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Immersive Room as an Innovative, Inclusive, and Sustainable Tool for Presenting and Experiencing Cultural Heritage: Strategy and Action Plan

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1. Introduction

Contemporary museums are much more than places dedicated to the placement and display of collections and works of art; they are today considered a privileged means of communication and play a central role in making culture accessible to mass audiences. One key aspect when approaching the general public is the use of new technologies and new interaction paradigms. **The world of museums is experiencing a profound transformation, driven by the advent of increasingly sophisticated digital technologies and the need to offer the public engaging and interactive experiences.** Digital and interactive museum set-ups fit into this context as innovative tools to enhance cultural heritage and promote learning in an active and stimulating way. The impressive technological growth has deeply impacted our ability to experience, manipulate, create, and shape the world. Multimedia data, like pictures, audio, videos, text, graphics, animations, and other multi-modal sensory data have grown at a phenomenal rate and are now almost ubiquitous.

The concept of visualization is central in this area as it represents both the cognitive activity of forming mental images and an important discipline of information technology linked to multimedia.

This function of displaying objects and information represents the underlying connection between modern virtual environments and the historical role of galleries and museums. In this context, immersive rooms are revolutionising the cultural and tourism industry. They represent an innovative evolution in the panorama of cultural heritage valorization, offering the public an engaging, multi-sensory and unforgettable experience. Through the use of advanced digital technologies, such as virtual reality, augmented reality and immersive projections, and 5G technology, these environments allow the visitors to completely immerse themselves in the historical and cultural context, significantly enriching their experience and creating a deep emotional connection with the heritage.

The purpose of digital cultural heritage is not to replace the physical heritage, but rather to offer another type of encounter with it.

It allows for the adding of layers of information related to physical objects, and provides visitors with the opportunity to recontextualize or approach cultural heritage either from a cognitive or sensitive, emotional point of view.
These technologies allow visitors to experience cultural heritage in an immediate and highly engaging way, taking them out of time and space.

The use of technology allows for the expansion of art, and breaks down the boundaries between work, artists and visitors. It is then the visitors themselves who become the protagonists, transforming from passive observers into active participants within a dynamic environment.Furthermore, new technologies have become a powerful purchase motivator to experience a destination even before a choice has been made; on a large scale, AR can be used for marketing the destination to potential visitors, while on a smaller scale, VR can give visitors a preview of what they nwill experience during their chosen vacation.
Innovation in the field has had such a significant impact on the sector that it has transformed not only what and how museums exhibit their art, but also where audiences experience and, to some extent, coproduce these works. Visitors are no longer just meant to look at an exhibit; they are encouraged to experience, document and share it. How they construct their presence in these exhibits then becomes of paramount importance even in considering the design of new museum and cultural heritage spaces.
The aim of this study is to provide guidelines and strategies for creating immersive rooms for the valorization and promotion of cultural heritage, which can be used as a framework for replicability in different contexts.

To this end, this work will:

* **Provide an overview of the cutting-edge technologies** available for the creation of immersive virtual rooms for the valorization of artistic and cultural heritage;
* **Analyse the added value of these technologies** in terms of accessibility and inclusiveness, in particular for the involvement of people with hearing and visual impairments;
* **Focus on sustainability aspects** and in particular energy consumption;
* **Present several concrete applications** of these technologies, as examples of successful practices;
* **Capitalize on available research and successful experiences**, to design an innovative immersive room for the re-use and valorisation of Tolmin Castle, a fortress ruin on the ridge of Kozlov Rob, above the town of Tolmin in southwestern Slovenia.

These guidelines are intended to support readers in consciously informing themselves about immersive technologies, getting inspired by relevant case studies, and starting the design of their own immersive room.

2. Definitions

Immersive technology
Technology that blurs the lines between the physical, virtual, and simulated worlds, thereby creating a sense of immersion. (Lee, Chung, et al. 2013) [1]

Virtual Reality (VR)
Technology that generates an interactive virtual environment designed to simulate a real-life experience. (Lee, Chung et al., 2013, Wojciechowski et Cellary, 2013) [2]

* Non-immersive VR
The VR content is displayed via a computer screen. Traditional media, such as keyboards and mice, are used for the interaction. Non-immersive VR does not require users to wear any equipment.

* Immersive VR
Users are required to wear a head-mounted display and are completely encompassed by the virtual environment. In an immersive VR environment, user responses can be observed and recorded in a controlled situation.

Augmented reality (AR)
Technology that enables users to interact with virtual information superimposed onto the physical world, integrating digital elements into the real world. This immersion increases user experiences and interactions by offering interactive information and multimedia content. (Dunleavy, Dede, & Mitchell (2009); Rochlen et al. (2017)) [2]

Mixed reality (MR)
The space where the physical and virtual worlds co-exist. Within the reality-virtuality framework, a generic MR environment is a space in which real and virtual objects are presented together within a single display. (Milgram and Kishino (1994)) [3]

Immersive projections

Immersive projections use large surfaces to create 360-degree immersive environments. They involve spectators or users first-hand in high-impact visual and interactive experiences, which can vary in complexity and scope. An innovative video projection technique transforms surfaces into natural screens and creates an immersive experience. (Chad Kunimoto, 2022) [4]

Holograms

Holography is the technology of storing optical information in the form of extremely fine interference patterns using a coherent laser beam (both spatially and temporally) The so-created image is characterized by the illusion of three-dimensionality. (Haleem, Javaid et alii, 2022) [5]

Sensory effects

A direct biophysical effect involving a transient disturbance in sensory perception or a minor and temporary change in brain function. This can be induced by fragrances, sounds and vibrations that help create a more immersive and realistic experience.

Cultural heritage site

Refers to a place, locality, natural landscape, settlement area, architectural complex, archaeological site, or standing structure that is recognized and often legally protected as a place of historical and cultural significance. (ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites, ICOMOS, 2008) [6]

Re-use of cultural heritage site

Refers to the process of reusing an old site or building for a purpose other than which it was built or designed for (Conservation Principles, English Heritage, 2008) [6]

Ruined site

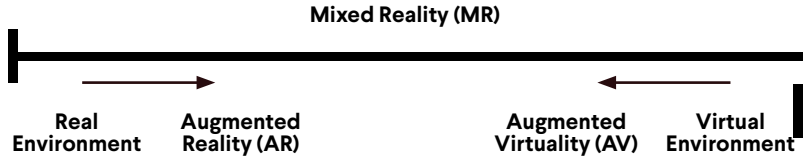
Refers to a building which, having lost a substantial part of its architectural form, has ceased to function as such (John Ashurst, Conservation of ruins, 2007) [6]

Sustainable development

Refers to development that meets the needs of the present without compromising the abilty of future generations to meet their own needs.

3. Application of new AV and RV technologies for immersive experiences in cultural heritage sites

The concept of a reality-Virtuality continuum was theorized by Milgram and Kishino i.e. 1994. [3] This is a continuous scale ranging between the completely virtual, a virtuality, and the completely real, reality. The reality–virtuality continuum therefore encompasses all possible variations and compositions of real and virtual objects.



Reality-virtuality continuum, by Milgram and Kishino (1994).
It explains how the different levels of reality interact through this network

As outlined in the previous section, **multimedia systems are by definition capable of delivering various sensorial immersive experiences**, but the main and most common application involves vision, usually as the primary experience driver.
There are many different types of technologies to create immersive experiences involving vision, ranging from augmented and virtual reality, to a mix between 360 video and virtual reality.

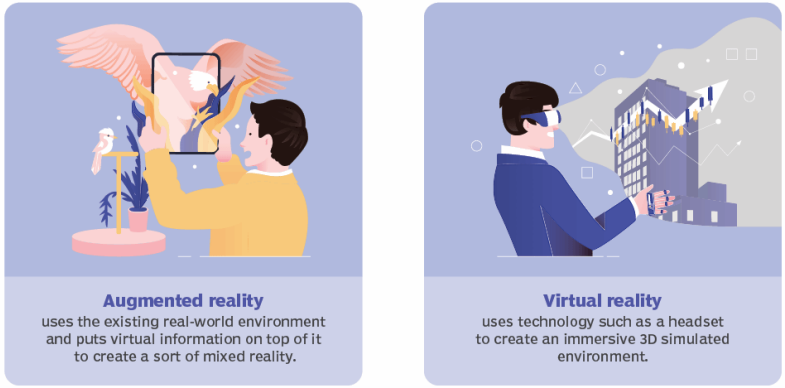
The term 5G refers to new generation technologies and standards for mobile communication. This "5th generation" is the very connection technology used by our smartphones, but also, and above all, by the many connected objects (IoT - Internet of things) around us. One of the main characteristics of this network is, in fact, that it allows many more connections at the same time, with high speed and very rapid response times. Specifically, 5G technology with its superior connection speeds and reduced latency, is opening up new possibilities for tourism, enabling the development of attractive services and experiences for tourists, all the while improving their direct experiences. "This technology facilitates the use of substantial datasets, cloud computing, and immersive applications like augmented and virtual reality. It enhances user interaction with the environment by overlaying real-time graphic content on a smartphone or standalone

viewer, thereby providing an immersive experience while enabling information processing and sharing cloud computing and immersive applications such as AR and VR, improving interaction with the surrounding environment and offering overlapping graphic content in real time by use of a smartphone or a standalone viewer support. It allows viewers to immerse themselves in a virtual reality, while also promoting the processing and sharing of information.

3.1 Augmented Reality & Virtual Reality

For the purposes of sustainable tourism development and through the use of enabling technologies that characterize the fourth industrial revolution, there are two closely related but distinct technologies allowing for access to the metaverse world (conceived as a digital and virtual landscape), that are rapidly transforming the way we interact with the world around us: Augmented Reality (AR) and Virtual Reality (VR).

Both have the potential **to revolutionize many aspects of our lives, from the way we learn and work to the way we entertain ourselves and interact with our surroundings,** changing our perception of the world around us. The way in which they differ concerns the perception of our presence. The choice between AR and VR depends on the specific function and the desired user experience. While AR shows reality and an added/altered version side by side, providing extra information and putting scenes into specific context, VR offers total immersion in a different new conceived reality. VR requires specialist technology, such as headsets, controllers and sensors; AR experiences only need a smartphone or tablet and are downloadable as apps.



Difference between AR and VR

Augmented reality (AR) refers to the integration of digital information within the user's environment in real time, experiencing a real environment with generated perceptual information overlaid on top of it, both visually changing the natural environment or by providing visual additional "artificial" contents (information) to users, seamlessly combining digital and 3D elements with our physical environment.

Example of VR application: https://mw2013.museumsandtheweb.com/

AR delivers visual elements, sound and other sensory information to users through devices such as smartphones, glasses or tablets with downloadable apps. Such supplementary information is added by the device to create a mixed experience where digital information modifies and integrates the user's view of the physical reality through adding details.

Therefore, AR is characterized by its ability to transform how we perceive and interact with the world around us, rather than just overlaying information, through enhancing, informing and empowering individuals and their experiences in various ways:

* **contextual understanding:** AR leverages real-time information about our surroundings to deliver relevant and timely data.
* **interactive experiences:** AR surpasses passive observation. Users can manipulate, respond to, and even collaborate with digital elements seamlessly integrated into the physical world.
* **increased efficiency and productivity:** AR streamlines complex tasks by providing visual guidance, step-by-step instructions, or remote assistance directly in the user's field of view.

AR-related applications allow not only greater usability of cultural and artistic events, but also of commercial, entertainment and learning ones, and can be seen as a platform for acquiring and expanding people's interests.
AR Data and info can be obtained using QR codes or downloaded apps (for smartphones and tablets) or through the use of standalone visors (i.e. Microsoft HoloLens, Magic Leap One, Varjo XR-3), visors for smartphone (Google Cardboard, Samsung Gear VR) or RA glasses (Google Glass, Vodaphone nReal Light). The latter offer a more immersive AR experience and even allow users to to view the holographic information in 3D and interact with it in a natural way.

With regard to the role played by Augmented Reality in cultural tourism and in this particular heritage site, **AR offers interactive and immersive elements to enhance and customise the tourist experience, complementing the authenticity of these sites by obtaining, in real time, added information and details** (as guides, insights, translations, other personalised contents) **directly on personal devices** (smartphones, tablets or glasses)**, while exploring the environment an individual is in.** The most straightforward way is to use it to add additional explanations to real subjects that are right in front of you.

Moreover, AR offers the opportunity to add a third dimension to displays, bringing objects or scenes to life, demonstrating, in the case of heritage site virtual reconstructions of the environment as it was or will be.

Presently, connectivity is a potential limitation and challenge of AR in tourism, due to shortcomings and lack of developments, awaiting new generation technologies, which are however not expected before 2030. Like most applications, AR technology relies heavily on mobile data or the internet for which wireless connectivity is a basic prerequisite.

Nevertheless, AR technology continues to grow as the popularity and familiarization of apps and the use of devices. In the short term, the expansion of 5G networks may make it easier to support cloud-based augmented reality experiences, for example, by providing AR applications with higher data speeds and lower latency.

On the other hand, collected data and analytics can complement the AR experience by gathering travellers' preferences and information requests, setting the conditions for further optimisation of performances and implementation of services.

Brief overview of AR apps. An Augmented Reality app is a software that integrates digital visual content (and sometimes audio and other types) into the user's real-world environment. AR apps are written in special 3D programs that allow the developer to relate animation or contextual digital information in the computer program to an augmented reality "marker" in the real world. AR applications for smartphones and tablets typically include GPS (Global Positioning Systems) to determine the user's location and its compass to detect device orientation. They are mostly free (freemium) applications.
Examples of the most common AR apps (gaming) include the following: Sky Map, Civilisation Map, Google Map, Google Translate, MagicPlan, World Brush, SketchAR, SplunAR.

AR technology examples

Microsoft HoloLens is a line of mixed reality smart glasses developed and manufactured by Microsoft, launched in 2015. It was designed to provide an augmented reality experience by overlaying digital content and holographic images onto the user's physical environment.

Costs: from around 2.200 to a max of 4.600 euros.

Google Glasses is a brand of smart glasses developed and sold by Google launched in 2013. It is a wearable, voice- and motion-controlled Android device that resembles a pair of eyeglasses and displays information directly to the user. The device offers an augmented reality experience by using visual, audio, and location-based inputs to provide relevant information. Glasses are truly hands-free and offer a head-mounted display, allowing users to access the mobile internet browser, camera, maps, calendar, and other apps by voice commands.

Costs: launching price was around 1.500 euros, but sales were suspended on March 15, 2023.

Examples of application of AR solutions at Friuli Venezia Giulia (FVG) heritage sites

The **National Archaeological Museum of Cividale del Friuli** uses AR to bring to life the ancient Roman forum and temple complex. Visitors can point their smartphones or tablets at markers around the site to see 3D reconstructions of the buildings, complete with people going about their daily lives.

The **archaeological site of Aquileia**, a UNESCO World Heritage Site, uses AR to allow visitors to explore the ruins of the Roman city in its prime. Visitors can view 3D reconstructions of buildings, statues, and other monuments, and learn about the history of the site.

The **Civic Museum of History and Art in Trieste** uses AR to allow visitors to see how the city has changed over time. Visitors can point their smartphones or tablets at old maps and photographs to see how the city looked in the past, and then step outside and see how it looks today.

The **Basilica of Santa Maria delle Grazie in Grado** uses AR to display information about the church's history and artwork. Visitors can point their smartphones or tablets at different parts of the church to see text, images, and videos that explain what they are looking at.

The **star-shaped fortress town of Palmanova** uses AR to show visitors what the town looked like in the 16th century, when it was built by the Venetian Republic. Visitors can view 3D reconstructions of the walls, bastions, and other features, as well as learn about the town's military history.

First Stolperstein in Trieste with Augmented Reality: This project, initiated in 2021, is a collaboration between Ca' Foscari University of Venice and the Jewish Community of Venice. It involves the implementation of AR with the Stolperstein (stumbling stones) to commemorate Holocaust victims (in this case dedicated to Carlo

Morpurgo), providing an interactive way for visitors to learn about the history and stories behind these memorials. Trieste is the first city after Venice to offer a Stone with such special symbolic value able to tell its story through AR technology.

The Last Supper by Pomponio Amalteo - Augmented Reality App: The Civic Museums of Udine has developed an AR app focused on "The Last Supper" by Pomponio Amalteo for the Gallery of Ancient Art. This downloadable application is based on detailed archival research and aims at reconstructing the provenance and story of the funeral carriage depicted in the painting, offering visitors an enriched understanding of its historical context.

Augmented Reality for the Roman Villa of Torre di Pordenone: A prototype developed for the Roman villa site in Torre di Pordenone uses AR to enhance the visitor experience. This initiative aims to valorise the archaeological site by allowing visitors to explore the villa through a virtual tour, which includes a detailed 3D reconstruction of the Roman building. The AR experience is accessible through video glasses (Head Mounted Display), offering an immersive exploration of the site.

Located in the EmotionHall Arena within the Tiare Shopping Centre in Villesse (Gorizia), the **Pinocchio Immersive Art Experience** space uses AR among other technologies to bring the Pinocchio fairytale to life. Young visitors can experience the story in a dynamic and interactive way, exploring the tale's themes and characters through a series of immersive rooms enhanced by AR, thereby engaging with the narrative on a deeper level.

Virtual Reality (VR) is a simulated 3D environment reality with which users can interact through the use of technological tools (glasses, headsets, gloves, sensors, etc.). It allows users to immerse themselves in a simulated real environment generated digitally with computer and software, enabling them to interact with the surrounding objects, giving the impression of really being in that environment.
Worn head, VR headsets project, these devices project images directly onto eyes, blocking out the real world. Some headsets also track head movements, so that the view in the virtual world mutates as the user turns their head, further enhancing the feeling of being there.

While sight is the dominant sense in VR, other senses can also be stimulated. Some headsets incorporate sound systems to deliver spatial audio, making you feel like sounds are coming from your virtual surroundings. Haptic gloves and suits can simulate touch, allowing you to feel virtual objects. More recently, experts are working on adding the sense of smell to further implement the experience.

VR environments are interactive, allowing un-limited mobility, object manipulation, an interaction with virtual objects, making the experience thoroughly engaging.

VR comes in various forms, such as:

* **Headset-based VR:** The most common type, using dedicated headsets,
* **Room-scale VR:** uses multiple projectors and sensors to create a larger virtual space that users can physically walk around in,
* **360° videos:** offer limited interactivity but provide immersive viewing experiences.

Present technology enables users to engage multiple sensations in a way that approximates reality; it has made significant progress in providing realistic sensory engagement and is poised for business use in a variety of economic and social fields. Generally, VR can be split into the following three categories:

* **Non-immersive.** This type of VR typically refers to a 3D simulated environment that is accessed through a computer screen. The environment might also generate sound, depending on the applied program. The user has some control over the virtual environment using a keyboard, mouse, console or other devices, but the environment does not directly interact with the user. A video game is a good example of non-immersive VR, as is a website that enables a user to design a room's décor;
* **Semi-immersive.** This type of VR provides users with a partial virtual experience that is accessed through a computer screen or some type of glasses or headset. It focuses primarily on the visual 3D aspect of virtual reality and does not incorporate physical movement in the way that full immersion does. This category of VR is used often for educational or training purposes and relies on high-resolution displays, powerful computers, projectors. A common example of semi-immersive VR is the flight simulator, used to train air pilots.
* **Fully immersive.** This type of VR delivers the greatest level of virtual reality, completely immersing the user in the simulated 3D world. It incorporates sight, sound and, in some cases, touch, providing high-resolution content with a wide field of view. There have even been some experiments with the addition of smell. The display typically splits between the user's eyes, creating a stereoscopic 3D effect, and combines with input tracking to establish an immersive, believable experience. Users wear special equipment such as HMD (head mount display) helmets, VR goggles or gloves, and are able to fully interact with the environment.

So, Immersive Virtual Reality technology, on which our attention will be focused, unites the physical world with the virtual one, interacting among them and creating, through the use of devices, a complete 360-degree experience that transports users into digital.

Immersive Virtual Reality employs advanced motion tracking techniques and high-quality 3D graphics.

Users explore and manipulate objects in a natural way, as if they were physically present in the digital environment. This achieves a sense of presence and realistic interaction. VR technology is very versatile. Developers use it to create 360-degree experiences, allowing users to fully immerse themselves in the digital world and actively participate in the projected action.

VR works by combining hardware and software to create a 3D, immersive experience.

Hardware requirements include a high-performance processor, a dedicated graphics card, and a large memory, in order to ensure that the virtual reality environment runs smoothly and without any lag.

Peripherals devices such as headsets are worn by users over the head, occluding the view of the real world and immersing them in a new virtual environment. Moreover, stereoscopic images are generated to simulate 3D vision using high-resolution screens and special glasses.
Other devices are also used to enhance users' interaction and, such as VR tracking (or motion) controllers, which allow for interaction with the virtual world through gestures. A VR controller typically consists of buttons, triggers, thumbsticks, haptic feedback devices (for tactile info) and sensors that track hand movements and translate them into actions in the virtual world. These controllers are designed to be lightweight, portable and comfortable, allowing for extended use without causing discomfort. The position and orientation in space of users' limbs are tracked to ensure realism.

Software is another key element in delivering a continuous virtual reality experience. Advanced algorithms and rendering techniques are used to create realistic visuals and smooth interactions, optimizing the creation of the virtual reality environment, and ensuring that the graphics are rendered in real-time and at a high frame rate, without any noticeable latency, thus reproducing a virtual world that is difficult to differentiate from physical reality. Furthermore, the software also includes features such as spatial audio, which enhances the immersive experience by providing realistic sound effects that change based on your position in the virtual environment. More recently, there is also the option to add new stimuli: new olfactory display devices, such as the FeelReal VR mask or the VAQSO VR scent device, are able to produce and deliver specific smells to the user's nose. Smell synthesis software, like the Smell-O-Vision software or the Scentee Machina smart diffuser, can generate and manipulate virtual smells.

VR technology examples

The main VR devices fall into the category of Headset-based VR. These are divided among:

Standalone VR Headsets

Meta Quest 3 (former Oculus), which offers a comprehensive VR experience without the need for a PC or console, a color pass-through camera for mixed reality experiences, higher resolution, a faster processor and an implemented eye-tracking technology.

Costs: from around 550 euros.

Pico 4, an alternate to the Quest series produced by ByteDance for European and Asian markets, with pancake lenses and a standalone experience.

Costs: around € 450.

Tethered VR Headsets

Valve Index known for its high-quality build and immersive experience, it is considered one of the best VR headsets on the market, especially for immersive VR.

Costs: around € 1.800

HTC Vive Pro 2 offers a high-resolution display and is compatible with Valve Index controllers for a premium VR experience.

Costs: around € 1.100

HP Reverb G2 a Windows mixed reality headset that offers a simple setup and is a solid choice for PC VR enthusiasts.

Costs: around € 750

Upcoming VR Headsets In terms of new products, it is worth considering the newly-launched on market Apple Vision Pro (AR/VR headset with advanced features like eye-tracking and iris-scanning, around € 3.500) and the Spatial reality headset, recently announced by Sony.
Other forms of VR technology include:

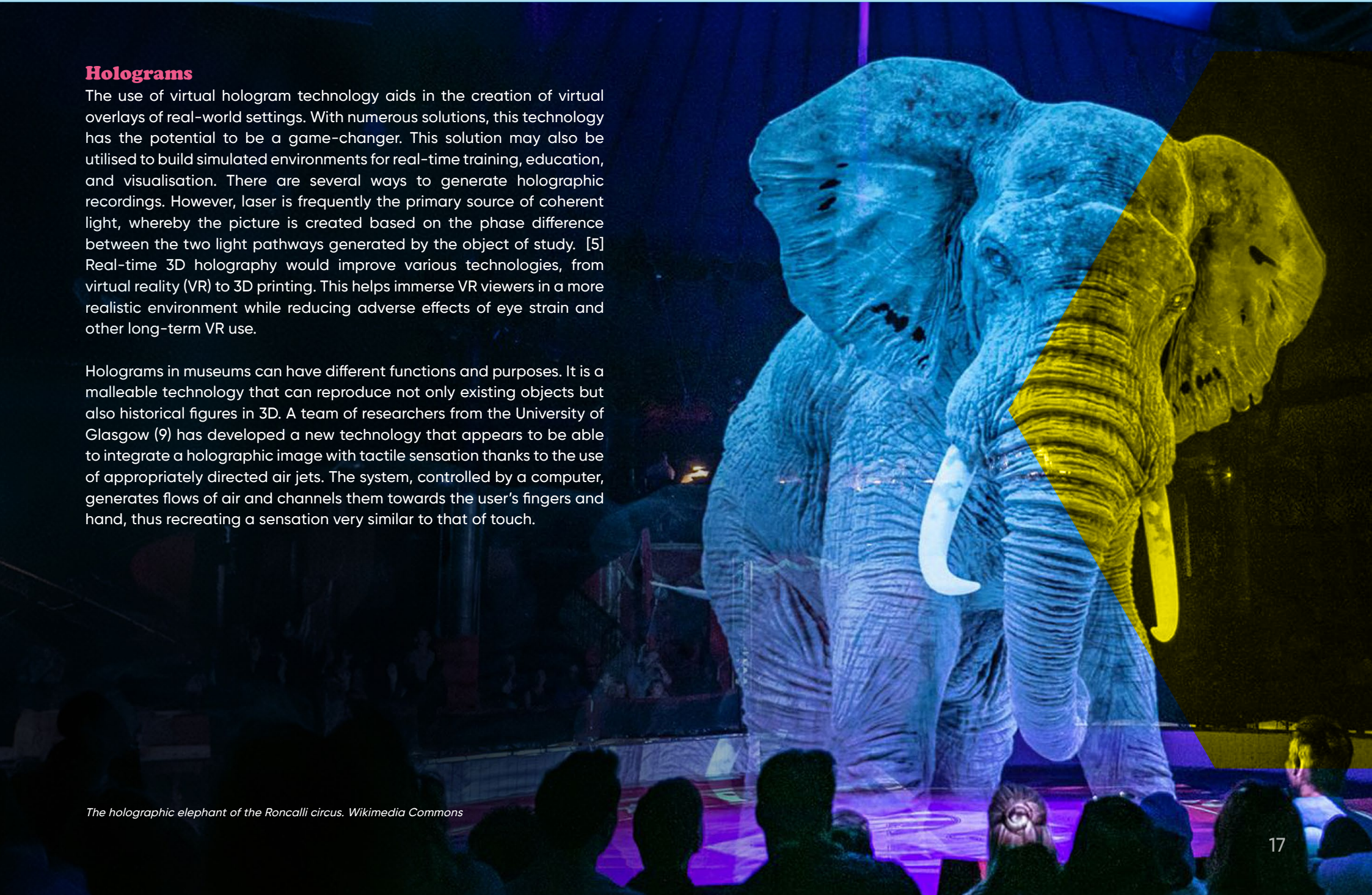
Room-scale, a design (VR) experience, which allows users to freely walk around a play area, interacting with a base station, with their real-life motion reflected in the VR environment. It uses multiple projectors and sensors to create a larger virtual space.

360° video, (or VR video, surround/immersive video), an interactive and immersive content that completely surrounds a user as if they were standing in the middle of a scene where a view in every direction was recorded at the same time and reproduced using an omnidirectional projector or a set of projectors. It offers limited interactivity but provide immersive viewing experiences.

Holograms

The use of virtual hologram technology aids in the creation of virtual overlays of real-world settings. With numerous solutions, this technology has the potential to be a game-changer. This solution may also be utilised to build simulated environments for real-time training, education, and visualisation. There are several ways to generate holographic recordings. However, laser is frequently the primary source of coherent light, whereby the picture is created based on the phase difference between the two light pathways generated by the object of study. [5] Real-time 3D holography would improve various technologies, from virtual reality (VR) to 3D printing. This helps immerse VR viewers in a more realistic environment while reducing adverse effects of eye strain and other long-term VR use.

Holograms in museums can have different functions and purposes. It is a malleable technology that can reproduce not only existing objects but also historical figures in 3D. A team of researchers from the University of Glasgow (9) has developed a new technology that appears to be able to integrate a holographic image with tactile sensation thanks to the use of appropriately directed air jets. The system, controlled by a computer, generates flows of air and channels them towards the user's fingers and hand, thus recreating a sensation very similar to that of touch.



The holographic elephant of the Roncalli circus. Wikimedia Commons

3.2 Creating an immersive projection room

AR/VR (or mixed) technologies are used to create highly immersive, engaging and interactive experiences in specific spaces. These rooms typically consist of large screens and/or projectors that display virtual content and are often combined with motion tracking systems and audio devices to enhance the user's sense of immersion.

Creating an immersive projection room involves a combination of technology, design, and creativity to transform a space into a captivating, multi-sensory environment. This process typically includes the use of multiple projectors to cover walls, and possibly even the floor and ceiling, with continuous visual content, creating an illusion of being inside a different reality.

The first step is to clearly define the purpose of the immersive room. Whether it is for education, entertainment, collaboration, or simulation, understanding the intended use will guide the design and technical requirements.

* **Choose the Right Space.** Selecting an appropriate room is crucial. Considerations include the size, shape, ceiling height, and the ability to control ambient light, since a darker environment enhances immersion. The room's acoustics also play a vital role in creating an immersive experience.
* **The number of projectors needed** depends on the room's size and the desired coverage. For full immersion, high-resolution projectors should illuminate not just one, but several or all of the walls, including the floor and ceiling. The number of projectors depends on the size of the room and the projections you want to have.
* **Projectors are placed strategically around the room**, often on ceiling or wall mounts. The larger the projection area, the more effective the projection looks. Short-throw projectors are often recommended for their ability to create large images from a short distance, minimizing shadows and the space required for installation. Several projectors provide the opportunity to create a panoramic projection and give guests a feeling of total immersion in another reality. For a 360-degree immersive experience, projectors must be carefully positioned to cover all walls seamlessly.
* **Walls or screens serve as the projection surfaces.** In some cases, the room's white walls can suffice, but for optimal results, surfaces may need preparation or specific paint to enhance image quality. Screens used in immersive rooms are typically made of a special material that reflects light without absorbing it.
* **Projection mapping** is a technique whereby digital images or videos are projected onto surfaces, transforming them into dynamic displays. This technology can be used in immersive rooms to create compelling visual environments and provide a sense of depth and realism. Advanced projection mapping techniques can adapt to the shape and features of the projection surface, resulting in seamless and immersive visuals that blend into the physical environment. With the use of multiple projectors, projection mapping can enhance the user's experience by wrapping entire walls or even the floor and ceiling with visual content.
* When using **multiple projectors**, it is essential to blend their images to avoid visible seams. This requires precise calibration and possibly specialized software or hardware capabilities in the projectors to ensure a continuous, unified image across all projection surfaces.

  Edge Blending technology combines the overlapping edges of images, adjusting brightness, color and contrast to achieve flawless uniformity.
* **High-quality audio** is as important as visual elements in creating an immersive environment. The room should be equipped with a sound system that complements the visual experience.
* **Adjustable and programmable lighting** can also enhance the atmosphere and immersion.
* **Incorporating additional interactive elements**, such as motion tracking or augmented reality (AR), can further enrich the immersive experience. These technologies allow users to interact with the content in real-time, making the experience more engaging and personalized.

Once the equipment is selected and the room prepared, the next step is the installation and calibration of the projectors, audio system, and any other technological components.
This process ensures that the visual and audio elements work together seamlessly to create a cohesive immersive experience. Immersive projection rooms can be used for a wide range of applications, from enhancing educational and training programs to providing new forms of entertainment and collaborative workspaces. The flexibility and adaptability of the technology allow for its use in various industries and settings.
Immersive room types can be distinguished as:

* **Virtual Automatic Quarries (CAVE):** fully screened rooms with projectors on all walls and on the ground, for a total immersion at 360 degrees.
  Immersive theatres: rooms with curved or dome screens, often used for flight simulators or virtual reality experiences.
* **Multipurpose rooms:** modular spaces with flexible projection configurations, suitable for different types of events and presentations.
* **Multisensory Rooms:** designed to stimulate various senses, multisensory rooms can incorporate a combination of sight, sound, touch, smell, and even taste elements to create an all-encompassing experience.

It is also important, however, to consider the costs of setting up such installation. This can vary depending on several factors, including the size of the room, the quality of the equipment, the app development complexity and the level of customization desired. It must be considered that:

1. **Basic VR hardware (headsets)** range in price from €500 up to €3.500; further equipment and peripherals (VR gloves, haptic suits, and treadmills), represent an additional expense starting from €100 increasing to several hundred euros based on the complexity and sophistication of the devices. As for PC connection, a robust system with high processing power and an adept graphics card are needed. This necessitates a budget ranging from €1.000 to over €2.000,
2. **Simple VR applications** with the shortest development time (purchasing or licensing) can cost up to €30.000; for more complex apps this cost can be even more than double this
3. **Room set-up** includes costs for arrangement and customization. This can include installing tracking sensors or cameras, setting up audio systems, optimizing lighting conditions, and creating a dedicated space with appropriate flooring and safety measures. The complexity of the room setup and customization will impact the overall cost,
4. **Pre-defined room Scale** AR Costs: €40-50.000 per room,
5. **CG (Computer Graphics)**-based environment applications: €50.000-€70.000 for a standalone VR application with minimal interaction design,
6. **Display and Projection:** Immersive VR rooms often incorporate large screens or projectors to display the virtual content. The cost of these displays will vary depending on the size, resolution, and quality desired. High-quality projectors can range from a few hundred to several thousand euros, while large-format LED displays can be significantly more expensive.

   Maintenance and potential upgrades must also be considered.

Examples of application of VR solutions at FVG heritage sites

In Friuli Venezia Giulia, we have several models of the application of VR technology to enhance the visitor experience and create immersive experiences. The use of VR in museums and castles is still a relatively new phenomenon, but it is rapidly gaining popularity. As technology continues to improve, VR is sure to become an even more powerful tool for museums and castles to use to engage their visitors and share their stories.

The **Miramare Castle in Trieste** offers a VR tour of the castle's interior that allows visitors to explore the museum or castle grounds, walking through the rooms and seeing the exhibits as if they were there in presence.

Udine Castle introduced a VR experience that allows visitors to explore the castle in an immersive way using a VR headset to move freely inside the castle, exploring the rooms, corridors and terraces, learn about the history of the castle and its architectural features and immerse themselves in the lives of the characters who lived in the castle.

The **Museo Archeologico del Friuli Occidentale in Torre di Pordenone** offers a VR experience that allows visitors to see a reconstruction of a Roman villa bringing historical artefacts to life.

The **Musei Civici di Udine** offers a VR tour of the Pinacoteca di Palazzo Manin, which houses a collection of paintings by Italian and European artists not always on display to the public.

The **Museo Revoltella in Trieste** offers a VR experience that takes visitors on a journey through the city's history.

Gorizia Castle offers a VR experience that allows visitors to explore the castle in an immersive way., moving freely inside the castle thanks to the use of headsets. An alternate "education" VR experience version also provides information on the history of the castle and its architectural features.

The **Museo Archeologico Nazionale di Aquileia** offers a VR experience that allows visitors to explore the museum's collection from anywhere in the world.

The **War Museum for Peace of Trieste (Museo Diego de Henriquez)** is a museum dedicated to the history of war and the promotion of peace. The museum uses VR technology in several ways to engage visitors and convey its message. One of the main applications of VR at the War Museum for Peace is the creation of immersive experiences that allow visitors to experience war first-hand by recreating important historical events. The museum offers a VR experience that explains the causes and consequences of wars.

In **Colloredo Castle of Monte Albano** VR offers an experiential journey into the cultural and landscape heritage, through engaging and innovative storytelling, in the immersive room inaugurated thanks to the Interreg Italy-Slovenia MerlinCV project.

In the **Historical Museum of Monte San Michele in Sagrado the Great War** is told through Virtual Reality – an almost unique international experience of 360-degree immersion of life on the front lines.the front lines.

Experience with digital presentation of heritage in Slovenia

In Slovenian tourism, digitisation of cultural heritage, as well as the strategies for the development of Slovenian tourism which bring fresh ideas into the presentation of the tourist offer and cultural heritage through the latest technologies, became an important topic of discussion of tourist offer providers over time. Strengthening the immersiveness and interactivity of the visitor experience has become more of a standard than an exception in tourism. The latest edition of the Days of Slovenian Tourism was also largely devoted to those topics. Tourism 4.0, probably the largest current project and platform in Slovenia, brings together over 190 partners and actively involves the local community in the development and strategy. The entire platform is based on the key points of sustainable tourism pursuant to the Industry 4.0 strategy which focuses on transforming the current tourism industry into a value economy through innovation, knowledge, and technology.

The most important effects of the project are 3D digital captures of cultural heritage units which are available at the website of the Digital Innovation of Cultural Heritage portal. For the town of Koper, for example, 3D models and images of the Praetorian palace, the Church of St Francis of Assisi and the Tavern were created. Virtual guides are probably the most widespread method of use of the integration of modern technologies into the tourist presentation of cultural heritage. The Nexto Guide application, for example, allows the user to select a location and then provides them with interactive tasks and quizzes that the user must solve by observing their surroundings, as well as with simulated discussions between historically famous people from a certain location (e.g. a discussion between the young Giuseppe Tartini and his father at the location of the Tartini monument in Piran). On a related platform, the Immersum application was also developed, enabling a virtual guided tour of the history of ancient Emona, in the framework of which the user can put themselves in the shoes of a Roman slave. In cooperation with the company Arctur, the Regional Museum Goriški muzej similarly developed MALT, an augmented reality application. The application offers a new way of exploring the sights of Nova Gorica at 17 locations once the visitors approach them at a distance of 10 metres or less. The "Most skozi čas" (Most through time) project application proposing digital walks and guided tours of the cultural and natural heritage of the town Most na Soči also works in a similar manner. The application Aviko Štanjel, the digital guide of Štanjel, also functions in a similar vein: Aviko, a child from the prehistoric times, takes you on a walk around the village castle and its surroundings, providing you with information and directing the tour by triggering eight information points located in the user's surroundings.

VR technology is constantly evolving, becoming more affordable, realistic, immersive, and accessible. Further advancements are predictable in the use of wireless headsets, higher resolution displays (for sharper and more realistic visuals), field of view, haptic feedback, brain-computer interfaces (aimed at a direct control of virtual environments with users' thoughts), making the virtual experience even more immersive. AI will also further combine Augmented Reality, which overlays digital information on the real world, with Virtual Reality, creating an even more composite mixed reality experience.

3.2.1 The Forerunners of Digital Immersive Rooms: Disney Parks

In the digital age, where technology pervades every aspect of our lives, one might think that the immersive experience is relegated solely to the virtual world. However, analog realities with the ability to transport us into fantastic worlds and entirely engage us, such as theme parks, have long existed. Within some of these parks, there are "analog immersive rooms"; the forerunners of digital experiences, which represent a combination of reality and fantasy, stimulating the senses and creating unforgettable emotions.

Theme parks are the most striking example of analog immersive rooms. Through elaborate sets, special effects, animations, and interactions with characters, visitors are catapulted into imaginary worlds, experiencing exciting adventures and letting themselves be transported away their imaginations.

Analog immersion refers to the ability to create an engaging and realistic experience using non-digital means. In Disney parks, this is achieved through a series of elements:

* **Elaborate sets:** Disney attractions feature meticulously detailed sets that faithfully recreate the environments of Disney movies and characters.
* **Special effects:** the use of special effects, such as lights, sounds, smoke and water, contributes to creating a realistic and immersive atmosphere.
* **Animations and interactions with characters:** Disney characters are an integral part of the immersive experience. Visitors can meet their favorite characters, interact with them, and take souvenir photos.
* **Engaging stories:** each Disney attraction tells a story that transports visitors to a fantasy world and makes them experience exciting adventures.

The origins of immersion: research and innovation

At the heart of the success of Disney parks lies a long history of research and innovation. **Walt Disney, the founder, was a pioneer in the field of animation and special effects and, from the very beginning, he invested in creating immersive experiences for his visitors.** A research division was created withing the Disney parks dedicated to the study of animatronics, the technique of animating mechanical puppets. This division developed innovative technologies that made it possible to create realistic characters that could interact with visitors. In addition, Disney parks were among the first to use film projections to create immersive experiences. For example, the 1953 attraction "Peter Pan Flight"; used a stereoscopic projection system to make visitors fly over London. It can be said that Disney parks were the forerunners of modern immersive rooms. Their ability to create immersive and realistic experiences using non-digital means has inspired the development of new technologies and paved the way for new forms of entertainment. Today's digital immersive rooms use advanced technologies such as virtual reality and augmented reality to create even more immersive experiences. However, the basic principles of immersion, such as the use of sets, special effects, stories and interactions, remain the same. Theme parks continue to represent a benchmark for immersion, proving that magic and imagination can be brought to life using both analog and digital means.

A striking examples are the famous Disney Parks, where each attraction represents an immersive journey into an iconic setting, from the Pirates of the Caribbean to the world of Toy Story.

Disneyland Paris, for example, boasts the innovative "Star Wars: Galaxy's Edge"; attraction, where guests can explore the planet Batuu, interact with droids and characters from the saga, and even pilot the Millennium Falcon.

3.3 The inclusive potential of new immersive technologies: engaging people with disabilities, and hearing and visual impairments in Augmented and Virtual Realities

While augmented and Virtual reality offer immersive experiences, they can sometimes be inaccessible for people with disabilities, or hearing or visual impairments. However, with some precautions, it is possible to make AR/VR inclusive and accessible to all.

For visitors with hearing problems:

* **Audiovisual feedback:** provide visual feedback for audio events, such as subtitles, icons, or vibrations. Incorporate virtual guides or characters who use sign language.
* **Spatial sounds:** use the position of the sound to convey information, helping orientation in virtual space.
* **Volume control:** offer the ability to adjust the volume or activate subtitling for all sounds.

For visitors with visual problems:

* **Voice commands:** allow you to interact with the virtual environment using your voice.
* **Integrate high-quality audio descriptions within the VR experience**, synchronized with the user's movements and gaze.
* **Accessible user interface:** enlarge texts, use contrasting colours and provide audio feedback for interactions.
* **3D Tactile Models:** develop 3D printed models of key exhibits or architectural features that visitors can touch and explore, providing a physical understanding of the space.
* **Haptics feedback integration:** using tactile feedback to convey information about objects and surfaces, simulating textures, vibrations, and temperature changes, enriching the sensory experience.

For visitors with combined sensory impairments:

* **Multimodal Experiences:** combine elements like audio description, haptic feedback, and text overlays to create layered experiences catering to different sensory preferences.
* **Choice and Control:** allow users to customize their VR experience by choosing their preferred combination of accessibility features and information delivery methods.
* **Inclusive Design Principles:** adhere to accessibility guidelines throughout the VR development process, ensuring compatibility with assistive technologies and usability for diverse audiences.

Other precautions:

* **Guides and tutorials:** provide guides and tutorials accessible in different formats (text, audio, video) to facilitate learning the AR/VR experience.
* **Adjustable sensitivity:** allow you to adjust the sensitivity of motion and tracking to suit individual needs.
* **Accessible AR/VR spaces:** ensure that the physical spaces in which the AR/VR experience takes place are accessible to people with mobility disabilities.
* **Sensitivity Training:** train museum staff on how to interact with visitors with sensory disabilities and provide support effectively.
* **Clear Signage and Communication:** ensure clear signage and communication within the physical museum space to guide visitors towards accessible VR experiences.
* **Collaboration with Disability Communities:** involve communities of people with sensory disabilities throughout the design and development process to ensure their needs and preferences are met.

With a little care and effort, AR/VR can become a truly accessible and engaging experience for everyone, regardless of their abilities.

Furthermore, when considering any type of disability, it is important to highlight the following key general principles:

* **Raise public awareness:** promote the importance of accessibility in AR/VR and raise awareness of the inclusive experiences available.

* **Investment in technology:** develop more accessible and easy-to-use AR/VR technologies.
* **Engage the community:** collaborate with people with disabilities and visual impairments to design and test inclusive AR/VR experiences. Following a user-centered design approach, co-design approaches are fundamental to integrate multiple perspectives related to lived experiences, which is extremely important when designing with people with different abilities.
* **Involve a multidisciplinary team, including for example experts in:** UX design, Special Education and Easy-to-Read guidelines, virtual reality application design, art history, learning disabilities and intellectual disabilities.

Considering the potential of the pedagogical role of immersive rooms, **the focus should be on the experimentation of innovative forms of support for inclusive didactics, concerning the design of accessible contexts and integrated technological systems capable of promoting accessibility, usability, and sustainability.** The Inclusion 3.0 project summarizes the main design criteria to ensure the accessibility of immersive virtual museums to people with disabilities and Specific Learning Disorders (SLDs) [8], considering i. exhibits feature and presentation, ii. content presentation to promote a better understanding, and iii. access to VR applications, as presented in Fig. below.

Exhibits	Content	Access to VR application
• Generous room design • Call for action • Enough space between exhibits 360° view of some exhibits • Economical use of effects • Easy to handle • Use of different media • Movies in simplified language	• Easy-to-read information • High-contrast layout • Big font • Text-to-speech system available • Visualization with pictorial language • Information material should be colorfully illustrated	• Enable people to edit brightness of their display • Provide customized high contrast skins for the environment to suit luminosity and color contrast requirements • Allow multiple input methods to be used at the same time • Applications should support multiple locomotion style • Ensure fine motion control is not needed to activate an input • Ensure field of view in immersive environments, are appropriate, and can be personalized - so users are not disorinetated • Avoid VR simulation sickness triggers

Design criteria to ensure accessibility of immersive virtual museum

Sensory-friendly spaces build on Universal Design principle by making the environment accessible from a sensory standpoint. Sensory-friendly environments engineer sensory stimuli in a way that empowers neurodivergent visitors to fully participate, engage with the physical space, and optimize their visit.

3.4 Sustainability and economic impact of sensory installations

Museums have considerable social significance, as they play an important social and cultural role through wide-audience exhibitions. To achieve its social and cultural value, today's museum must be sustainable to ensure continuous operations with the lowest possible environmental impact.
Through digitalisation, museums have the potential to become true hubs of sustainability, fostering a sustainable and respectful engagement with the environment and with the local community.
The design of immersive rooms must also take into account the environmental impact of the technologies used. Various solutions allow us to reduce energy consumption and make these experiences more sustainable.

Energy consumption: it is important to design sensory installations with attention to energy efficiency, using low consumption technologies and optimizing the flows of light and sound.

3.4.1 Resource saving techniques

Choice of eco-friendly technologies: opt for solutions that reduce environmental impact, such as LED screens and low-energy lighting systems.

Consumption optimization: implement intelligent energy management systems to monitor and optimize energy consumption based on needs.

Public awareness: promote eco-responsible behaviour among visitors, inviting them to turn off electronic devices and reduce the use of disposable materials.

Off-grid generators: for remote sites without access to the electricity grid, it is possible to use generators powered by renewable sources such as solar or wind energy.

Non-technological techniques: the use of scenographic elements, natural lights and sounds can help create an immersive atmosphere without excessive energy consumption.

Immersive fragrances: the use of natural fragrances can evoke atmospheres and sensations linked to the historical or cultural context, reducing the need for energy technologies.

Some examples of low energy consumption interactive museums are:

Museum of Natural History, London (UK)

www.nhm.ac.uk/visit

Uses LED lighting systems and motion sensors to reduce energy consumption.

Victoria and Albert Museum, London (UK)

www.vam.ac.uk

Employs energy-efficient augmented reality technologies to deliver interactive experiences to visitors.

Cost and benefits: sensory and immersive installations may require a significant initial investment, but can generate a positive economic return in terms of increased visitors, audience loyalty and merchandising.
One of the underlying reasons for the shift towards edutainment by heritage and museum institutions is budgetary. The amount of funding these institutions receive – if any – often depends on their attendance levels, which puts them under constant pressure to maintain or increase attendance figures. Museums therefore strive to attract new audiences, with an emphasis on younger visitors, by offering more entertaining and interactive displays. In this perspective, it is important to be careful not to fall into the risk of the so-called "Disneylandization" (10), to shift from the didactic to the spectacular.

4. Example of innovative immersive rooms and museums based on different user experiences

The past few years have seen an increase in the use of virtual reality (VR) in museum environments, reflecting an attempt by museums to embrace technological innovations, adapt to the challenges of the digital era and democratize and open up their collection. Nowadays not only have the largest museums in the world (Louvre, Vatican, British National Gallery, etc.) have implemented virtual and interactive environments but domestic museums are also succeeding in keeping up with the times and technology. In this section we aim to provide relevant examples of immersive rooms in relation to the different user experiences they create, exploiting digital and analogue technologies. As we have seen, an interactive digital medium allows various forms of navigation, assembly, and contribution to the artwork itself, which go beyond the traditional ways of experiencing art. It is often dynamic, in that it can respond to its audience. It can be participatory, relying on multi-user input. It can be customizable and adaptable to a single user's needs, to a scenario, or to the venue it is exposed in [11].

Immersion can be defined as **the physical feeling of being in a virtual space.** Usually it is achieved by means of sensory interfaces, which "surround" the user. Interaction is related to the user capability of modifying the environment and receiving a feedback to their actions.
Both immersion and interaction concur to achieve what is one of the main goals of a virtual experience: presence, i.e. the belief of actually being in the virtual space. The "immersive experience" is obtained when the scope and resolution of the imagery allows the viewers to leave the center of their focus, discovering and examining details of the scene and its context, in an entirely captivating environment. Large-scale displays for example are able to almost fully immerse their users in the space around them as if it were a computer-generated scenery, thus transforming the space in front of them into an interactive and, potentially, collaborative canvas.
VR, in particular, replicates an environment that simulates the physical presence of the user. The perception of this virtual world is created by surrounding the user in artificial sensorial experiences, including sight, hearing, touch, and smell. Immersive experiences have the unique ability to evoke emotional responses. They can increase empathy among visitors, making for example an historical events they recount more relatable and

By placing visitors in the midst of historical reconstructions, museums can create powerful social experiences, whether experienced in groups or alone.

As argued by Balcerak Jackson & Balcerak Jackson (2024) (21), in order to achieve this emotional response, there are four distinct types or aspects of immersive experience that should be distinguished:

1. Representational immersion which corresponds roughly to what is sometimes called "psychological presence": VR immerses you in a three-dimensional world you can see and hear as if you existed within it, creating mental models and putting the subject into a state of mind that is very much like the one you would be in... if you really were in that world. Some examples:

Immersive room in Villa Valmarana ai Nani, Vicenza

Where: Villa Valmarana ai Nani (VI) - When: permanent
Technology: Virtual reality
Experience: B2C generic
Created by Senso Immersive Experience
www.youtube.com/watch?v=UiZwQvLBO1M

A journey through time surrounded by Tiepolo's frescoes, illustrious figures such as Giustino Valmarana and Antonio Fogazzaro, who walk through the frescoed rooms of the Villa, and by noble girls engaged in elegant waltzes in the Salon of Ifigenia.

Van Gogh Multimedia Experience, Venice

Where: Palazzo Giustinian Faccanon (Mercerie of San Salvador) - When: from 2 June to 30 September 2018
Technology: Virtual reality
Experience: B2C generalist
Created by Navigare company and curated by Giovanna Strano

A multimedia exhibition at Palazzo Giustinian Faccanon dedicated to the Dutch artist. For the first time in Venice, "The life and works of Van Gogh" was presented by Multimedia Experience.
Together with the visual impact of the 700 images of the exhibition and the 3D reconstructions, the evocative power of the soundtrack created by the Brazilian master Marcello Cesena, broadcast by a latest generation Dolby Surround system, were used to immerse the visitors inside the works, making them discover, and almost touch, the painter's technique, images, sounds and words, in an itinerary of approaching the artist's profound humanity.
The music serves to generate a rich range of emotional and affective responses its listeners. Music can be particularly effectively immersive because of the potent way it combines our emotional responses with the moods of the music and the story it tells.

Atelier des Lumières, the exhibitions

Where: 38 rue Saint-Maur 75011 Paris - When: The temporary exhibitions are renewed periodically. Current exhibition: "The Orientalists, Ingres, Delacroix, Gérôme" - from 9 February 2024 to 5 January 2025
Technology: Virtual reality
Experience: B2C generalist
Created by Culturespaces Studio ® / Artistic Direction: Virginie Martin / Design and production: Cutback / Music supervision and mixing: Start Rec
www.atelier-lumieres.com

Digital projections of bespoke artistic masterpieces envelop audiences in spectacles of light and color. In the 19th century, the doors of the Orient opened to Western painters attracted by the mysteries of far off lands. Dazzled by the light of the far south, which reveals the topography of these arid landscapes and highlights the colours of the buildings' spectacular motifs, Orientalists like Delacroix, Gérôme and Ingres, and other major names from European expressionism, now invite you to embark on a pictorial expedition to the new, exotic and bewitching world of the Orient of our dreams. Delacroix's travel diaries begin the tale, immersing you in an itinerary steeped in the play of light and shade, the scent of spice, the rhythm of oriental instruments and quick sketches of hitherto unseen lives.

2. Participatory immersion, which is related to the interactive aspects of VR experience. Means to become part of it, in the sense of being an active participant, an agent whose actions help determine what that virtual world is like, how events unfold in it, and how IT experiences it. Some examples:

A multimedia room at the Filanda museum, Salzano, Veneto Region

Where: Salzano - When: Permanent
Technology: Virtual reality - interactive projection
Sustainability: The eco-sustainable setup is particular since the furnishings were made entirely of cardboard, a warm, natural and ecological material.
Experience: B2C (generic)

An innovative installation, a "magical place" in which a poetic and evocative graphic of virtual butterflies, designed by the architect Lorenzo Greppi of Fiesole, accompanies the visitor in experiencing new contents linked to silk, its production, and the protagonists who designed the ancient factory symbol of Salzano. An interactive projection characterized by a visual of butterflies, symbol of the spinning mill, guides visitors in the discovery of three video insights that can be activated, through motion sensors, without the use of touch. The visitor becomes the protagonist of a real experience by reliving what work was like in the ancient silk factory.
Particular attention was paid to young people and families, as well as people with disabilities.

It is both a "traditional" and "innovative" museum: "traditional" because it involves the display of materials and machinery specific to sericulture and spinning, and "innovative" because videos and animations, texts, music, sounds and noises allow acoustic/visual involvement and more complete enjoyment for both disabled and non-disabled people, through the use of technology, which in this case breaks down physical and perceptive barriers.
A playful interaction allows a new approach to museums and captures the attention of children and young people.

The contents were shared with the Romanin-Jacur family, the Padova Ebraica Foundation-Museum, the Experimental Bacological Station of Padua, the Serinnovation network, the Museum of Modern Art in New York and the Confcommercio del Miranese which gave birth to the Commercial District of the Silk Road. A network that is part of the Italy-Slovenia 2014-2020 cross-border cooperation program which, with the "Merlin CV Project", has allowed particular funding from the European Commission. Italian and Slovenian partners have thus put together their know-how and experience with the aim of building new paths to increasingly and effectively enhance the excellence of tourism with a view to enhance and attention to the environment.

3. Affective immersion, which relates to the subject's emotional relation to the experience: as the subject engages emotionally with the people and events she encounters in VR. For example:

The Anne Frank House in virtual reality

Where: Amsterdam and online - When: permanent
Technology: VR app
Experience: individual
www.annefrank.org/en/about-us/what-we-do/publications/anne-frank-house-virtual-reality

The Anne Frank House in Amsterdam employs multimedia installations and VR reconstructions to share Anne's story, fostering empathy and understanding among visitors. You can explore the hiding place of Anne Frank and her family in virtual reality using the 'Anne Frank House VR' app. The app provides a very special view into the Secret Annex where Anne Frank and the seven other people hid during WWII.
In the VR app, all of the rooms in the Secret Annex are furnished according to how it was when occupied by the group in hiding, between 1942 and 1944. Everything was carefully built and modelled in 3D by Vertigo Games, the creators of the app.
The virtual reality tour takes about 25 minutes, it is available in seven languages: Dutch, English, German, French, Spanish, Portuguese and Hebrew, and is free of charge. The VR app is suitable for Oculus Rift and Quest, Gear VR, Steam and PICO.

Frida Kahlo exhibition, Lichthalle MAAG in Zürich

When: from 21 September 2021 to 2 January 2022
Technology: Virtual reality - high-performance projectors
Experience: Generalist
www.fridakahlo.it

The "Viva Frida Kahlo" – Immersive Experience exhibition is being staged at the Lichthalle MAAG in Zurich, the first immersive art experience museum in the country. Frida Kahlo stands for a tragic personal fate, and is perceived to be in close connection with the women's movement. Her paintings – a total of 144, of which 55 are self-portraits – fascinate with their folk character, exuberant colors and accessible symbolism. In her paintings, Kahlo worked out her own suffering; in fact, her small symbols often refer to her wounds. Through an immersive presentation with video projections and light and sound effects, images come to life in the projections, while a voice-over playing the role of Frida Kahlo comments on the events with a specially composed soundtrack that functions as the presentation's acoustic background.
The new Lichthalle MAAG uses high-performance projectors to project images onto walls, columns, ceilings and floors up to 10 metres tall and 34 metres wide, to create a breath-taking 360° experience.

4. Narrative immersion which captures the phenomenon of being caught up in the flow of events experienced. A VR experience is narratively immersive when and to the extent that the subject's experience in VR has a coherent narrative structure and flow.

A fundamental aspect of immersive museology is in fact storytelling. The key lies in using technology to craft compelling narratives that resonate with visitors on a deeper level. Some examples:

Historium Brugge, Belgium

Where: Brugge, Belgium - When: permanent
Technology: Virtual reality – 4D experience
Experience: B2C/generalist
www.historium.be

This is an immersive experience that will transport you back in time to 15th-century Bruges, recreated with realistic sets, special effects and immersive animations. You'll be able to explore the city as it was back then and even interact with some of its residents using your virtual hands.

In **"The Historium Story"** you'll be swept up in a wonderful medieval love story as you walk through seven historical themed rooms, complete with magnificent medieval backdrops, film, music and special effects.
Using the audio guide, you will learn all about the Golden Age of Bruges and you will feel like you are really travelling back to the time of Jan Van Eyck, one of the great Flemish painters, whose paintings inspired the reconstruction of the rooms.

Sensorial interaction: a 360-degree museum experience

Sensory interaction represents a new frontier in museum setups, with the aim of involving all of the visitors' senses and creating a deeper and more immersive experience. The use of fragrances, sounds, vibrations and other sensory elements allows us to reconstruct an environment or historical contexts in a more realistic way, to convey emotions linked to works of art and to facilitate the learning of complex contents. The analysis of case studies of successfully-created immersive rooms allows us to identify the most effective technologies and the models of use most appreciated by the public.

Live Sketchbook:
"Night safari" - Dubai's Arte Museum Digital Canvas
Where: Dubai, United Arab Emirates - When: permanent
Technology: Virtual reality - touchscreens
Experience: B2C generic
dubai.artemuseum.com/LIVESKETCHBOOK

The Live Sketchbook exhibit is an interactive experience that allows visitors to unleash their inner artist by creating their own art relating to the theme of "night safari". The Live Sketchbook exhibit uses a combination of projection technology and touchscreens to create the immersive experience. Visitors can create their own animal sketches on paper, then scan their artwork to see it come to life on the big screen.
Multi-sensory Safari Experience: The scent of wet soil is diffused through a scent machine, filling the exhibit with an evocative aroma. Visitors can watch their scanned drawings transform into moving creatures on the exhibition walls, surrounded by the sights and sounds of a peaceful jungle.

Other original examples:

Bassins de Lumières : an example of of re-use

Where: Bordeaux (France) - When: Permanent
Technology: Virtual reality/AR etc...
Experience: B2C (generic)/ Generalist
A former World War II submarine base, where the largest digital art center in the world was inaugurated on 17 April 2020. Responsible for this project, which represents a true homage to contemporary art, is the Culturespace Association, a private leader in the promotion of cultural events. They deserve the credit of reignited public interest in submarine warfare structures a submarine warfare structure.

Le Petit Chef, in Como - dinner-show with 3D projections

Where: Hilton, Lago di Como - When: permanent
Technology: Virtual reality - 3D Projection Mapping
Experience: B2C
What: Le Petit Chef is only 6 centimetres tall and will never grow. Thanks to the latest generation of technology, known as 3D Projection Mapping, you will witness the preparation of your dish live. In fact, the table transforms into the place where the little chef prepares his delicacies right on the plate. Skullmapping tells stories with incredible visual effects to create an unprecedented, immersive and engaging gastronomic journey. The show also features with specific musical themes and a succulent and exquisite five-course menu.

Boutique Dolce&Gabbana – VR and fashion

Where: Corso Venezia 7, Milano - When: permanent
Technology: Virtual reality
Experience: Generalist
Using animated images, expressive videos, scenic element transformations, interactivity, worlds built with a surreal mix of settings and performers, and visual characteristics inspired by the fashion collections, the Corso Venezia 7 boutique immersive room creates an innovative experience for the consumer, allowing them to completely immerse themselves in the world of Dolce&Gabbana. The room recreates the fashion house's four emblematic and iconic themes: Leopard, the Sicilian Cart, Zebra, and Mediterranean Blue. It is an all-encompassing customer experience that was made possible by the Dolby Sound System and the room's layout comprised of two spacious areas. The first room measures 2.5m x 3.75m while the second is 3m x 3.75m. Both are 2.5m, representing a total of 71,875 m2 of installed LED.
The immersive room was set up by M-Cube, a company specializing in-store digital engagement solutions, which boasts more than 45,000 installations worldwide, many of which are related to fashion & luxury.

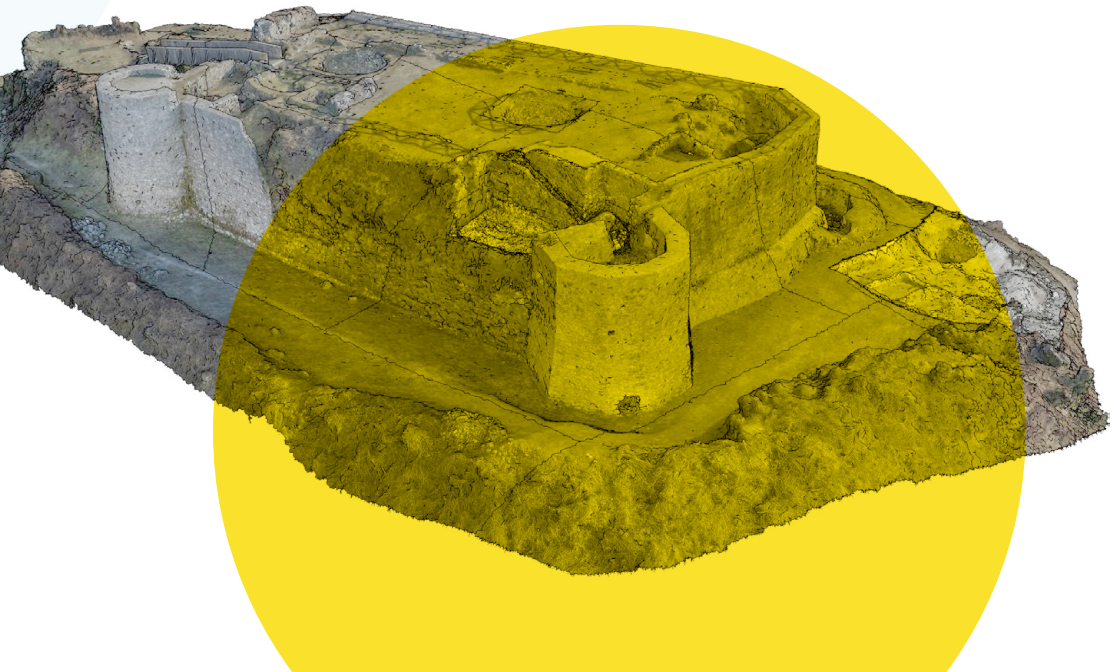
These examples illustrate how museums, leisure and fashion locations have been experimenting with a range of technologies to generate novel kinds of encounters with artworks and heritage, so as to develop more participatory and immersive experiences.
Some of these experiences augment the world of the viewer by relocating them to places which no longer exist, or are too remote, or dangerous, while others encourage them to experience a piece of art from within or see elements of it which are not visible to the naked eye. Some also encourage viewers to relate an exhibit to the physical world or offer a multisensory experience or, alternatively, make it possible for them to adopt multiple roles. Interestingly, some exhibits also use all these strategies concurrently, turning the act of visiting into an active experience in which visitors become the performers of the work, often in collaboration with other visitors.

Within these deep spaces, which are occupied not only in the museum but also, increasingly, in the metaverse, outside of the museum, visitors continuously reposition themselves in time and space, recreating their presence, and thus their self in the world accordingly.
Looking ahead, the future of museology holds endless possibilities. Imagine holographic displays allowing visitors to converse with historical figures or AI-powered guides personalizing museum experiences based on individual preferences. In summary, immersive experiences are redefining the museum landscape, transporting visitors through time, space, and imagination.

As technology advances, museums will play a crucial role in preserving the past, inspiring the present, and shaping the future of our collective history.

In an era where digital media dominates entertainment and education, museums are experiencing a resurgence. They are captivating new audiences by transforming historical narratives into dynamic, immersive experiences.

5. Design of the immersive room for the Tolmin Castle "case study": key principle and technical aspects"



The Venice Charter (1964) expanded upon the conservation concept, underlining the need to have an active conservation, understood as monument integration with the social life and its dynamics of change, stating: "The conservation surrounding monuments is always facilitated by making use of them for some socially-useful purpose". **Sustainable re-use of historical ruined sites is an essential component of heritage conservation efforts.** Museums have several functions as custodians of heritage and culture, and disseminators of knowledge about heritage. They offer visitors a diverse range of experiences including visual, sensory, esthetic, recreational, sociable, educational, celebrating and enchanting. Worldwide, museums are experiencing declining attendance due to increasingly demanding consumers with becoming shrinking leisure time and a wider range of entertainment options. Determining and establishing the appropriate strategy, objectives, actions and implementation structures to manage and, where appropriate, develop cultural heritage in an effective and sustainable way is fundamental for these values to be retained for present and future use and appreciation. This implies a consideration of the cultural heritage needs, with the needs of the 'users' of the heritage and the responsible governmental and/or private/community bodies. [11]
Through the description of the development phases of the Tolmin Castle project, we want to provide a concrete "action plan" that guides the reader through the different steps needed to create an immersive room for experiencing cultural heritage in an effective and sustainable way, starting from the definition of the objectives, up to the technical realization.

5.1. Aspects to consider in the design process of the immersive room

Over time, consumer needs have evolved from commodities and products to services, and from services to experiences. Consumers now desire holistic and long-lasting personal experiences that combine affective memories, sensation and symbolism.

When considering the "experience" in the field of museums and cultural heritage, **four main experience economy realms** need to be considered [11]: **education, entertainment, escapism and esthetics.** In particular, the so called "edutainment"(a neologism created from the combination of education and entertainment) is the most important experience realm in determining visitors' satisfaction, revisit intention and word-of-mouth intention. [13] Nowadays, the development of all these realms requires organizations to add value to their offerings and provide customers with memorable and satisfactory experiences that engage them on an emotional, physical, intellectual and spiritual level.
From this perspective, in the definition of an immersive room, two fundamental continuous dimensions must therefore be considered that characterize the museum visitors' experience: **participation and connection.**

A switch from passive to active participation: instead of simply being "there", visitors are involved in participating, learning and experiencing the "there". [14] Museums need to go beyond collection, research and exhibition functions to engage in experiential marketing.
Connection, the second dimension, comprises two extremes - absorption and immersion. Being absorbed in an experience implies being mentally involved in the experience, such as watching a live cultural dance demonstration, while immersion implies being physically involved in the experience, for example, when participating in such cultural dancing.

The concept of "presence" is crucial to understand the operation of museums, while the use of digital technologies has completely revolutionized the concept. The functioning of presence in virtual environments indicates the degree to which participants feel that they are somewhere other than where they physically, all while experiencing a computer generated simulation.

Digital museum spaces should be augmented, performative and relational, operating as microscopes, by bringing visitors closer or even inside artworks, and/or as telescopes, making it possible for visitors to experience remote artworks or heritage sites.

These new spaces allow for the creation of deep areas that can be encountered both inside and outside the museum, constantly renegotiating visitors' continuous repositioning of their own presence across different temporalities and spatial configurations. [15] Virtual augmented, and mixed reality environments in which presence is experienced can consequently be described as "networks in which people and things construct themselves mutually". [16] Digital artworks often consist of augmentations, of a museum gallery that superimposes digital and physical spaces. These augmentations are activated by visitors who become the performers of the work. What is exhibited is no longer an object, but rather an environment which responds to one or multiple users who often find themselves literally inside the artwork.

In the following case study, the key steps that Castle managers undertook during the design and implementation of the immersive project room include:

Step 1
Identifying cultural heritage assets with potential for development through digital technologies.

Step 2
Brainstorming potential ideas in collaboration with digital product developers.

Step 3
Presenting and coordinating the developed ideas with cultural heritage institutions.

Step 4
Securing financial resources for the project.

Step 5
Finalizing the project plan based on approved funding.

Step 6
Selecting a service provider and executing the project.

Step 7
Evaluating the completed project and considering ideas for further development of the chosen site or alternative locations.

5.2. Case Study: a mobile immersive/multimedia room for Tolmin Castle

Kozlov rob, called "Grad" (castle) by locals, has incredible historical and cultural significance, and is a popular recreational area in the Tolmin basin.

The castle building, mentioned for the first time in the 12th century, has hosted the patriarchs of Aquileia, the counts of Gorizia and Cividale, the Venetians, and the Habsburgs over time. Since the castle, today declared a cultural monument, has changed hands repeatedly over the years, its architectural appearance has also changed several times, especially following the serious earthquakes of 1348 and 1511. It was last renovated in 1608 by the nobles of Dornberk.

In the second half of the 17th, under the rule of the Coronini family, the castle was abandoned. In recent years, the ruins of the castle have been gradually reconstructed.

Restoration to active use of historical ruined sites may be the most viable way to ensure their continued existence.

A bird's eye view of the remains of the castle on the Kozlov rob hill © 2024 Stik Group". ©Skupina Stik

A bird's eye view of the remains of the castle on the Kozlov rob hill and the town of Tolmin in the valley ©Jošt Gantar

A bird's eye view of the remains of the castle on the Kozlov rob hill ©Jošt Gantar

3D visualization of the Kozlov rob castle (by Peter Leban) in XVII century during the restoration works by Gasper Vid Dornberski

Throughout the restoration and re-use project of Tolmin Castle, the fundamental principle of **"Preservation of Authenticity"** was applied by adding a contemporary layer. This layer sought to provide both value and respect in terms of the future, while also aiming to retain the building's significance as far as its heritage was concerned.
The project also respects the basic tenets of **sustainable development** that relate to the attention paid to the environment and consumption of resources, as well as to the enhancement of social cohesion, wellbeing, creativity, economic appeal, and promoting understanding between communities. Furthermore, as a place of memory, and a treasured space for the community, these Tolmin castle experiences will be accessible and welcoming to everyone. **Accessibility** is not limited to the purely physical point of view but also includes the aspects of cognition and usage.
The use of modern technologies is an innovative and effective example that perfectly responds to the needs of bringing historical ruined sites back to life, adding value for contemporary society, in a non-invasive and sustainable way that respects the authenticity of the cultural heritage.
Each site has its own individuality, and therefore requires an independent approach. The form of re-use seen in relation to Tolmin castle was studied based on the specific characteristics of the buildings and contexts, thus privileging a **cultural and educational function, combined with the entertainment aspect** (edutainment), finding the right balance to offer a truly meaningful experience without turning the museum into a meaningless theme amusement park, [17]
Nowadays, Virtual Reality is used more and more frequently as an education, divulgation or storytelling tool, as information is not mediated by linguistic codes but conveyed mostly by sensorial feedback (images, sounds, etc.) and therefore easily understood even by non-specialized users.
One aspect to consider when designing a VR experience that re-creates a time in history is that it must abide by specific standards of scientific accuracy and ethics criteria. This also relates to concerns repeatedly raised by museum professionals regarding the authenticity of the experience offered. [17] In many cases, the amount of information needed to create a VR is very large and not always available. Thus, curators and other scientists will have to make interpretive choices which, if not made carefully and based on specific criteria, may result in a VR which is only meant to recreate and not to enlighten, educate or even immerse the visitor.
The creation of an immersive VR room will therefore allow Tolmin Castle:

* to be used for training and educational activities aimed at schools (workshops, trips, guided tours) or universities (visit to restoration sites, training on restoration techniques)
* to return to play a fundamental role in the social and cultural life of the community
* to become tourist attraction.

Castle Kozlov rob, current state

Castle Kozlov rob, rennovation plan (2025)

Castle Kozlov rob, rennovation plan. ©Simon Kutin

We want to use Virtual Reality to create a sense of immersion in habitats and environments that no longer exist, so as to literally make it possible for visitors to penetrate the historical site and explore it from within.
An **interdisciplinary team** dedicated to the development of the immersive room has been established to bring a variety of expertise, including:

An Astrophysicist specializing in interactive museum design: this team member brings their expertise in astronomy and physics to the project to help create immersive experiences. They have expertly consulted on the design of interactive exhibits that are both educational and engaging.

An Immersive Graphics Designer: this team member has experience creating visually stunning and engaging graphics that will transport visitors to another world. They can use a variety of techniques, such as 3D modeling, animation and virtual reality, to create truly immersive experiences.

An Art historian specializing in highlighting historical and artistic content: this team member will be responsible for ensuring that the historical and artistic content of the immersive room is presented accurately and engagingly.

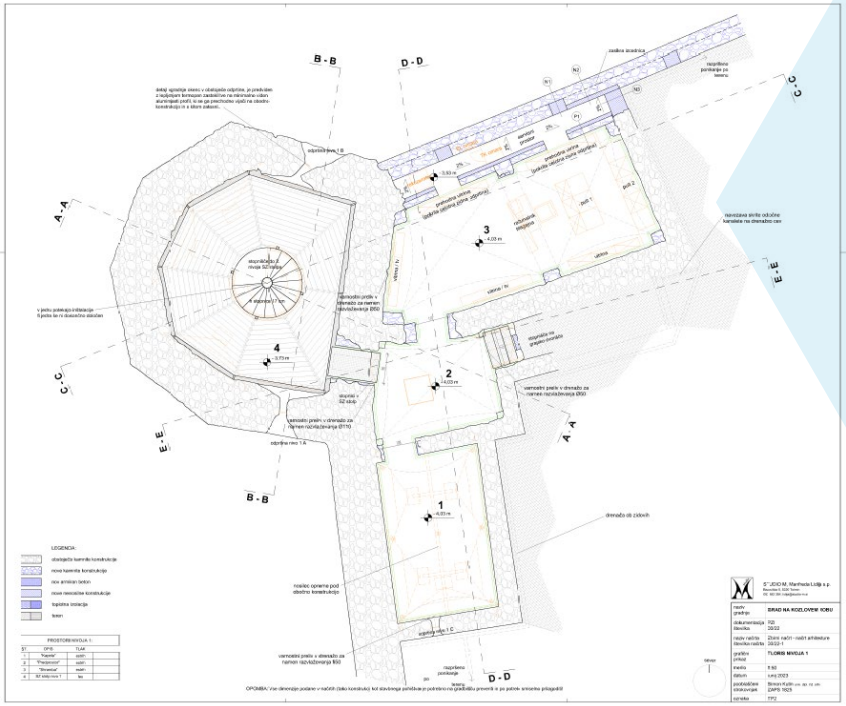
A Computer Programmer for Hardware and Software Systems Design: this team member will be responsible for the design and development of the hardware and software systems that will power the immersive room.

A Graphic designer for creating graphics: this team member will be responsible for creating the graphics that will be used throughout the immersive room.

This team brings together a wide range of skills and expertise that are essential for the success of the project.

Funding: ensure suitable funding for the implementation and maintenance of the immersive room, but also to ensure an adequate digital literacy of museum professionals, through targeted training.

Securing adequate funding is crucial not only for the creation of an immersive experience, but also for the ongoing maintenance of the immersive room. This is because digital technology, compared to analog experiences, is far more delicate and susceptible to issues such as power surges, humidity, and system glitches. There's nothing worse for a museum visitor than to arrive and find that most of the installations aren't working. Therefore, it is essential to not only address any malfunctions promptly, but also to establish a regular maintenance and inspection schedule (typically costing around €1,200 per month).
However, equally important is investing in targeted training for museum staff to foster adequate digital competencies and enable them to resolve minor issues independently.



Castle Kozlov rob, ground plan of tower and immersive room

The immersive room, designated as Room 1 on the floor plan below, will be strategically located within the castle to maximize visitor access to the unique experience. This room serves a dual purpose: firstly, to convey the castle's rich history and significance in a captivating and "modern" way, and secondly, to establish itself as a distinctive and alluring attraction for visitors. Designed to be a portal to the past, the immersive room will be a windowless space (equipped only with a small window) featuring a flattened cross vault. The ceiling will come alive with the magic of 5-6 projectors, transforming the room into a canvas for a captivating historical tapestry.

Interactive Projection: Where Imagination Meets History

But this isn't just a passive viewing experience. The immersive room incorporates a layer of interactivity, inviting visitors to become participants in the castle's narrative. Through the use of interactive projection technology, visitors can contribute their own artistic flourishes to the projected scenes. The immersive room transcends the limitations of a physical space, transporting visitors on a journey through time. By incorporating interactive elements, the room not only informs but also ignites the imagination, leaving visitors with a lasting and memorable impression of the castle's past.

Castle on Kozlov rob, architectural cross-section visualization. ©Simon Kutin. The immersive room project will occupy the chamber located to the left of the stairs, in proximity to the rendered person

5.3. The combination of digital and non-digital technology for an immersive experience

Digital Features

When choosing the specific Virtual Reality set-up for the immersive room, we considered both the value of the perceived sensorial experience and the "quick" usability of the systems. The first is important as a measure of the provided feeling of "presence", while the second is important since in exhibition contexts, it is important to immediately engage visitors, allowing them to interact with the materials without any steep learning curves, and in the most natural way.

These means radically change the learning process: the user observes and perceives the object by means of their senses and controls the object or the action through their movements, a more natural and instinctive way of learning than the one based on symbols, which are inaccessible to perception.

The choice of the specific digital features to be used was also made on the basis of a SWOT analysis evaluating strengths, weaknesses, risks and opportunities, as illustrated in the table below:

Immersive AR/VR technologies SWOT Analysis

Strengths	Weaknesses
Immersive experience: AR and VR can provide an immersive experience that allows visitors to feel like they are actually part of the historical or cultural event.	**Cost:** AR and VR technology can be expensive to develop and implement.
Increased engagement: AR and VR can make cultural sites more engaging and interactive, especially for younger visitors.	**Technical skills:** AR and VR technology requires specialized technical skills to develop and use.

Educational value: AR and VR can be used to provide educational information about cultural sites in a fun and engaging way.

Accessibility: AR and VR can make cultural sites more accessible to people who are unable to visit them in person.

Sustainability: AR and VR can help to reduce the environmental impact of tourism by reducing the need for travel.

Opportunities

Technological advancements: The rapid advancement of AR and VR technology is creating new opportunities for their use in cultural sites.

Public interest: There is growing public interest in AR and VR, which could lead to increased demand for their use in cultural sites.

Partnerships: Cultural institutions can partner with technology companies to develop and implement AR and VR experiences.

Funding: There are a number of funding sources available to support the development of AR and VR experiences in cultural sites.

User experience: AR and VR experiences can be uncomfortable or disorienting for some users.

Content development: Creating high-quality AR and VR content can be time-consuming and expensive.

Authenticity: There is a risk that AR and VR experiences could be seen as inauthentic or artificial.

Physical/physiological harms: users may experience motion sickness or discomfort, or encounter tripping hazards while using VR.

Risks

Competition: There is increasing competition from other attractions and experiences that use AR and VR technology.

Obsolescence: The rapid pace of technological change could lead to AR and VR experiences becoming obsolete quickly.

Vandalism: AR and VR experiences could be vulnerable to vandalism or misuse.

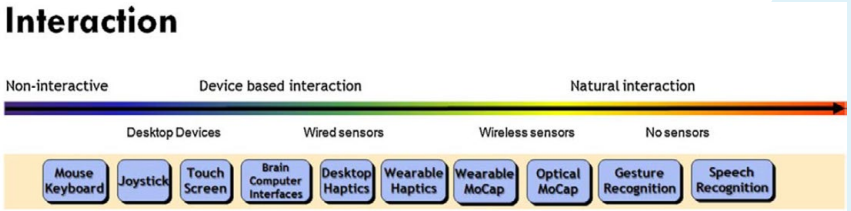
Privacy: There are concerns about the privacy implications of using AR and VR technology in cultural sites.

Equity: There is a risk that AR and VR technology could widen the gap between those who have access to technology and those who do not.

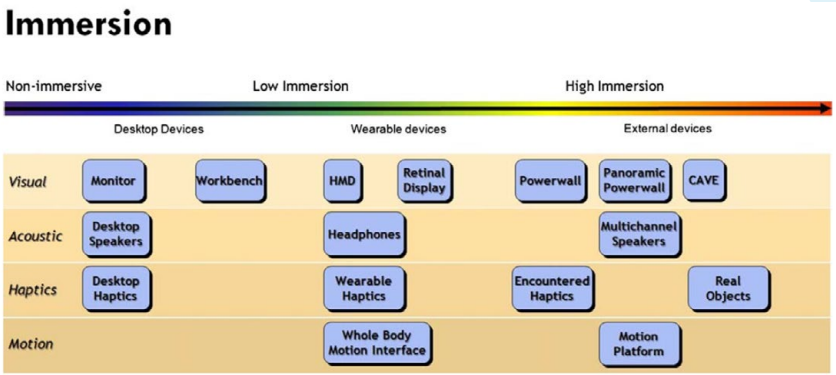
For the immersive rooms, the chosen features are:

* dynamic visual perspective based on user's head movements;
* stereoscopic vision;
* binaural acoustical feedback;
* realistic interaction with the environment by means of interfaces for the manipulation;
* operation and control;
* haptic and/or motion feedback.

Based on the level of abstraction of the VEs (Virtual Environments), starting from totally abstract VEs (such as information landscapes), and then moving on to non-realistic VEs (where abstract and realistic elements are copresent), realistic VEs (either modeled or digitally acquired), and photo-realistic VEs, which may be hardly distinguishable from real counterparts, the immersive room in the Tolmin Castle will be configured as realistic VEs. Based on the classification of the level of interaction and immersion defined by M. Carrozzino, M. Bergamasco, 2010, for different digital technologies:



Classification of VR devices on the interaction axis.



Classification of VR devices on the immersion axis

The room designed for the Tolmin Castle will be highly interactive (natural interaction) and highly immersive (non-invasive immersion).

The immersive room will be a self-contained space, designed to transport visitors into a fully-realized virtual world. To achieve this level of immersion, a combination of cutting-edge technologies will be employed:

* **High-Resolution Projection:** Multiple high-resolution projectors will be strategically positioned to seamlessly cover the walls and ceiling of the room, creating a panoramic canvas for captivating visuals.
* **3D Stereoscopic Vision:** By using 3D stereoscopic glasses, visitors will perceive the projected imagery in three dimensions, adding depth and realism to the virtual environment.
* **Binaural Audio:** A sophisticated binaural audio system will deliver spatialized sound, allowing visitors to hear sounds from different directions within the virtual world, enhancing their sense of presence and immersion.
* **Interactive Interfaces:** To facilitate interaction with the virtual environment, users will be equipped with specialized controllers or wearable devices that enable them to manipulate objects, navigate through the virtual space, and engage with the projected elements.
* **Haptic Feedback:** For an even more immersive experience, haptic feedback devices will provide tactile sensations,such as vibrations or gentle pressure, corresponding to events within the virtual world, further blurring the lines between reality and the digital realm.

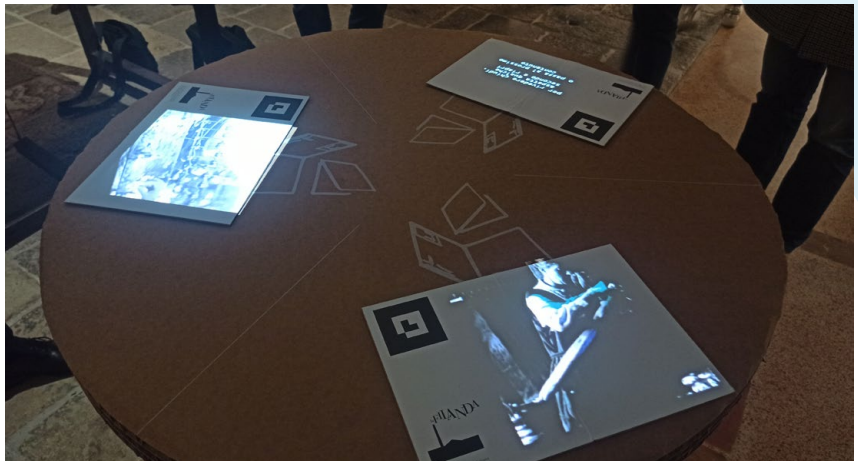
Drawing Inspiration from live skatching project

Drawing inspiration from innovative live drawing projects like AR Alive Skatching Projection (www.difwod.com) and The Live Drawing Project (thelivedrawingproject.com/) , the immersive room will incorporate interactive drawing features that will allow visitors to contribute their own creative touches to the virtual environment.

The “Live Drawing Project” was a series of events across Europe where citizens could engage with large-scale, dynamic projections. Participants were invited to draw live on their smartphones, which were connected to the exhibition in real-time.

As they created their artworks, these drawings were instantly integrated into the massive projection, allowing individuals to see their contributions come to life as part of the collective visual experience. This innovative project blended art and technology, making the audience an active part of the evolving digital artwork.
The “Night Safari” is an immersive projection room that seamlessly blends the physical with the digital, enabling visitors to actively participate in the exhibition. By coloring animal outlines on provided sheets of paper, visitors can see their creations come to life within the digital environment. The presence of cyber visual tags on these sheets is crucial, as they ensure the accurate scanning of the drawings, allowing the animals to be animated and integrated into the large-scale wall projection, creating an engaging and interactive experience.

Cyber visual tags are symbols similar to QR codes that, when applied to physical objects, allow cameras and software to recognize them, enhancing technological interaction with the real world. For example, at the Filanda Museum in Salzano, simple cards with cyber visual tags placed on a specific table were recognized by a camera, triggering the projection of a video that transformed the cards into interactive tablets.



The tecniques of having QR Codes or similar tag on the paper, to be recognised by scanner or projectors

Analogical Features: Engaging the Senses

To further enhance the immersive experience, the room will incorporate analog features that engage multiple senses:

* Scent Diffusers: Subtle scents will be released to correspond with the virtual environment, evoking the atmosphere of different historical periods or locations.
* Environmental Effects: Wind machines and fans will simulate the sensation of wind or breezes, adding a touch of realism to scenes that take place outdoors or in windy environments.
* Musical Cues: Carefully curated music will accompany the projected visuals, creating an emotional resonance and enhancing the overall immersive experience.

By combining these cutting-edge technologies with analog features, the immersive room will not only inform but also transport visitors on a multisensory journey through time, leaving them with a lasting and unforgettable impression of the castle's past.

Sustainibility:

Inclusivity and accessibility:

Adaptable features include:

* Adjustment of ambient light exposure and color temperature;
* Adjustment of the focus level, through the setting of vignetting effects, which allows the width of the field of view to be narrowed;
* Possibility to choose between different museum guide modalities: text descriptions with highly readable fonts (i.e., OpenDyslexic) or audio/video guide that repeats slavishly the text of the description, which can be turned on/off by the user through a dedicated button;
* Possibility to navigate the environment with a mouse and keyboard, gamepad, or by teleporting to the location and then exploring the surrounding space within a range of 2 meters, with natural movements (i.e., walking).

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Castle on Kozlov rob, ©Simon Kutin

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Kozlov rob 1 "A bird's eye view of the remains of the castle on the Kozlov rob hill ©Jošt Gantar"

Kozlov rob 3D "3D visualization of the Kozlov rob castle (by Peter Leban)

Museo della Filanda, Salzano. Image courtesy of Venetian Cluster