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Augmented and Virtual Reality for the enhancement of Cultural Heritage.

Methodologies and good practices

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Abstract. The use of Augmented Reality (AR), Virtual Reality (VR) applications and new digital technologies have achieved a rapid evolution, especially in recent decades, in a large number of areas due to the technological progress that began in the early 2000s. In the same way, digital tools are becoming increasingly important to protect, preserve, and valorize cultural heritage. The digitalization of the archive's documents and ancient books, the realization of augmented reality apps for museums, or even the creation of virtual realities set in cultural or landscape environments that are protected or not open to visitors, are examples of the use of the new technology in the field of cultural heritage. In addition, recent advancements in virtual reality technologies provide new opportunities for cultural heritage organizations to attract, engage, and support end-users more efficiently and effectively by creating unprecedented interactive experiences that can scaffold users' creativity, learning, collaboration, and entertainment. In this article we will analyze all these aspects, showing some examples of how the use of virtual and augmented reality and new digital technologies represents an important tool for protecting, conserving and enhancing our cultural heritage in all its forms.

Key words. Virtual Museum, Virtual reality, Cultural heritage, Stellar atlas, Astronomy, Educational activities, augmented reality, Selfie

1. Introduction

According to UNESCO cultural heritage is the value of "*cultural legacy which we receive from the past, which we live in the present and which we will pass on to future generations*[1]" and includes the inheritance of tangible (books, buildings, landscapes, monuments) and intangible (folklore, knowledge, language and traditions) assets of a group or society, and which must be protected, preserved, and valued, for future generations to be inspired.

The increasing advances in digital technologies are impressive and ever-growing, from 3D technology to artificial intelligence and virtual/augmented reality. The possibilities opened up by all these tools can be used to not only ensure preservation but also to capture younger people's imagination. Today, ideas like Virtual Museums or virtual collections are being eagerly adopted, fuelled by the notion that if one cannot get physically to the museum, the museum goes to us (Paolini et al. (2000)). Especially during the Covid-19 pandemic, many institutions expanded their digital offerings by creating virtual tours, and smartphone apps, like MAUTO[2] - the app of the Museo dell'Automobile of Turin - or Depot[3] - an augmented reality app of the Boijmans museum in Rotterdam. The National Institute for Astrophysics contributed by making virtual tours and 3D models of astronomical instruments preserved at the Astronomical Observatory of Palermo, and with virtual exhibitions.

All these gimmicks allow virtual visitors, comfortably seated in slippers on their sofas, not to miss the programming of the main cultural institutions.

New technologies also play a fundamental role in protecting and conserving historical heritage. The digitisation of cultural heritage is important for the protection, conservation, restoration, research, dissemination and promotion of tangible and intangible cultural assets, coming from all types of cultural institutions (museums, galleries, libraries and archives, monuments and sites), for example, many of the rare books preserved in the various Italian Astronomical Observatories are digitized and can be consulted in the "*Teca Digitale*"[4] of the website "*Polvere di stelle*".

In this context, digital tools or virtual technologies cannot replace the real experience of visiting a museum or archaeological area, but they can increase knowledge and improve the promotion of cultural heritage (Latham & Simmons (2014)).

The first part of the article will describe ATON, a framework designed to create Web3D/WebXR apps and their use for cultural heritage. The second part will present augmented and virtual reality strategies developed for unveiling the valuable scientific instruments, acquired during the 200 years of activity of the Specola Museum of Palermo. Finally, the last part will show "Look up!", a virtual exhibition aimed at enhancing and giving maximum dissemination of the collection of the stellar atlases, cometography and selenography preserved in the Observatories of the Italian National Institute for Astrophysics.

2. XR on the Web: challenges, tools, and perspectives for Cultural Heritage

Nowadays open protocols like WebXR (`https://immersiveweb.dev/`), allow the presentation of immersive AR or VR experiences with full interaction (Jones & Waliczek (2019)) directly through a web browser (on mobile devices or on head-mounted displays). This combined with recent advancements in terms of 3D presentation on the web and tighter integration with devices hardware, offers great opportunities, especially within cultural heritage. Recent experimentations like the ones explored by Meta (project Flowerbed[5]) Mozilla (A-Painter[6], Hubs[7]),

[1] Definition of the Cultural and Natural Heritage, adopted on 16 November 1972

[2] `https://www.museoauto.com/app/`

[3] `https://www.boijmans.nl/en/depot/app`

[4] `https://www.beniculturali.inaf.it/teca-digitale/`

[5] `https://flowerbed.metademolab.com/`

[6] `https://blog.mozvr.com/a-painter/`

[7] `https://hubs.mozilla.com/`

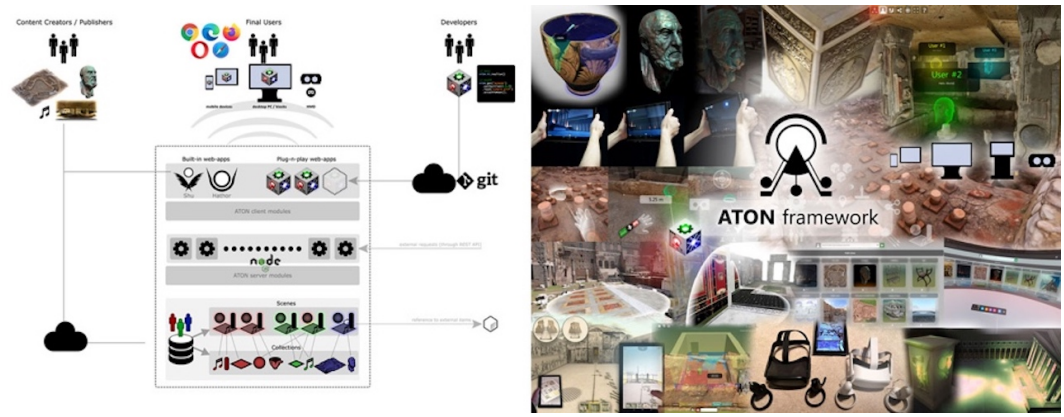

Fig. 1. The ATON framework.

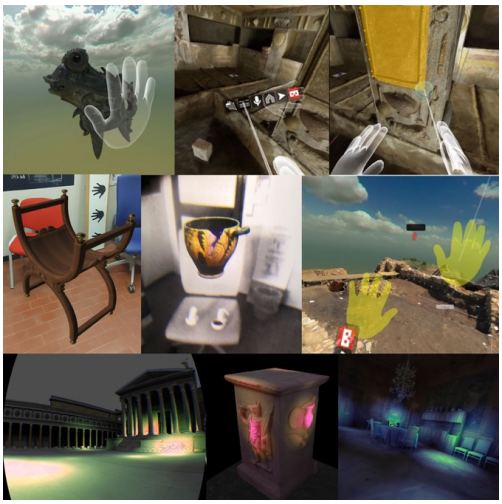

Fig. 2. Top: immersive VR inspection and annotation of online 3D models. Middle (from left to right): AR and MR examples, collaborative VR. Bottom: immersive analytics examples.

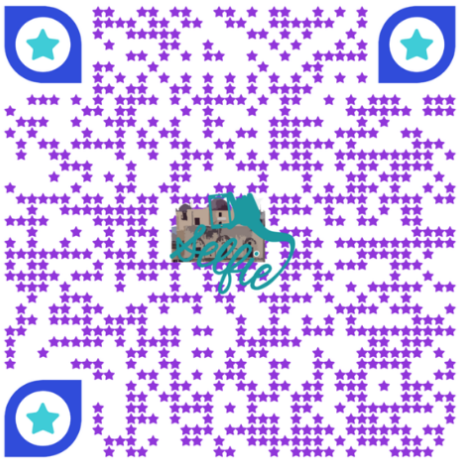

Fig. 3. The QR code to activate the experience "Selfie at Specola Museum".

Matterport[8], and the New York Times R&D[9], are paving the way toward incredible XR experiences on the Web.

However, the use of web technologies leads us to face several challenges, including streaming 3D models, performance limitations (especially on mobile devices), and interaction models. On the other hand, we have the excellent opportunity to deliver XR experiences or tools directly to the final user without any installation.

Within the Cultural Heritage domain, the open-source framework "ATON[10]" (Fanini & Cinque (2020)) by CNR ISPC (Fig. 1), allows to craft "liquid" Web3D/WebXR applications that can be consumed on every device, from

[8] https://matterport.com/

[9] https://rd.nytimes.com/projects/streaming-vr

[10] https://osiris.itabc.cnr.it/aton/

Fig. 4. The Meridian room from the virtual tour.

Fig. 5. *Left panel:* 3D model of Bonne's terrestrial globe; *Right panel:* 3D model of one of Piazzi's book.

smartphones up to 6-DoF head-mounted displays.

The framework offers multi-user and real-time collaboration, is highly modular and customizable - and adopts modern web standards. In particular, ISO standards like glTF (Robinet et al. (2014)), are designed for the transmission of 3D models on the web, including advanced compression and robust definitions of materials. Other interoperable open standards, like 3D Tiles by Cesium, also allow massive datasets' delivery and presentation (including WebXR) through multi-resolution. The interoperability offered by these standards allows fluent integrations with research infrastructures (RIs), as well as existing 3D providers and platforms already embracing those standards (e.g. SketchFab).

With such ingredients, we can create and deploy XR applications targeting the Heritage Science domain, following existing guidelines. These involve the design of proper spatial interfaces and metaphors to interact with immersive content (Fig. 2, top), including models for interactive XR discovery of hidden layers (e.g. temporal, invisible, etc.). It is also pos-

sible to share our XR experience with other remote participants in real-time, right in the browser, for didactic purposes, serious gaming, etc. (Fig. 2, middle right). Finally, we can also deploy WebXR tools to record and inspect users' sessions (visual/immersive analytics – Fig. 2, bottom) to remotely analyze how users interact with our 3D spaces or objects (Fanini & Cinque (2020)), supporting the discovery of interaction patterns on a larger scale.

3. Innovative technologies at INAF OAPa's Museum of Specola

In line with the indications of the Ministry of Cultural Heritage, the Observatory has formulated some innovative communication strategies and realized digital, interactive, and immersive content in Virtual Reality (VR) and Augmented Reality (AR). The aim was to enhance and spread the knowledge of the Specola Museum throughout the local and national territory and make it more accessible, not only to specialists in the field of Astronomy but also to the general public.

INAF - Palermo Astronomical Observatory (OAPa) started to use AR for the communication and enhancement of its Specola Museum between 2018 and 2019 with the creation of two prototypes. These two applications can be downloaded for free and can be activated using a smartphone or a tablet with an internet connection.

The first interactive experience was named "Discover the Museum of Specola" (Leonardi (2019)), powered by Zapworks[11]. It is divided into six main sections both in Italian and English and illustrates the history of the more significant astronomical instruments kept in the Museum. The user can choose the path and the aspects to deepen, thanks to hypermedia learning composed of texts, images, sounds, movies, and animations. The second prototype is an educational game named "Selfie at the Specola Museum" (Leonardi (2019)), see Fig. 3), and it was created with Metaverse by Studio Gometa[12]. This experience uses the word selfie to appeal to teens' attention, constantly surrounded by fast and connected information. The user is free to choose one scene among three. After choosing, people can share selfies on their social networks to raise awareness of the Museum of Specola throughout the territory. This application was presented during the scientific festival *Esperienza InSegna 2020* (Fiasconaro & Leonardi (2020)), where we were able to virtually house in the Museum more than 15,000 participants in just five days. An unbelievable result, considering that the Museum can hold a maximum of 20 visitors per tour, for security reasons. These experiences are a sort of game capable to bring young people closer to the history of Astronomy and the cultural heritage preserved at the INAF - Palermo Astronomical Observatory.

Thanks to these tools, the Museum of Specola launched a new era in which the history of Astronomy meets new communication technologies through a multimedia system of encoded information. In fact, in 2020, a new virtual tour of the Specola Museum (see Fig 4) was inaugurated, rich in insights and high-quality panoramic pictures, allowing a more immersive and interactive exploration of the Museum. Among the experiments conducted for the safety of the artistic and cultural heritage, there is also the realization of some interactive 3D models of astronomical instruments kept in the rooms of the Museum (see Fig. 5, left panel), and of precious ancient volumes hold in the historical archive of the Observatory (see Fig. 5, right panel). 3D models are published on *Sketchfab* and are also available on play.inaf.it inside the "virtual reality" section[13].

4. "Look up!" a virtual exhibition about the historical astronomical atlases

Together with research activities in different fields of Astrophysics and astronomical technologies, the Italian National Institute for Astrophysics promotes projects to preserve

[11] `https://zap.works/`

[12] `https://studio.gometa.io/landing`

[13] Play Inaf, section "Virtual Reality", `https://play.inaf.it/risorse/realta-virtuale/`

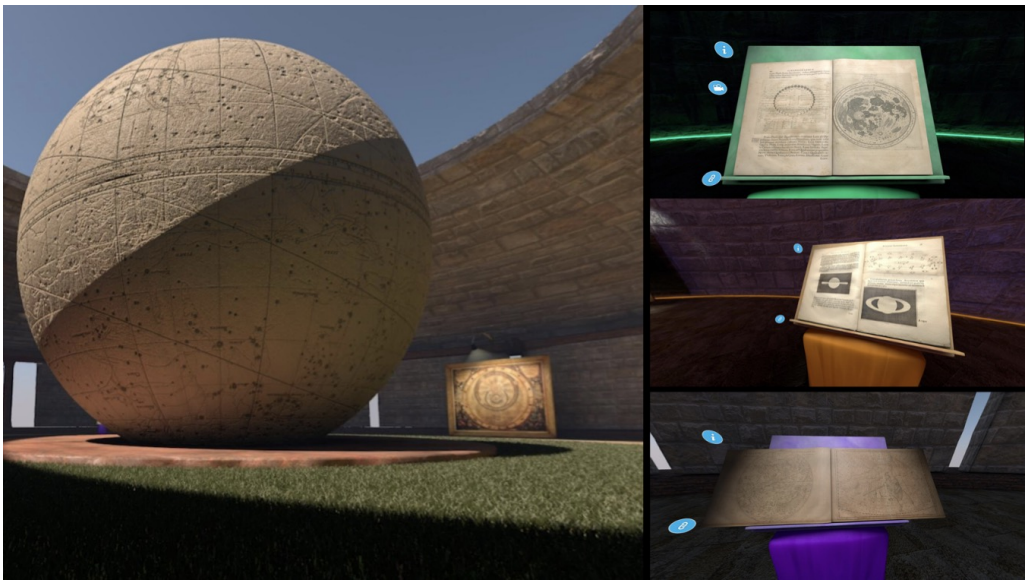

Fig. 6. Some examples of visualization of the atlases. Through the hotspots next to the atlases, visitors can browse the various celestial atlases, interact with 3D models, view videos, etc.

and valorize its bibliographic, archival and instrumental heritage including projects' public engagements.

The Observatories are the oldest scientific institutions in Italy, and they hold more than 7000 rare books, over 1200 astronomical instruments, dating from the 11th century to the first half of the 1900s, and more than 3 million documents. Within the INAF cultural heritage, the collection of celestial atlases plays an important role in the history of modern culture. The timeline starts from the 1022 stars in Ptolemy's *Almagest*, moves through the observations made at the beginning of the telescope era, and arrives at the great stellar surveys realized in the last two centuries.

To describe and enhance these treasures, the INAF "*Cosmic Pages*" (PI Mauro Gargano) and "*Touch the sky*" (PI Antonella Gasperini) projects were developed. They led to the creation of the virtual exhibition "Look up!", (Di Giacomo et al. (2022)) an exhibition with no maximum number of people, open and accessible with all devices, PC, tablets, smartphones or cardboard. It is an effective communication tool aimed at enhancing and giving maximum dissemination of the entire collection of celestial atlases (see Fig. 6), cometography and selenography preserved in the INAF Observatories. These works, for their meticulous care, represent testimonies of rare beauty that blend art, mythology and science, as well as having a role of particular importance in the history of scientific culture. This virtual exhibit was designed and built so that digital visitors can navigate, explore and understand how our knowledge of the cosmos, the Moon and the planets have evolved and changed (Chinnici & Gargano (2022)).

In the first step of this work, we digitized all the atlases preserved in the various Observatories and then uploaded them to the "*Polvere di stelle*" web portal (Schiavone (2011)). After that, we started to realize the virtual museum which is divided into three different rooms, each dedicated to a different element of the exhibition (star, moon and planets). Using the most advanced technologies, virtual reality, 3D models, videos etc., visitors can explore the scientific and cultural contents of the stellar and cartographic atlases. Users interact with them to have information about the

Fig. 7. Picture of Lu at the entrance to the exhibition. Here Lu welcomes users by describing the exhibition and how to use it.

instruments used to observe and measure the stars, the cosmology of time and the cultural environment in which the atlases were created. Visitors are accompanied in the different sections of the exhibition by Lu (see Fig. 7), a special robotic guide, which describes the scientific, artistic, and historical characteristics of every astronomical atlas shown in "Look up!".

Finally, with the exhibition, educational activities were also developed, organized in collaboration with Save the Children Italy, to reach both students of all levels and the school-age population most in difficulty. The intent is to encourage and support the self-determination of the individual and self-expression, regardless of personal condition, gender, social status and culture of origin, using the cultural heritage of Italian Astrophysics.

5. Conclusion

Today, we live in a digital world where everything is fast, connected and interactive. The relationship between cultural heritage and advanced technologies could be complex. However, from the results we presented, it's clear that we need new and advanced 3D technological skills to valorize and protect the past and make it available for the present and future generations.

The next steps for the "Look up!" will concern the translation into English of all the captions and the audio present inside the exhibition. We are also working on the implementation of new 3D models. In particular, we are creating the model of the celestial globe covered in the atlas by Giuseppe Simone Assemani, a volume that describes a rare Arab astronomical globe from the 13th century.

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