Daniel Oltean, Enhancing heritage experiences through AR/VR technologies

Introduction

Cultural heritage (CH) exists in three forms: tangible, intangible, and digital. Tangible heritage comprises objects, monuments, and archaeological remains. The intangible one includes practices, memories, and knowledge. The last one refers to digital texts, images, and tools.

The digital heritage is created either by scanning physical objects already existing or digitally, using different 3D modelling techniques. Digital cultural content helps to capture cultural memory and preserve it for future generations. This commonly accepted classification shows the important place won by digital heritage in recent years.

Augmented reality (AR) and virtual reality (VR) technologies have recently become dominant currents in terms of heritage preservation, reconstruction, and promotion. The keywords that both advocate and explain AR/VR innovative impact and inclusive approach in this field are the following (Karadimas et al., 2019):

- 'forever': AR/VR offers an accurate immersive description of the reconstructed object/site's time evolution, which is not possible through other methods; as natural disasters and human conflicts have considerably destroyed global heritage, some places are now rebuilt and popularized in AR/VR environment;
- 'for everybody': AR/VR technologies have enlarged availability, which allows everybody to access and appreciate object/site's features;
- 'from everywhere': AR/VR technologies offer free accessibility from everywhere, which considerably increases the visibility of the objects/site under discussion.

In fact, this kind of approach is not entirely new. It dated since 1977 when Andrew Lippman released Aspen Movie Map, which anticipated and preceded the famous Google Street View application by 30 years. In the field of CH, VR solutions have been suggested to enhance visits since the late '80s, while AR has advanced pioneer solutions since around 2000 (Marto et al., 2022). Some recent open projects (such as Google Arts & Culture + CyArk, with more than 200 sites in 40 countries photographed since 2003, and Zamani Project, which popularized more than 65 historic sites in 18 countries, especially in Africa, since 2005) have consistently promoted immersive technologies.

Methods in AR/VR technologies

AR/VR technologies applied in CH are based on recent developments in two main domains: Building Information Modelling (BIM) and Computer Graphics (CG) related to XR immersive environment.

The first of them, BIM, is the standard 3D platform used in many fields (like construction and architecture) in managing (storing, documenting, and sharing) heterogeneous content regarding buildings. The model is based on advanced survey techniques (such as laser scanning and digital photogrammetry) to define the so-called scan-to-BIM processes.

The second domain, Computer Graphics (now commonplace in many areas of human activity, from computer-assisted design to scientific visualization and entertainment), plays an important role in the domain of cultural heritage. It includes different immersive forms of interactivity between the representation of an object/site and users.

The point of intersection between those two fields is the Heritage/Historic Building Information Modelling (HBIM), the application of BIM technology to historic buildings. It includes the prototype library of parametric objects that describe monuments and sites of historical value and a system of cross-platform programmes for mapping those parametric objects. This model has become the new system of modelling historic structures after the publication of two notorious articles by Maurice Murphy et al. in 2009 and 2013.

HBIM comprises five main processes:

1. Data collection.

This step first includes the study of historical records related to the object /site/monument under discussion. This preliminary phase is continued by 3D surveys, which encompass three main methods:

a. 3D laser scanning, a method that permits identifying different types of volumes and surfaces by capturing many points in the space, recording the real distance between them, and generating a 3D scan;

b. terrestrial/aerial photogrammetry, which is the science of deriving 3D geometry from both terrestrial and aerial photographs; this method drastically decreases the number of grey (inaccessible) areas that remain after 3D scanning;

c. creation of a geodetic network (using total stations, which are electronic/optical instruments used to read slope distances from the device to points of interest); it consists of placing the investigated object in its natural position on the earth.

Those three methods provide a set of points (data) that define the spatial coordinates (x, y, z) of the scanned object. The products are defined as point clouds; they are the skeletal framework that allows recording the geometry/structure of the thing.

2. Data processing (scan-to-BIM process).

This step includes work on the data registry obtained in the previous phase using software programs. The information requires first a pre-processing stage that involves cleaning and removing erroneous data. Then, the point clouds are used to create polygonal surface meshing, which is defined as a collection of triangular contiguous, non-overlapping faces joined together along their edges and thus forming the representation of the object's faces. All the point clouds are linked by those triangular networks using algorithms (such as Delaunay triangulation). Finally, the triangular mesh is textured from the associated image information.

The result is then transformed into 3D digital objects using non-uniform rational basis spline (NURBS) algorithms and pre-existing libraries of 3D parametric objects. Different degrees of generation (GOGs) are applied, which enable the creation of interactive configurations for the site/monument analyzed.

3. HBIM object generation

The transformation of NURBS models into HBIM objects is the third and final stage of HBIM. The result is the so-called ortho-images, which include details behind the object's surface, methods of the object's construction, and material make-up, accompanied by complete 3D documentation. The ortho-images are realistic 3D models containing the width, breadth, and height of an object; they can therefore represent the elevation, plan, or section of an object; they automatically create cut sections, details, schedules, and orthographic projections. To have an idea about those models, we can evoke the case of castle Masegra, located in the city of Sondrio (Lombardy region, Italy), for which an accurate HBIM model stored in 500 MB Autodesk Revit file format provides a considerable point cloud comprising 7.5 billion points (Barazzetti, Banfi, 2017).

It is worth noting that HBIM (and generally BIM) could be not only a 3D graphic representation of a construction/site but also a so-called 7D solution, able to share information and management products. Beyond the 3D geometry, 4D simulation adds time (the sequential phases of a project), 5D provides a list of costs, 6D refers to building life cycle management, and 7D concerns facility and asset management (Barazzetti, Banfi, 2017).

4. XR environment

This phase comprises the transfer of HBIM objects (static objects) in an XR immersive environment characterized by interactive virtual objects (IVOs). Different exchange formats are used to this end. The goal is a perfect adaptation of the geometric model to interactive XR projects (360° panoramic images) aimed at a wider audience. The platforms often allow carrying out modelling and programming simultaneously, extracting 3D urban contexts and verifying changes in real-time.

5. VR/AR implementation

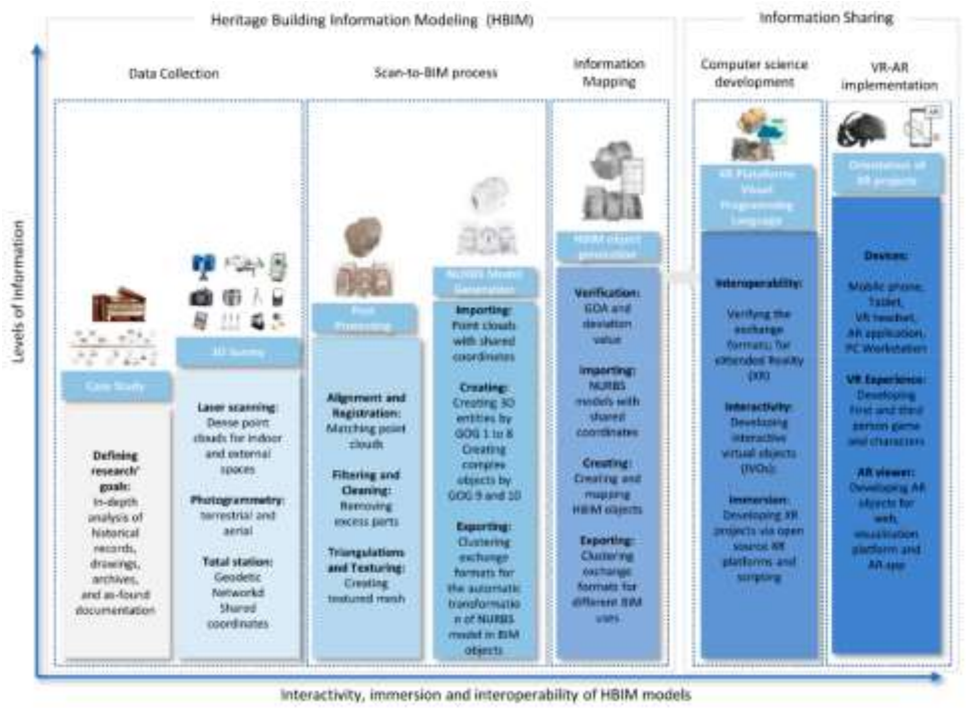
The final step encompasses the transfer of IVOs to VR/AR libraries developed for each objective/monument of interest. They are fully exploited through user-friendly AR/VR technologies (such as Unity 3D, one of the most powerful immersive environments). Interoperability now plays an important role, which allows for increasing the levels of interactivity and immersion. This approach usually entails multiuser environments, high-definition imaging, stereoscopic displays, and sometimes interactive cinema.

In this respect, VR/AR technologies are probably the best solutions for preserving and promoting cultural heritage. On the one hand, VR applications offer panoramic virtual tours generated from 3D digital models. The visualization is built on predefined images corresponding to different locations inside and outside the original site/monument. The devices more frequently used for VR applications are desktop screens (non-immersive), projection screens (semi-immersive), CAVE (Cave Automatic Virtual Environment) devices, and HMD (Head-Mounted Display) devices (both fully immersive).

On the other hand, AR allows the user to perceive and interact with both the real environment and virtual content in real time. Mobile phones and tablets are generally used for this purpose.

In addition, the idea of using more human senses than the audio-visual approach (i.e., smell, touch, and taste) has been developed in recent years, encouraging new explorations and discoveries (Marto et al., 2022).

The whole process, which could be defined as a scan-to-BIM-to-XR one, is resumed in the following schema (Banfi, 2021, under CC-BY-4.0 license, without changes):



Conclusion

Nowadays, AR/VR technologies are widely used in cultural heritage in different ways: either stimulating alternative approaches for specialists in digital restoration and conservation or offering new applications and opportunities for a more comprehensive user community interested in cultural tourism. These technologies bring positive news in reflourishing cultural heritage site that is in urgent demand and gives a solution to the paradox of balancing the booming tourists and aging buildings.

The field is in full development and will undoubtedly provide new outcomes in the future. It will allow connecting people and heritage in an even deeper way, creating knowledge, and preserving the cultural treasures of humanity.

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