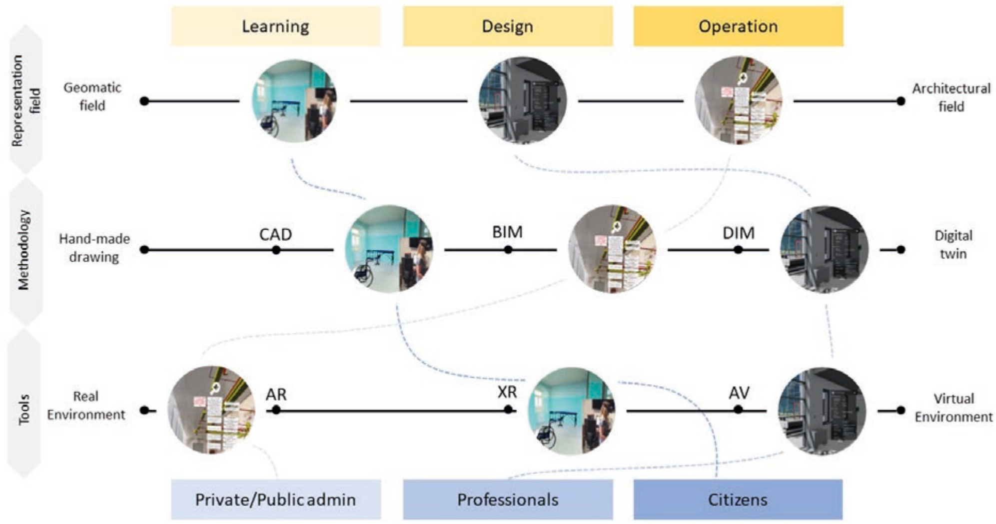

Fig. 1. AR Framework for AEC Industry (authors' elaboration).

Fig. 2. Case Studies selected (authors' elaboration). The images are extracted from the master students thesis listed in the acknowledgements.

The building is a monumental complex characterized by complex architectural elements (i.e., vaults) that have changed over the years. These characteristic elements are digitized to simulate innovative spatial scenarios through the BIM methodology, making comfortable the environments intended for patients' motor rehabilitation through VR technologies. In this case, Unity 3D was selected as the VR platform, while the HTC Vive Head Mounted Display (HMD) was selected as the immersive technology. In particular, two specific areas (e.g., gym, hospital room) have been identified as the basis for the virtual environments. The immersive application has been characterized by aspects related to both the gamification approach and the therapeutic elements.
The second use case selected is the Trompone complex (Moncrivello, VC), which offers several healthcare services to support high complexity patients and relatives. It consists of several buildings, including a nursing home, an assisted healthcare residence (RSA), a convent (part of which is now used as a training center), and the sixteenth–century sanctuary. In this case, the attention is given to designing a small daily center for Alzheimer's patients within the existing complex. Starting from a BIM model, different VR software platforms were investigated to improve the new spaces' design, controlling the possible interferences between the architectural, structural, and systems disciplines. The interaction with the digital model has taken place through two VR tools, Enscape and Autodesk Live. While the first

allows you to navigate within the space even before the projects are done, implementing changes in real–time through HMD devices, the second enables to query the model's components by displaying its alphanumeric properties.
The third case study is the service center of the single headquarters of the Piedmont Region (Turin). It is a five–story above–ground building with a lobby and a nursery on the ground floor. The information management for the operational step of the equipments, has been studied through the development of an AR application for mobile devices, based on the Unity 3D platform integrated with Apple ARKit. In this way, the specialized technician can visualize information useful for the localization and maintenance of plant visible and hidden components by storing and updating data exploiting the links with external databases. The tested methodology acquires various aspects according to the field in which it is applied: as an example, in the construction phase, the operator can verify the reliability of the model by comparing it with the shop drawings.

Results

The different use cases selected for this paper highlighted how the digital evolution imposes different virtual models but also across the growing needs of the interactive user.
In this sense, the connection of the three use cases defines the right procedure for optimal human–building interaction, overcoming interconnected systems' limitations. The results obtained from these experiences allow describing the first image of DT aimed at both the collection and the enrichment of data required for a participatory DT. This definition implements the digital twin features based on physical objects, virtual models, and connections by including user interaction as the fourth main component for its implementation.
A digital model was obtained as a real Construction and participatory DT from the analysis of the real environments (fig. 3). The next step will be implementing AI and ML techniques by using standard and open–source data exchange formats to increase its level of maturity. Unfortunately, to date, many obstacles do not allow for the best integration of different systems and different data sources with real user needs. The applications developed are considered a prototype useful to raise some thoughts about developing a DT.
In the first case, the user interacts with the virtual environment by composing a virtual puzzle and using motion sensors and immersive HMD devices. The advantage the selected technology consists on medical progress monitoring during rehabilitation, learning and memorizing shapes, colors, and positions. Currently, data automation is the real critical issue, which is fixed through web protocols. The second use case highlights the potential of participatory design with BIM through VR platforms to support decision–making.
The most critical issue found concerns the loss of data due to proprietary viewers who have some limitations in returning answers in real–time. The following aspects are evident through the immersive experience: i) understanding of space and relationship with pre–existence; ii) reconstruction of paths and memorization of objects and settings; iii) developing a sensory environment oriented to Alzheimer's patients. The AR application developed with the third case study also highlighted the potentialities of overlaying digital content in the real environment. Currently the model georeferencing with the reality is one of the major criticalities that, in this case, has been solved by inserting a fixed positioning point. About data updating, further developments are required according to the challenge of data–sharing.

Conclusions

The AEC industry is facing a transition phase in which new technologies highlight the current gaps that traditional systems can no longer fill. Using ICTs and Augmented and Virtual Reality systems as tools for participatory design, learning and operations lead to a new vision of working and thinking about the built environment. In this way, the construction industry is educated better to meet human beings' needs and an intelligent city. Through the experience offered by the proposed use cases, the paper evaluates strenghts and weaknesses of the relation between virtual and physical environments world, considering different degrees of immersion. Although the interaction between the digital and physical worlds is not yet optimal, artificial

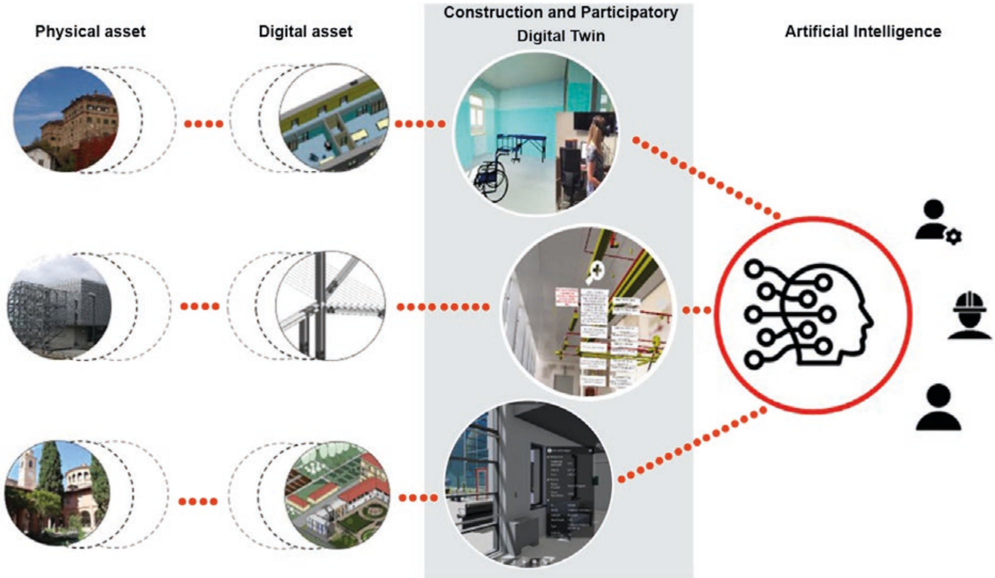

Fig. 3. Construction and Participatory Digital Twin for AEC Industry (authors' elaboration).

intelligence through algorithms and augmented reality may soon facilitate their interaction through collaboration and interoperability. Such complex systems can facilitate relationships between public and private administrators, professionals, and citizens within a new city model defined as augmented building/city. The advantage expressed by models with a high capacity of response and data cataloging is related to representing the urban/architectural model. The transformation of virtual models into construction and participation digital twin allows virtual machines to process traditional forms and properties into future elements.

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References

Baheti Radhakisan, Gill Helen (2011). Cyber–physical systems. In *The impact of control technology*, 12.1, pp. 161-166.

Boje Calin, Guerriero Annie, Kubicki Sylvain, Rezgui Yacine (2020). Towards a semantic Construction Digital Twin: Directions for future research. In *Automation in Construction*, 114, 103179, pp. 1-16.

Grieves Michael (2015). *Digital Twin: Manufacturing Excellence through Virtual Factory Replication.* White Paper.

Salgues Bruno (2018). *Society 5.0: industry of the future, technologies, methods and tools*. London: John Wiley & Sons.

Sharma Pradip Kumar, Park Jong Hyuk (2018). Blockchain based hybrid network architecture for the smart city. In *Future Generation Computer Systems*, 86, 2018, pp. 650-655.

Van Dinh Dzung, Yoon Byeong–Nam, Le Hung Ngoc, Nguyen Uy Quoc, Phan Khoa Dang, Pham Lam Dinh (2020). ICT Enabling Technologies for Smart Cities. In *2020 International Conference on Advanced Communication Technology (ICACT),* pp. 1180-1192.

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