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Dynamic Interactive Models for Built Heritage

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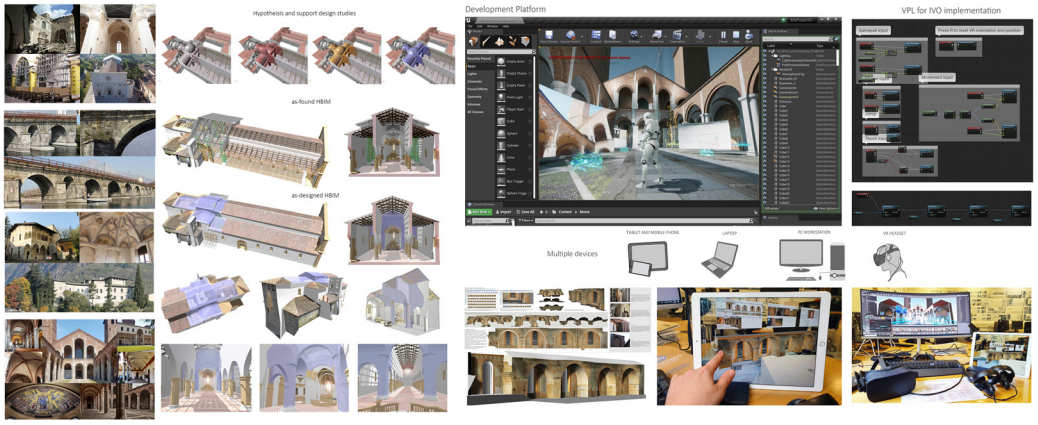
Abstract

In the last few years, innovative methods able to improve the digitization process of heritage buildings based on a scan-to-BIM process, have brought countless benefits in different disciplinary fields oriented to the management of the built heritage. On the other hand, the scan-to-BIM process still involves static forms and low levels of interactivity between the user and digital models. For this reason, in recent years, the author's research has focused on increasing the utility and interactivity paradigms of digital models with the aim of improving the transmissibility of the tangible and intangible values of our built heritage through the implementation of the latest generation tools and techniques in the field of HBIM, Digital Twin and Extended Reality (XR).

Keywords
scan-to-BIM, built heritage, eXtended reality, interactivity, technologies, digital-sharing.



The digital models based on a scan-to-BIM process and the levels of interactivity obtained through the latest generation XR techniques and devices.

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Introduction

In recent years, scientific research in the field of digitization of built heritage has taken up the challenge imposed by the major multinationals and governmental bodies aimed at supporting the life cycle of buildings through increasingly advanced techniques and methods. In this context, the digital representation of buildings has benefited from new tools and methods capable of increasing the dissemination of information related to any type of artefact, passing from the scan-to-BIM process, to eXtended reality (XR), up to artificial intelligence (AI). In particular, disciplinary sectors such as 2D / 3D digital representation, computer science, preservation, restoration and geomatics have contributed to strengthening the transition and digital management of historical artefacts of high historical and cultural value, increasing exponentially not only the profile of the 'method' but also that of the 'content'. In this context, the osmosis created between digital representation and IT development oriented towards the creation of new digital solutions capable of responding in turn to the needs of different categories of professionals such as architects, engineers, archaeologists and restorers, has proved decisive for increase the usefulness of digital models for different types of analysis. In this new scenario, characterized by profound economic-social and technological changes at the cutting edge, it was crucial to understand and then apply the potential of a 'fil rouge' constituted between digital representation, information technology, geomatics and supporting the preservation of built heritage. For those reasons, the contribution collects the direct experiences made in recent years in the field of digitization of built heritage, demonstrating how technological developments and latest generation methods can support the life cycle of the building by increasing the usefulness of the models and their capacity to interact with user-input by passing from static models to interactive dynamic models.

The ability to innovate through applied research in the era of digital sharing

Currently, the construction sector is witnessing profound economic, social and technological changes. This new scenario has greatly influenced applied research in the construction sector, proposing and developing interesting methods and digital tools capable of supporting the life cycle of the building. As is well known, the advent of BIM and mixed reality (VR-AR) have allowed professionals to go beyond simple two-dimensional representations, exponentially increasing the information content of 3D digital representations [Carrión-Ruiz et al. 2019: Paladini et al. 2019]. In particular, the scan-to-BIM process was able to demonstrate how to transform simple points in space (scans, point clouds) into parametric objects capable of communicating contents characterized by different types of information (mechanical, physical, historical, etc.). From year to year disciplinary sectors such as design and information technology have defined a 'fil rouge' capable of increasing the usefulness of the models for different types of analysis and fields of application. The figure of the architect, therefore, had to deal with a profound generational change, where acronyms such as LOD (level of detail) and LOI (level of information) have increasingly characterized the representation of complex digital models and various international standards. Some interesting studies have also taken up the challenge and demonstrated how to bypass the rigid architecture of BIM software such as Autodesk Revit and Graphisoft Archicad not oriented to the management of complex historical buildings [Banfi 2020, Brumana et al.,2018; Previtali et al., 2021]. In this context, in addition to 3D surveying, digital modelling has proved crucial to define new scan-to-BIM requirements, regulations and best practices capable of digitizing the built heritage with a high grade of accuracy (GOA). LOD, LOI and above all GOA have therefore become factors capable of communicating the reliability of the models. In summary, the advent of new information technologies has made it possible to shift the focus more on 'how' to do things, facing new challenges imposed for the most part by software developers oriented to the management of new buildings. Consequently, innovative research case studies aimed at supporting the conser-

vation and restoration process of historic buildings have shown how digital representation can take different forms of sharing, such as 'digital sharing', expanding the 'content' of digital models through innovative 'methods' not yet fully consolidated and applied at the national level [Della Torre 2017].

Beyond the scan-to-BIM process: from HBIM models to new levels of interactivity

Digital sharing and the spread of open source have a direct impact on the life cycle of the building. Thanks to cloud sharing techniques and new levels of interoperability of digital models, it is possible to create growing participation and sharing among all the users involved in the process, defining culturally and spatially open perspectives and approaches. As has been said and repeated, in recent years, the innovation process has required the definition of innovative information processes and specific digital skills. In this context, experts in the construction and IT sectors have defined new professional figures and digital workflows capable of proposing new digital methods of data sharing. This holistic approach has seen the reworking of a large number of functions, codes, digital tools with the main objective of increasing the immersion and sharing of digital models, increasing the model-user interactivity paradigm [Tan et al. 2019]. From a digital point of view, the model was therefore considered a digital container of information capable of interacting and connecting the user with the heritage built in different forms. Once the user has created the geometric model corresponding to what was detected by the 3D survey campaigns, he can enrich the semantic value by inserting heterogeneous information capable of describing not only the materials and architectural elements used but also their historical and cultural heritage. In this scenario, NURBS modelling and grade of generation (GOG) were found to be decisive for managing the paradigm of the complexity of historical buildings from 3D surveys such as the Basilica of Collemaggio after the 2009 earthquake, Masegra castle in Sondrio, Azzone Visconti bridge (Lecco) and the basilica of Sant'Ambrogio (Milan) (fig. 1).
The following figure shows the comparison of the three main steps that lead to the creation of scan-to-HBIM models aligned with the main project requirements and objectives (fig. 2). Among the various commissions, in recent years it is necessary to mention in particular ENIservizi, which financed and supported the restoration of the Basilica of Collemaggio, which was awarded the latter with the European Heritage Award in the 'Conservation'

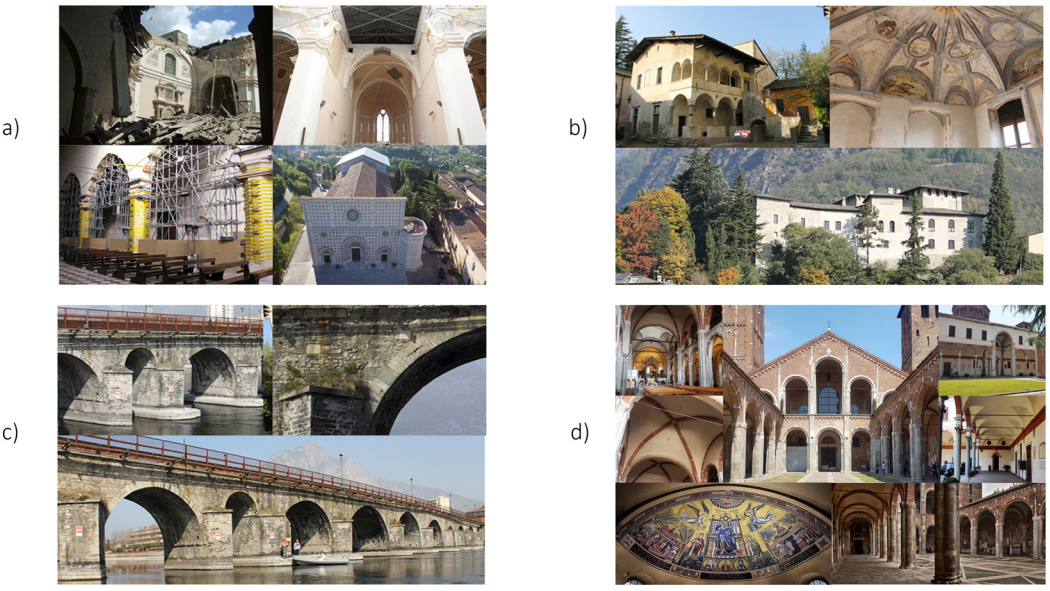

Fig. 1. The research case studies: a) The Basilica di Collemaggio in L'Aquila, b) Masegra castle in Sondrio, c) Azzone Visconti bridge in Lecco, d) the Basilica of Sant'Ambrogio in Milan.

category. The entire project was based on a public-private partnership that involved the collaboration of three different universities [Brumana et al. 2018].
Thanks to this research case study, research in the field of HBIM has allowed the author to investigate forms of digital representation capable of communicating the complexity of the heritage building to different disciplines, from restoration, preservation to construction site up to finite element analysis (FEA). The project, in particular, envisaged the creation of a model capable of communicating dynamic information of a geometric, material and design nature both in terms of the state of the project, the latter alternating with the classic preliminary, final and executive design phases. Figure 3 shows the level of dynamism and interactivity achieved in a phase of development for the basilica di Collemaggio (L'Aquila).
Subsequently, a second opportunity to improve and share dynamic information through HBIM models was the case study of Castel Masegra (Sondrio) and Ponte Azzone Visconti (Lecco). Thanks to deep historical research of the artefacts it was possible to identify well-defined historical phases and create specific BIM parameters within the two projects to allow end-users to interact dynamically not only with the architectural and structural elements of the digital models but also with specific data such as historical phases, finite element analysis (FEM), data monitoring and mixed reality (VR-AR) [Barazzetti et al. 2015; Prevtiali et al. 2021].
Thanks to the identification of several phases and a digital representation that involved the application of different levels of detail (LOD) and grade of accuracy (GOA), it was

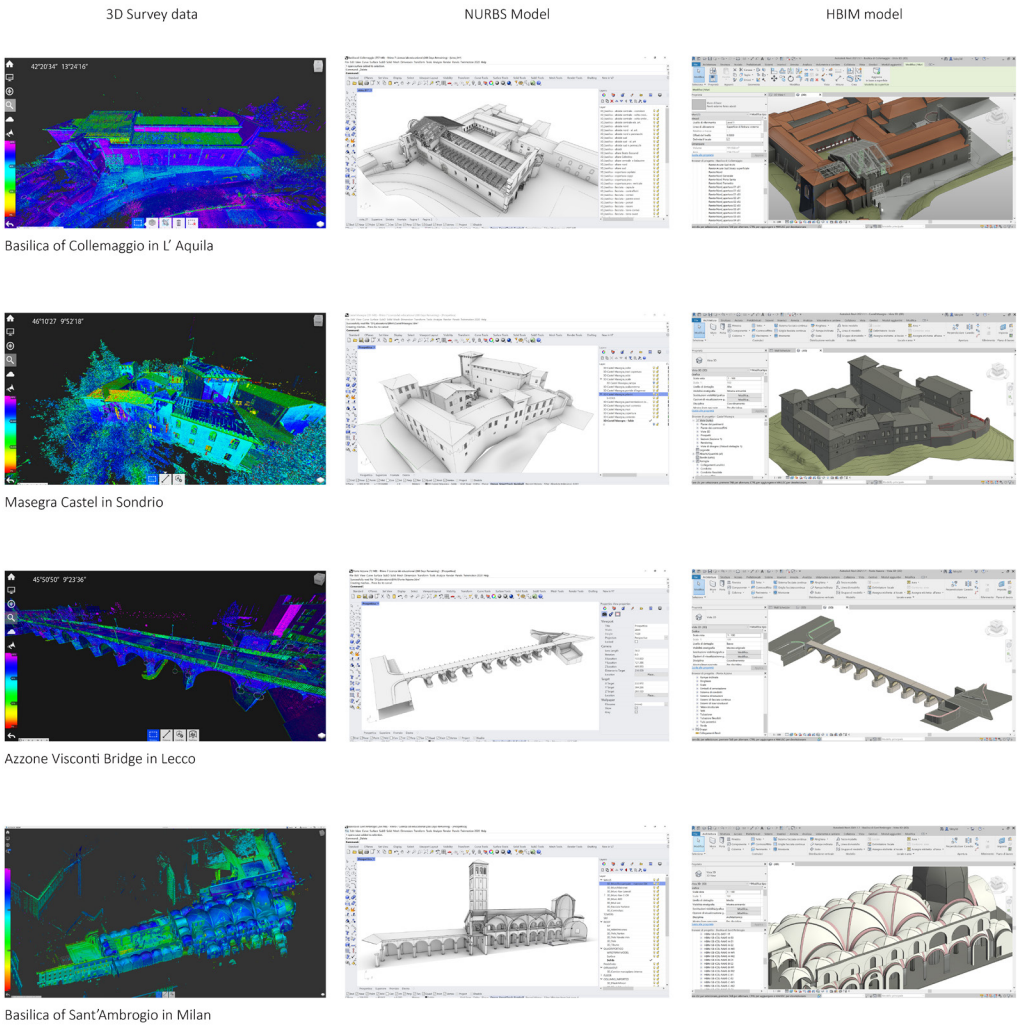

Fig. 2. The digital workflow applied to the research case studies: from 3D survey to HBIM as-found models.

then possible to go into the development of a dynamic graphic information display. This required the identification of objects no longer corresponding only to complete wall partitions but to subdivide the latter also in semantic and temporal terms (granular objects) [Banfi 2020](fig. 4).
Despite the results obtained for the latter two case studies, both models, the related abacuses and two-dimensional representations (plans, elevations and sections) could be viewed and analyzed through the BIM platform with which they were developed and the BIM-based software used for the subsequent analyses. Consequently, the informative

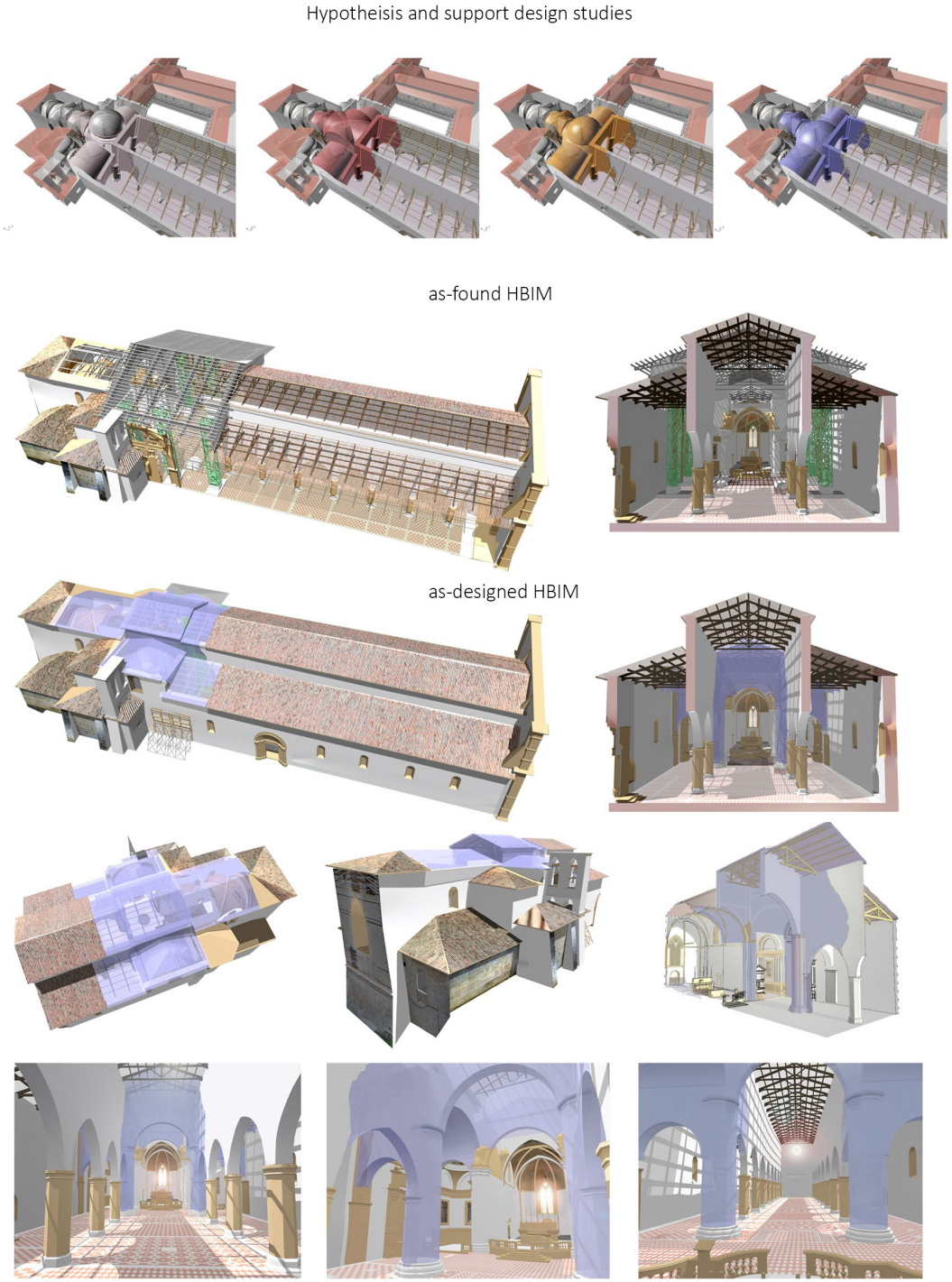

Fig. 3. The HBIM model of the Basilica di Collemaggio and its dynamic configurations for the restoration project.

value and the very usefulness of the models were intended for a small circle of experts able to interact and manage complex models with professional software that require advanced skills.
For those reasons, as briefly described in the next paragraphs, the growing need to go beyond BIM platforms such as Autodesk Revit and Graphisoft Archicad and facilitate the use and reading of BIM models, has required the development of methods capable of guaranteeing professionals but also for non-BIM and digital modelling experts (such as students and virtual tourists) an easy reading of the information models and to interact dynamically with interactive virtual objects (IVO) and open BIMcloud platforms (currently under development) capable of communicating new types of 'content'.

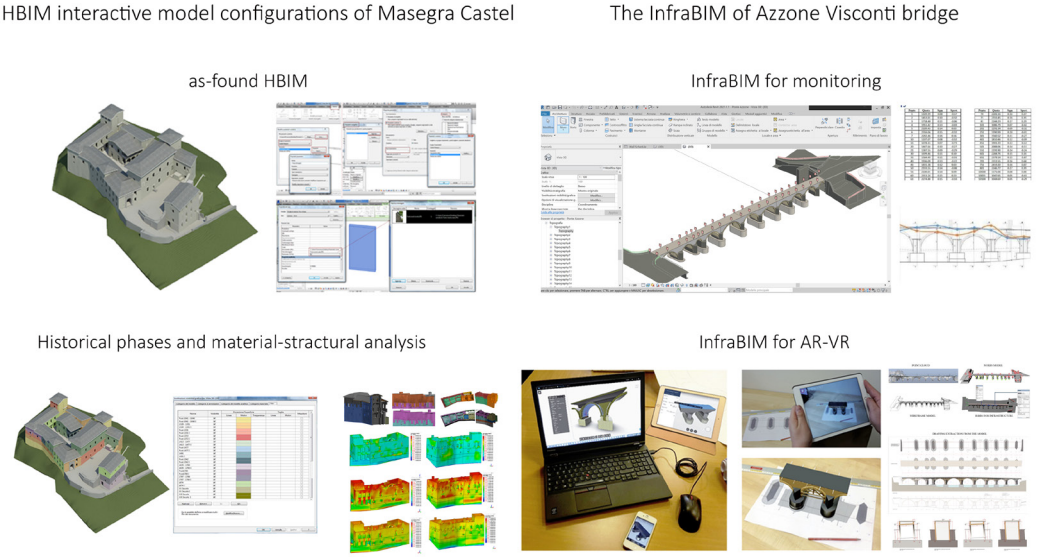

Fig. 4. The second phase of development: implementation models for semantic enrichment based on dynamic phases.

Digital sharing, dynamic models and interactive virtual objects (IVO) for built heritage

As briefly anticipated, nowadays it is possible to develop graphical platforms and interfaces thanks to the study, analysis and reworking of specific APIs shared by the main architecture software manufacturers. The development of an open cloud-based BIM platform is currently underway, with the main objective of collecting, storing and sharing a large number of case studies [Wong et al. 2014]. In this project, the level of interactivity will lead the end-user to immerse themselves and interact dynamically with a large amount of content, from classic text files and multimedia files to more complex HBIM and MR projects. On the other hand, recently, the third phase of development has been investigated as regards the level of user-model interactivity. Video game development platforms have been employed in the construction sector to increase the digital sharing of architectural projects. At the same time, platforms such as Unity, Blender, Unreal Engine and TwinMotion have allowed a completely open logic to be able to develop digital worlds capable of interacting with the user through different types of devices: from the mobile phone and tablets up to the latest generation headset VR such as the Oculus Guest. For this last phase of development, the case study of the Basilica of Sant'Ambrogio was oriented towards the virtual-visual storytelling of their historical, cultural and artistic background. The following figure shows the applied method that allowed the conversion of a large number of static objects into IVOs. In particular, the transformation from static models to IVOs was supported by the visual programming language (VPL) known as BluePrint. It is any node-based VPL that lets users create programs by manipulating program elements graphically rather than by specifying them textually. Figure 5 shows

the added value of consolidated methods capable of transferring the informative and geometric richness of the scan-to-BIM models in immersive environments characterized in turn by interactive virtual objects able to communicate different types of information based on user inputs.

Conclusion

This paper critically reports the developments and results obtained in the digitalization process of the built heritage, analyzing the pros and cons of the solutions proposed given the new UNI 11337 standard which will outline methods and contents in the coming years in the national panorama. On the other hand, the case studies reported show a progressive increase in the levels of interactivity between user-model and related content in support of historical-social-cultural realities. The application of a scan-to-BIM process and the subsequent IT implementation laid the foundations to be able to respond comprehensively to the European needs aimed at extending the usefulness of digital models to the built heritage and the digitization of museums and their collections. For those reasons, the focus is mainly on 'how' digital models can come to life thanks to user-model interaction, passing from static 3D representations to dynamic models and interactive virtual objects (IVO) able to share different types of information and multimedia outputs in favour of new forms of digital sharing and eXtended reality (XR).

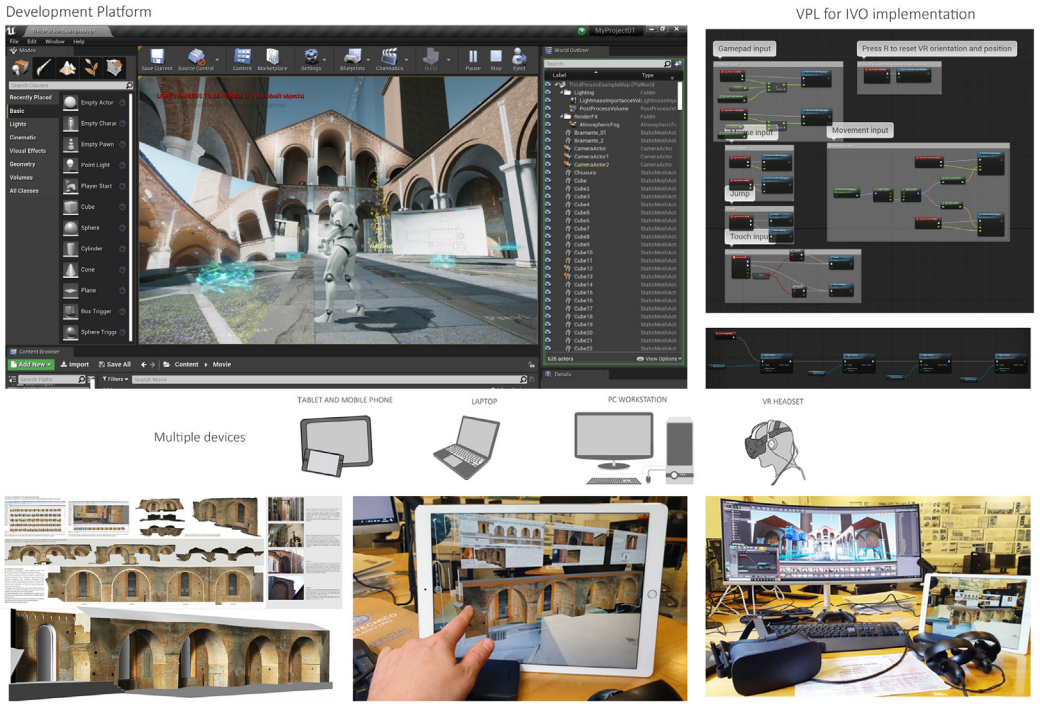

Fig. 5. The fourth phase of development based on visual programming language (VPL): from static models to interactive digital objects (IVO).

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