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Towards the development of a cloud-based BIM platform and VR apps for complex heritage sites subject to the risk of flood and water level changes

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Towards the development of a cloud-based BIM platform and VR apps for complex heritage sites subject to the risk of flood and water level changes

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Abstract. 3D acquisition methods and systems for totally or partially submerged cultural heritage (CH) allow the developments of methods able to integrate complex BIM projects for rivers, lakes, maritime structures and infrastructures with the world of Virtual Reality (VR) and BIM monitoring. Thanks to an open approach this paper shows the results obtained in the field of programming language for the development of an open-source BIM platform able to get a fusion between the application fields of BIM sensor, monitoring, historic building information modelling (HBIM) and VR. Several preliminary test results are reported in order to show the potential of the proposed method for multiple research case studies, and also proposing future perspectives and developments oriented to get a holistic, inclusive and unified platform able to manage complex scenarios accurately such heritage sites subject to the risk of flood and water level changes.

1. Introduction

In recent years, thanks to the most modern 3D acquisition and monitoring techniques, it is possible to store, analyse and manage a large amount of data of complex scenarios such as archaeological sites and infrastructures. On the other hand, the organization and management of digital data are not always easy to use, analyse and share. Thanks to the integration of advanced modelling techniques and programming languages, this research offers a BIM-cloud platform based on the collection, processing and transformation of a large quantity of data for the management and monitoring of archaeological sites and infrastructures in contexts subject to the risk of flood and water level changes. In this specific field of application, various researches and methods have been proposed in the last decade with the common goal of improving the management and preservation of the built heritage [1]. One of the most investigated aspects it is the transformation of data derived from the most modern 3D data acquisition techniques such as photogrammetry, laser scanning and monitoring into ‘informative’ models capable of incorporating high levels of information (LOI), sharing it with the various professionals involved. Furthermore, the generation of HBIM models capable of faithfully representing the detected reality, the complex geometries of historic buildings has been widely investigated and resolved in different ways [2,3]. In particular, the creation of BIM objects capable of representing complex historical architectural elements has made it possible to increase the grade of accuracy (GOA) and the level of detail (LOD) of BIM projects aimed at the restoration and conservation of the built heritage [4].



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However, HBIM, for the most part, requires high skills in the field of digital modelling, 3D survey and monitoring. As a result, data analysis and management is aimed at expert professionals such as engineers and architects with specific skills who are able to digitally manage complex BIM projects. For these reasons, thanks to the sharing of application programming interface (API) libraries, it has been possible to direct research in this specific field towards more simplified management (in terms of use, analysis and reading), facilitating holistically professionals who are not always able to interact with complex BIM projects.

2. HBIM-VR Framework, findings identified and research objectives

The field of application of BIM and VR is mainly oriented for the management and life cycle of new construction projects. In recent years, innovative research has oriented the benefits of BIM projects for complex contexts such as buildings of high historical and cultural value and infrastructures and archaeological sites characterized by higher levels of detail (LOD) and information (LOI) than new buildings. Consequently, thanks to the development of methods capable of managing the complexity of the built and cultural heritage in BIM logic with the most modern monitoring techniques and three-dimensional survey, it was possible to improve the restoration, the rehabilitation of historic buildings, maintenance, and life cycle management of archaeological sites, and complex infrastructures [1,6].

This integration of three-dimensional modelling techniques, HBIM and 3D survey is also known as the Scan-to-BIM process where the management and monitoring of complex scenarios takes place through the grade of generations (GOG) capable of representing the artefacts detected with a GOA of about 1 mm in the most complex cases and to orient the scale of representation and the LOD according to the project needs and the quality of the data derived from photogrammetry, monitoring or laser scanning [4].

As is well known, all these techniques, studies and methods proposed require high knowledge in different fields of application such as geomatics, restoration, design and a high computer skills, professional figures able to appropriately manage the 3D survey, the BIM and 3D digital modelling at the same time.

In the last year, to facilitate the reading, analysis and sharing of a large amount of data coming from monitoring, 3D survey and complex BIM projects, the main IT development techniques for the generation of immersive VR environments and BIM cloud platforms have been investigated. Research and development have been directed towards the development of a holistic, inclusive and unified platform capable of managing, storing and sharing a large amount of digital data such as analysis, 3D models, reports, data from real-time monitoring and 3D survey.

The main objectives were:

- generation of Scan-to-BIM projects of two heritage sites subject to flood risk and water level changes;
- creation of an open cloud BIM platform capable of sharing the collected data and the Scan-to-BIM models generated simultaneously;
- transmission and better sharing of data from surveying and monitoring;
- design and development of a web interface capable of displaying and managing 3D and non-3D data with different exchange formats;
- development of VR apps for different devices (mobile, desktop) for different types of users using the main open VR development techniques.

3. Open digital solutions to manage heritage sites subject to the risk of flood and water level changes

Recently the main cases of BIM software production, digital modelling and VR gaming such as Autodesk and Epic Games have shared cloud libraries of APIs and software with which it is possible to develop new digital solutions that can improve the management and sharing of information and multimedia data.

For the selection of these resources, various studies, analyse and tests were conducted with the main objective of proposing a holistic digital method and solution based on open development logics (Fig.1).. The main API libraries used for the development of an open cloud-based BIM platform are Autodesk Forge and Revit API while for the development of VR apps Unreal Engine 4 has been selected thanks to its user-friendly development logic.

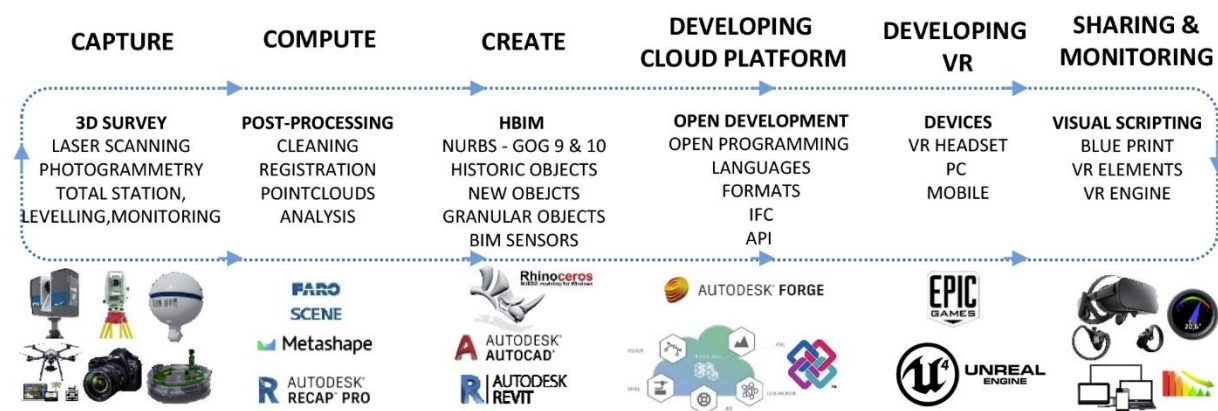


Figure 1. The open workflow to develop two ITC solutions (cloud-based BIM platform and VR app) for complex digital scenarios.

3.1. An open BIM-cloud Platform for complex heritage scenarios: from multi-residential building to archaeological sites and historic infrastructure

In last two years, thanks to the project “*HOMeBIM liveAPP: Sviluppo di una Live APP multi-utente della realtà virtuale abitativa 4D per il miglioramento di comfort-efficienza-costi, da una piattaforma cloud che controlla nel tempo il flusso BIM-sensori – ID 379270* funded by Regione Lombardia, has been possible to improve the thermal monitoring management of residential and office buildings through the development of a platform capable of displaying the data derived from the sensors in a cloud BIM platform. Thanks to the sharing of specific APIs, it was possible to develop a platform capable of communicating certain types of data in real-time, such as the internal temperature of the various rooms monitored, and all information related to the BIM model such as the physical and mechanical characteristics of each individual architectural element. To facilitate analysis of complex systems, it has developed an interface capable of connecting information, 3D objects and data from monitoring through information panels, graphs and reports.

IT development based on open programming languages like C ++, Apache Hbase (open-source stream processing platform is written in Java and Scala and developed by the Apache Software Foundation), Apache Kafka (open-source stream processing platform is written in Java and Scala and developed by the Apache Software Foundation), PostgreSQL (object-based DBMS released with a free license, BSD License style), have allowed authors to go beyond the possibilities offered by the Autodesk Forge platform (Fig.2).

Considering the platform, all software components are developed and designed to be transferred both to a local system (on-premise) and to the cloud.

Two implementation studies were therefore carried out, one of which was on-premise and one in the cloud. Specifically, the solution adopted for the development of the platform has made it possible to achieve the following results:

- an easily installed, configurable and adaptable sensor system for data acquisition and transfer by a typical technical operator. To ensure the required flexibility, the system had to be easily scalable with the addition/removal of sensors and transferable as a whole,
- a software architecture capable of recording, analysing and graphing the data received from the sensor system in a 3D BIM space accessible online and the calculation of thermal comfort according to ISO 7730: 2005-08 and EN 15251: 2007-08,
- a software application capable of speeding up the generation of a BIM model from point clouds acquired through various 3D surveying techniques (static laser scanner, dense photogrammetric matching, mobile scanning systems based on SLAM systems).

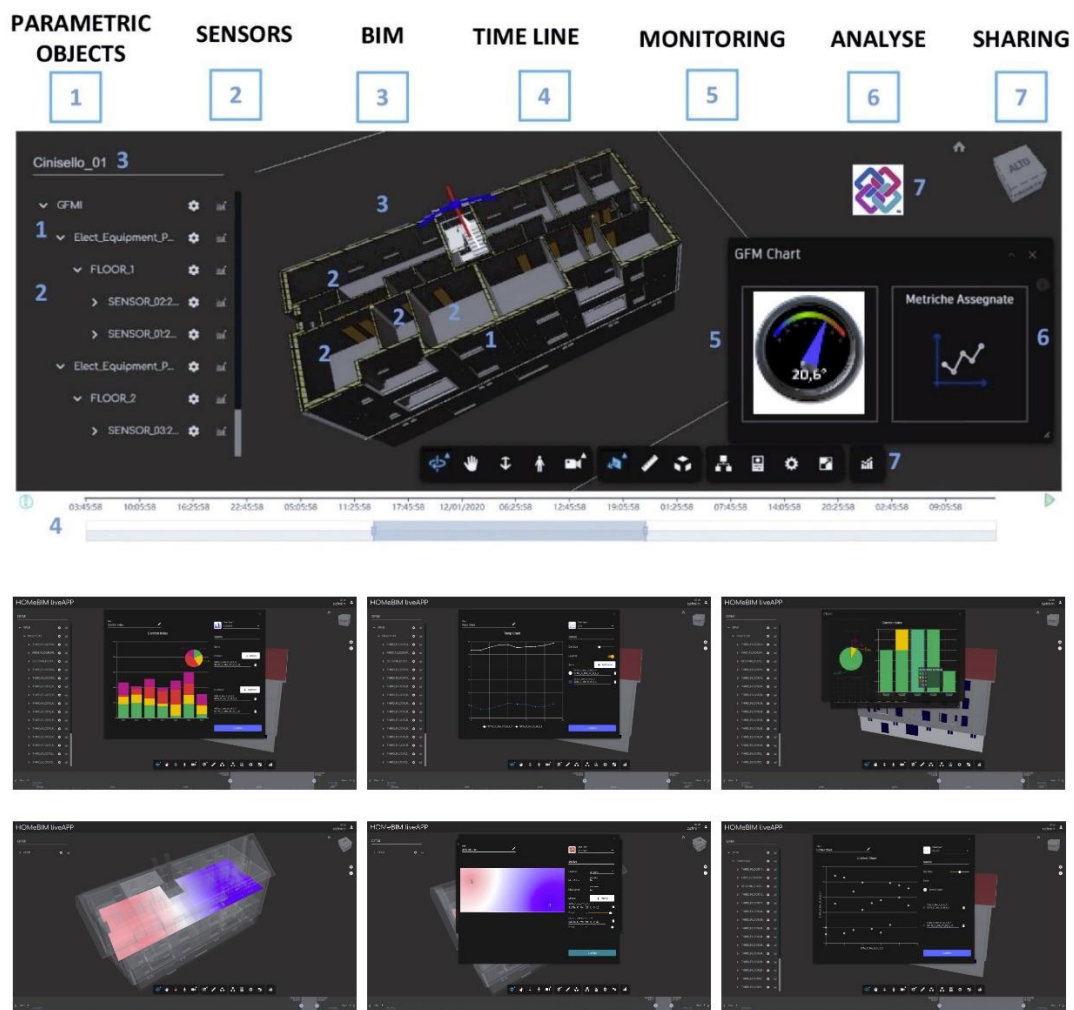


Figure 2. Cloud-based BIM platform developed for traditional BIM projects: a residential building.

Once the results have been consolidated, a further development phase of the system has been envisaged, capable of accommodating other types of BIM data and models. Considering the growing difficulty of monitoring complex scenarios such as historic buildings and infrastructures, this study has increased the platform's interoperability levels through one of the most widely used open formats in the BIM: the IFC field. The IFC format, as is well known, was developed with the aim of transferring the geometric and informative value of digital models made in Autodesk Revit or Graphisoft Archicad (commercial software) in a non-proprietary format free from constraints of use. Over the past decade, the development and interoperability levels of the format have led to the use of different versions of the format, including the IFC 2x3 format and the IFC 4 format. Bodies and governments have subsequently adopted this format as a standard. England and the United States of America are a perfect example where BIM models are transferred between the various figures involved in the projects through this open format. On the other hand, in terms of development, this format is critical and not always easy to use. For this reason, IT development has decided to identify descriptive fields and identification codes within the BIM project that can be automatically recognised by the cloud platform when the monitoring data is connected to the BIM model. This development phase has consequently allowed four additional advantages compared to previous works [7;8] (Fig.3) :

- to connect the flow of data derived from sensors and monitoring to new customised cloud-based BIM platform;
- to increase the interoperability level of the platform for complex scenarios such as archaeological sites, infrastructures and historic buildings;
- to share and analyse cloud and on-premise data from monitoring sites subject to flood risk and water level changes;
- to use proprietary and open exchange format.

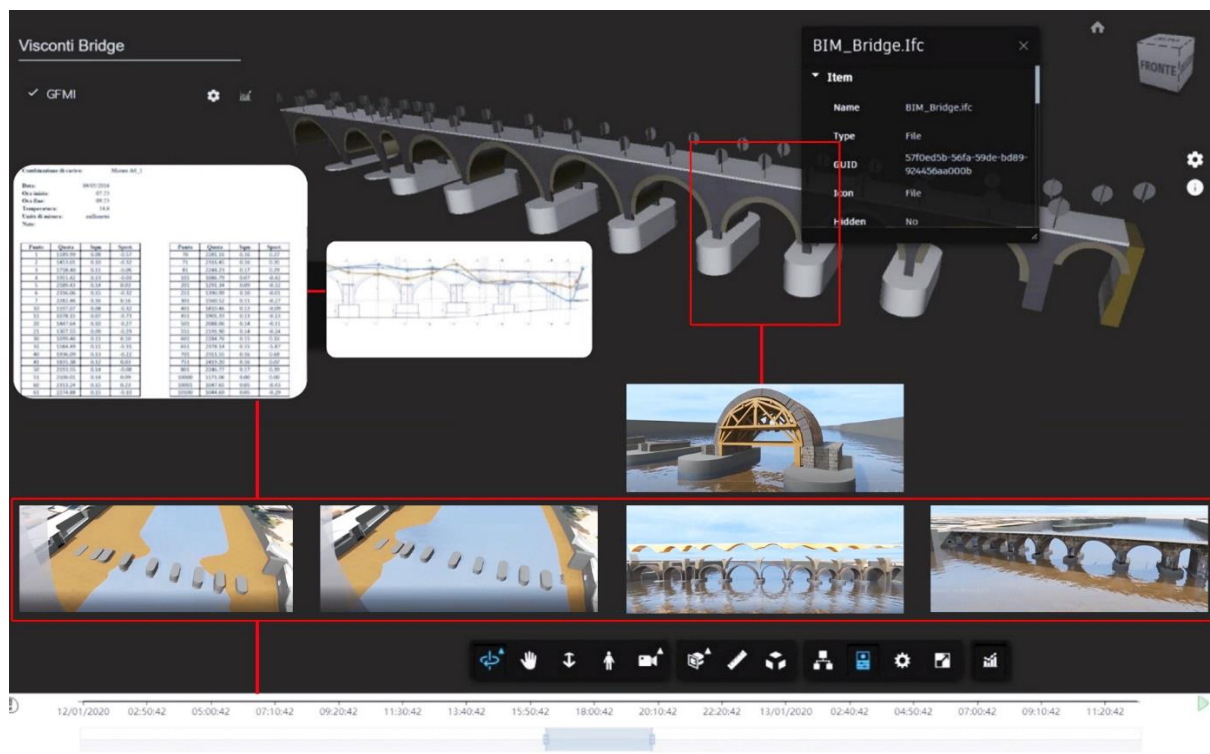


Figure 3. Cloud-based BIM platform developed for complex scenarios: the HBIM of Azzone Visconti bridge in Lecco, 3D survey data, monitoring analysis and the water's level simulation displayed through the developed cloud interface.

3.2. *The Development of VR projects and apps for multiple devices and users*

In recent years, the HBIM world is been oriented to new educative VR project to maximise the utility of digital models for a different type of analysis and project needs. Thanks to previous studies [9] it was possible to optimize the results obtained through an HBIM project for a historic infrastructure: the Azzone Visconti bridge in Lecco. In particular, through the development of a VR app, it was possible to simulate the water level changes of the river of the city of Lecco, analyzing the structural behaviour of the bridge at different times of the year.

The particularity of the case study and the high level of detail (LOD) of the bridge model allowed to optimize all the information obtained in different phases: from the first phases of a photogrammetric survey and laser scanning to the different phases of structural monitoring through levelling. A second advantage found in the use of a project capable of transforming point clouds into digital information models was that of being able to increase the level of use of these models for VR.

Unreal Engine 4 is a suite of integrated tools for game developers to design and build games, visualizations and simulations. It is based on an open development logic that allows users to customize and create immersive environments able to share digital worlds and data with a different type of devices such as pc, mobile, and VR headsets.

The proposed approach allows developers to create multiple VR/AR project through a specific visual programming language (VPL) based on blueprints. It lets users create programs by manipulating program elements graphically rather than by specifying them textually, visualizing expressions, spatial arrangements of text and graphic symbols, using them either as elements of syntax. Figure 4 shows the digital process created for the development of a VR app capable of simulating through various portals and dimensions the various river level changes both for the Azzone Visconti bridge and for the Albenga archaeological site. The process is so structured:

- 3D photogrammetric survey via river and via drone;
- 3D laser scanning and total station survey;
- levelling and monitoring;
- generation of a NURBS mathematical model able to correspond to 3D survey data with a high degree of accuracy;
- transformation of the NURBS mathematical model into a parametric BIM model through the main generation degrees (GOG 9 & 10),
- creation of a BIM project capable of linking analyzes and monitoring data to the model, database and schedules, textures and orthophotos;
- export to the main 3D formats to transfer BIM models to Unreal Engine 4 such as .obj and, fbx,
- choice of devices to view the VR app;
- generation of the VR model through the Unreal Engine 4 editor using the main blueprints for the management of the model, avatars (both first and third person), textures, information panels and temporal phases associated with changes in the water level of the river;
- development of the VR app by defining the main PC-oriented packaging parameters, Samsung gear, and Oculus Rift.



Figure 4. From reality to the VR project of the archaeological sites of Centa River, Albenga (Italy).

4. Preliminary results and future developments

The richness of HBIM models both from the geometric point of view (reliability of the level of detail and accuracy) and semantic term (storage and sharing of a large amount of information) has been favoured by an IT development based on an open format such as IFC, which allowed the association of the data flow to the BIM model and the use of the cloud-platform with more complex scenarios such as the archaeological site of Albenga and the Azzone Visconti bridge of Lecco. Still in open logic, two VR applications have been created that are able to simulate and display the water level change of both case studies, thus promoting the monitoring and preservation of two complex scenarios also subject to flood risk. Future developments are aimed at improving the integration of sensors and the monitoring system with the BIM cloud platform of both case studies, with the main goal, in addition to improving the analysis and sharing of data for any type of user, to increase the protection of complex scenarios such as archaeological sites and historical infrastructures.

Conclusion

Recent European history has shown how the life cycle of infrastructures and archaeological sites is in a precarious and fragile balance, which requires actions and research aimed at improving the monitoring of complex scenarios characterized by a large number of variables such as climate, the durability of the structural components, the water flows and the car traffic. Scan-to-BIM and BIM sensors projects have made it possible to improve the accuracy of the models, starting from the use of different types of data such as point clouds and real-time monitoring data. This article summarizes and demonstrates the results obtained in the open BIM cloud and VR field, aimed at improving the management and monitoring of any type of building, such as archaeological sites and infrastructures subject to floods and changes in water level. The flow of data from the sensors installed on-site have been connected to BIM cloud models corresponding to the detected reality, allowing to rationalize operations aimed at the analysis and protection of different types of artefacts such as archaeologists sites, historic buildings, infrastructures, residential buildings and offices, moving from the use of proprietary formats to one of the most widely used open formats in the infrastructure and construction sector in general.

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