Beyond Virtual Museums: Adopting Serious Games and Extended Reality (XR) for User-Centred Cultural Experiences

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1. Introduction

Since museums, heritage sites and archives are important for the preservation of our cultural heritage; recently there has been an attempt to promote better absorption of cultural knowledge by involving the learners in the process. This new tendency along with the digitalisation of the learning environment has sparked the creation of Virtual Museums (VMs). According to Schweinbenz (1998), VM is

considered a set of digital objects built in a variety of media, which due to its capacity to provide access and connection between users and objects, goes beyond the traditional methods of interacting with the visitors. A VM provides different levels, perspectives and depth of information about a specific topic: it provides a variety of multimedia from visual information to audio and digital data that have not been filtered out through traditional methods of presenting them (Hoptman 1992).

As VMs have become the new paradigm in museology, a step has been taken further to shift from a 'collection-driven museum' to a more 'audience driven' and user centred approach. A user centred approach that relates to a particular visitor group and answers to their interests. The possibilities of outreaching these groups and reinforce such an approach to VM can be achieved through the rapid advances in digital technologies in recent years from new media (Augmented Reality) to high-speed networks, such as the longed for 5G cellular network evolution (Brusaporci et al. 2018). The possibilities to reach out to new age visitors with different demands and expectations can be offered not only by telecommunication services but also by innovative and engaging methods that other mediums, such as serious games, can provide. Such technologies are easily employed using engaging AR interfaces that immerse and fascinate audiences and create the space for both synchronous and asynchronous cases, where visitors can be either offsite or onsite. All of these can be achieved by delivering the content through existing telecommunication networks and low cost smartphones; a recipe for ubiquitous propagation and dissemination of culture related content to the masses.

Furthermore, serious games have long been used to support cultural heritage purposes. The popularity of video games among young individuals has made serious games an ideal medium to engage them. Serious games can occur in a variety of forms of mobile applications, simple web-based solutions or in the shape of more complicated applications that combine digital and physical interactions, all of which can be used for different cultural heritage applications. In combination with multimodal interfaces, serious games aim to engage the user and let him explore in their space and time. However, as the field matures, several studies aim to assess the effectiveness of their use regarding the overall museum experience, virtual or otherwise (Roussou and Katifori 2018). There are several challenges that need to be addressed for the design and deployment of such technologies, including lack of one-size-fits-all implementations that restricts the personalisation of the experience and limits user control. Therefore, there is a danger that inept attempts can lead to impractical or ineffective experiences that instead of exploiting the potential of the medium might deprecate its value. Nevertheless, innovation in this area maintains presence in museums as well as providing compelling experience which has to be strongly connected to the synergy between expertise knowledge in the field and the role of these new technologies (Papagiannakis et al. 2018).

This chapter presents firstly a critique the state-of-the-art on mixed reality technologies and serious games that can be used along with them which aim to bring the user to the centre of cultural heritage experiences, exposing the opportunities and challenges. This chapter will start by presenting the state-of-the-art in mixed reality technologies for VMs, then presents the attempts using serious games both past and present. It will continue by discussing the challenges and issues identified in cases studies and then builds on the practical implications to direct the future developments in the area to achieve a sustainable user centred approach in cultural heritage. Finally, we will conclude by discussing the future directions and the potential next steps.

2. Virtual Museums: bringing the user to the centre

According to Sylaiou et al. (2009), there are three types of VMs that can be divided between brochure museums, content and learning museums. The brochure museum that is information heavy, mainly used as a marketing tool to motivate the audience to visit the museum. The content museum that offers information related to the collections in the museum and is object oriented. The latter, the learning museum is the one offering information in a more context oriented way so that it can be accessed by a variety of visitors from different age groups, background and knowledge level. These learning museums are usually connected to other information, which aim to motivate the visitors' interest. The ultimately goal of these museums is to create a personal relationship with the museum so the visitor would visit again.

Despite the digital opportunities and the deep understanding of the user needs and expectations, developments in the VM area have not progressed extensively, with a few examples diverging from this model. According to recent studies, online museum collections are the least popular features on a museum's website, (Haynes and Zambonini 2007; Fantoni et al. 2012; Fernandes 2018). Several museum experts have related that to limited interest by the visitors in viewing objects through a computer screen. While this might be true for a segment of the population, there are also studies which argue that the low popularity of the online museums is due to their poor user experience (MacDonald 2015). These studies suggest that some VMs have not considered whether the visitor would repeat the visiting and some have completely ignored visitors' personal agency and the post-visit user experience (Perry et al. 2017). In this sense, these VMs can be viewed as outdated tools with questionable relevance for the visitor.

The need to nurture a connection between the visitor and the museum has turned the focus towards the design of the user experience in a VM. User experi-

ence has become an integral part of the cultural institution's approach to attract visitors. Museums have a need to embrace a more holistic approach, targeting to connect with the visitor in a personal and emotional level. The digital era played an important role in shaping these experiences and creating VMs that go beyond the typical learning experience only by providing access to different layers of interaction, which can be either personalised, synchronous, asynchronous, or even plain and monotonous.

The more recent innovative examples of VMs, which focus on visitors engagement by employing different methods of interactivity, mostly experiment with storytelling, personalisation, adaptation and social media activity (Perry et al. 2017). A four-year European funded project V-Must (Virtual Museum Transnational Network, 2011 -2015) looked at different VM projects across Europe and beyond resulted in proposing a framework for "responsive museums". The term refers to the aim of museums to explore different kinds of interactions that engage the visitors (Hazan and Hermon 2015) the framework presented guidelines for implementation that includes, among others, interactivity, personalisation, coherent content and narrative. In this sense, the VM can be stretched beyond the traditional institutionalised tools and connect with visitors in a measurably emotional and interactive way. To achieve this, an employment of 'new' and 'older' paradigm tools can provide new level of engagement beyond the standard expectations of VMs, such interacting with basic images and videos similar to any information based website. These tools, which often involve game mechanics and immersive technologies, allow visitors to personalise their experience, relate to the content, actively re-use it and also participate by contributing their part to the narrative.

Therefore, VMs in fact open up new directions with the user-driven scenarios for the museums themselves but also for the perseverance of cultural experience. They offer the opportunity to the visitor to interact with both physical and non-physical museum with contemporary ways making use of emerging tools. The next section reviews the state-of-the-art in cases of using Serious Games in place or accompanying VMs to a more participatory experience. Then we move forward by discussing other technologies that bring forward the user experience by adding different layers of depth in the process.

3. XR and Virtual Museums: working towards immersive experiences

Extended Reality Technologies (Fast-Berglund et al. 2018) as a term is now including a spectrum defined by AR, VR, MxR which are technologies that are

aimed at creating immersive experiences. Such technologies and approach have a long history in cultural heritage, virtual museums and tourism.

ARCO (Wojciechowski et al. 2004) was one of the earliest architectures that used AR and VR for virtual representations of virtual museums. The system developed in this project used a sophisticated pipeline to build and manage VR and AR exhibitions based on 3D models of the artefacts. The system showed very interesting and successful results when used to provide exhibitions (Walczak et al. 2006). However the AR and VR hardware has come a long way since. The focus of the system was always on the artefacts, as evident in the interfaces provided, however recent approaches clearly show that a non-user centred approach will not provide the same log-term results.

Haynes (2018) proposes the development of Veholders (Virtual Environment for Holdings and Online Digital Educational Repositories) as community projects, where related artefacts, objects and collections are assembled together in order to create blended environment to improve visitor experience and immersion. The research suggests that using AR on smartphones allows visitors to take an active role in the curation and creation of exhibits, changing the role from passive consumers to a blend of consumer and active contributor.

An important aspect that requires investigation is the acceptance and perspective of the users when using new technologies such as AR and VR. Different groups of population have differing willingness, requirements, perspectives and abilities that should be considered (Southall et al. 2019). Museums are a core part of the culture and tourism industries which attracts visitors from various age groups, cultural and financial backgrounds, and physical abilities. A recent study (tom Dieck et al. 2019) has conducted interviews with elderly tourists at a cultural heritage tourist attraction in the UK, examining the impact of VR on their experience. The results demonstrated an overall positive attitude towards the use of technology in this context and suggested strong intentions to revisit due to the experience of VR.

A recent study (Hammady and Ma 2019) has looked at utilising MxR through Microsoft HoloLens in order to create Virtual Museum Guides. They identify that the use of MxR was highly popular with visitors and genuine physical guides that take advantage of the real world by enhancing it with information and guidance has a positive immersive effect on visitors. However, they identify several issues with the device. The main issue that is addressed by the research is the narrow field of view on the device. They design a Spatial UI to tackle this problem and demonstrate that suitable interaction and UI design can improve the user experience. Other issues identified includes instability of spatial mapping in the current hardware, bulkiness of the current devices which can hinder long-term use and engagement, and finally concerns over the real-time rendering which could lead to lags and delays.

The current state-of-the-art XR has clear benefits for attracting visitors and encouraging revisits. However they also identify various issues and shortcomings which relate to the hardware, software and designing an experience that would be immersive and encourage long-term use and further visits without losing its novelty.

4. Serious Games and Virtual Museums: past and present case studies

The use of SGs in cultural heritage has been demonstrated and tested with promising results with regards to the learning outcomes. However, the state of the art in SGs can be reviewed and given the emphasis in regards to a variety of contexts. For example, the use of SGs in museums, the outcome measures, the learning experience, the gaming technology or the increase in museum visits. There is also a substantial part of the literature reviewing the integration of learn and fun in SGs used in cultural heritage (Andersen et al. 2011; Bellotti et al. 2012; Mortara et al. 2014; Holloway-Attaway and Rouse 2018). The main issue in presenting the state-of-the art in SGs is the lack of a standardisation in evaluation methods among the different case study prototypes which makes it difficult to compare all of them and discuss challenges or advantages (Paliokas and Sylaiou 2016). This chapter that discusses the use of SGs to bring users to the centre and create experiences that are unique, personalised and flexible. This section will review the techniques used by specific case studies to develop VMs and SGs that focus on the user.

Establishing a connection between people and museums, is a goal that often museums struggle to achieve. As it has been recommended by the International council of Museums (International council of Museums (ICOM) 2019), the museums are not just institutions where visitors are educated but also places for enjoyment. To achieve this, among many other ways, is to allow people to rediscover the museums on personal and emotional level. SGs can spark curiosity by embedding rewards in the whole narrative experience. In other words, SGs can create the narrative that is missing from the museums that unfolds a story while people are playing. These kind of SGs can be of great use for museums because storytelling is an important communication tool for cultural experiences.

A case study of a SG that was created as part of a cultural exhibition experience, themed “The Building Works of Saint NEgratia: The pantheon under the republic”) is the game Solis’ Curse (Neto et al. 2011). This game belongs to the category of the virtual museum, mainly due to the different scenes in the game which are digital representations of the cultural heritage sites. The main purpose of this

game was to assess the knowledge of the visitors that was acquired during the exhibition visit. Apart from that though, this SG provided a different way of interacting with the exhibition as it offered speech interaction with an embodied agent that navigates the user through the 'game' and assist him to complete the tasks. This embodied Conversational Agent (ECA) has been developed with a personality to invoke feelings of empathy towards specific audiences to communicate effectively the cultural values and to determine the importance of maintaining them. As, Mortara et al. (Mortara et al. 2014) have suggested empathy with a game character can be valuable for understanding historical events or different cultures and historical behaviour or problems. Even though the visitor is not physically a player in a game, as it would consume too much time for the player to explore the scene and missing the information conveyed by the agent, the narrator accompanies the player between rooms that depict the exhibition. This interactive dialogue not only allows the user to engage in a personal way with the exhibition but also gives the opportunity to participate with an active role, feeling that he is part of the unfolding story. Additionally, this SG allows for an asynchronous visit to the exhibition so that the visitor can engage with the game even when not in the site which provides access to a variety of visitor groups. As Sylaiou et al. (2017) confirmed from an evaluation study involving online museums resources that can enhance participants leaning outcomes, VMs in the form of interactive experiences apart from effective engaging methods, are also efficient methods of learning due to the edutainment dimension connected to game-like experiences (Doulamis et al. 2011).

Another game that used embodied conversational agents as companions to children during the time spent at an art museum is the "Monsters Eat Art" (Rehm et al. 2014; Rehm and Jensen 2015). The 'monster' of the game serves as the narrator that guides the children through a treasure hunt at the art museum but at the same time is also passing information about the artworks to the children. Treasure hunts in museums have been criticised as it motivates visitors to see the cultural space as a bunch of disconnected artefacts and not as part of a narrative, which would have a deeper cultural meaning (Klopfer et al. 2005). Similarly, a treasure hunt embedded in a serious game for museum environments focusing in younger generations demonstrated successfully the potential of education using serious games in museum (Doulamis et al. 2011). Additionally, as was shown at the study conducted at the Boston Museum of Science where the "Mystery at the Museum " game was used by family members to gather information in a problem solving activity, participants felt that they had a participatory role in the museum experience which added value to their visit (Klopfer et al. 2005). Treasure hunts as part of a pedagogical approach has enacted quite well with children in the older years even without the digital means that exist today (Elliott 1926). In the experiment, where 57 children participate, it was shown that children engaged more with the artefacts when they played a digital tablet version of the game rather than a paper based

version. The results also showed a higher retention rate for the details of the artworks.

An example of using digital technology and serious game methodology to enhance visitors experience in the museums is the "Undercroft Game" which was developed along with another mobile application for Herbert Museum and Art Gallery to enrich visitors' experience (Petridis et al. 2013). The purpose of the game was to offer further insights on the daily activities of the monks of Coventry's original Benedictine monastery. The game also tried to increase the younger audience's interest towards cultural knowledge. It is a simple puzzle game where the player has to interact with various non-player characters uncovering clues to solve the puzzles. The evaluation of the enjoy-ability of the game, even though was conducted with a small sample size (five users), showed potential in using the game to learn and understand more about the history of Priory Undercrofts. This example reinforces the digitisation of VMs but not just in the rigid context of a Virtual exhibition of artefacts but rather an interactive way of bringing the user in the centre of the learning experience.

Whilst users employed digital technology to access the game, it does not allow engagement for ongoing long-term experiences. As Benford et al. (2009) have pointed, new techniques need to be employed to support visitors for episodes of engagement. Apart from the bespoke interface that currently most museum tools rely on, there is a need for orchestrating tools than can automatically (or semi-automatically) create the interfaces based on the specification of an experience.

Despite the tools like SGs and embodied conversational agents, narrative is the most usual approach as a method to communicate through the selection and display of the artefacts. Similarly, museums have tried to embed the storytelling aspect in the VMs. However, most of the times it remains descriptive or scholarly prose (Perry et al. 2017). In most cases of SGs or narratives in VMs the meaning is communicated in didactic fashion, not connected with emotions and morals that have proven to motivate large audiences (Vagnone and Ryan 2016). An ongoing project to engage visitors emotionally by designing a VM that focuses not just on the story but which supports interaction among the visitors and the objects themselves is EMOTIVE (Katifori et al. 2019). This is an EU funded (HORIZON 2020) project that aims to integrate activities, which take place pre-during and post-visit and involves interactions with tangible and intangible objects. This project tried to cater the patterns of visitors while in cultural sites or museums and sees them more as visitors in social experiences. The approach employed is user-cantered both in the design but also in the evaluation phases and customises the experiences using customer profiles that allow creating personal views of the visitors as social agents. In terms of the technology, there is a mix of 3D/2D spaces that were integrated without though focusing a lot on the technology itself but rather in the emotional part of the experience. The preliminary results were promis-

ing, potentially opening new doors in involving multi-disciplinary work to approach and orchestrate new interfaces that will engage visitors and initiate meaningful cultural experiences.

Digital storytelling for cultural applications is not new in museums virtual or not. For example, the PEACH Project automatically creates video clips on visitor's device and it is using a life-like character to present the information (Damiano et al. 2008). In a similar manner with game mechanics, in Ghosts in the Garden (Poole 2018), visitors use a device to view the "ghosts" of characters based on real people in a historical garden in Bath, UK. Finally, CHESS project (Katifori; et al. 2014), which was also EU funded, was looking to develop stories that were interactive, personalised and adaptive. Using game mechanics and storytelling techniques the main aim was to motivate visitors to find personal and meaningful connections with the objects.

5. Current Challenges and Opportunities in the Industry

The proliferation of Extended Reality Technologies (Fast-Berglund et al. 2018) included to the spectrum defined by AR, VR, MxR enables for immersive experiences in the area of cultural heritage, education and also tourism. Opportunities arise to develop more emotional and impactful experiences relevant to heritage, tradition, culture, and history of a place or folk with the use of such advanced immersive technologies. The next generation of XR apps will have to build on and beyond the state-of-the-art of VMs as described in Sections 3 and 4.

This means that they would have to appeal to a wider audience, thus at a more personalised level (Bohnert and Zukerman 2014), as well as the penetration to markets and end users that lack the technological elements that these technologies might require for financial reasons. For one, inasmuch as AR can be seen as a cutting edge technology, one could argue that is not so widely accessible only judging by the short length of compatible devices across available major AR SDKs (Vuforia[1], ARCore[2], ARKit[3], Wikitude[4]). Same applies for VR with expensive headsets not widely accessible to user groups potentially defined as target groups for immersive heritage related apps. Content delivery on those platforms can be proven a challenge and it limits, in technological terms, the extent to which one can reach out to users. Add to that the costs of app and content development and maintenance and the proliferation of such products to mainstream solutions is

[1] https://developer.vuforia.com/
[2] https://developers.google.com/ar/
[3] https://developer.apple.com/augmented-reality/
[4] https://www.wikitude.com/

bound to be limited. A recent study for museums and technology in the USA reveals that 35.5% of visitors think that the museums in their proximity never exhibit new technologies (Stage 2 Studios 2018) with another 20.5 answering "rarely" and 37.2% answering "sometimes"; only 6.8% of the population finds that their museums exhibit new technologies. This is an indication that the average museum visitor does not interact with these technologies for various reasons. One of which is lack of simple and easy to use apps that can be directly installed on their mobile phones.

This latter assumption of using the visitor's own device to run the museum app to serve the content in one XR modality is limited by the performance of the device and its compatibility with various SDKs. Hence, there is a need to overcome this issue and realise a platform agnostic solution that could be ubiquitous in terms of compatibility.

The evolution of telecommunication infrastructures and the longed for fifth generation of mobile cellular networks (5G) that encompasses also Multiaccess Edge Computing (MEC) can provide a consequential solution to this problem. Having provisioned a MEC server close to the user (edge) provides an immense capability of computational performance that is characterised by low distance to the user, thus low latency, and also the opportunity to design system architectures that would enable the balance of computational need lopsided to the network instead of the end user's device. In other words, the need for computational intensity can now be moved to the Cloud, releasing the pressure from the mobile device, thus enabling content to be accessible to many more users and not limited to those with compatible devices. Processes such as rendering of 3D models, lighting and visual effects can be allocated to the MEC and streamed with low latency to the mobile device. This fact solves another significant issue apart from the need for expensive and high end mobile devices for XR experiences. Recent announcements from technological giants such as Google (Stadia[5]), Microsoft (xCloud[6]) and Apple (Arcade[7]) for relevant gaming platforms with remote rendering for ubiquitous access and with any kind of device demonstrate that 5G will be the enabling arbiter to define the future of Virtual Worlds, being entertaining games or educational applications such as VMs.

Content creation is another blocking point for the proliferation of such experiences. Content availability is scarce across mainly micro-enterprises (freelancing) and availability of quality content is not yet centralised (Tan and Rahaman 2009; Pacheco Estefan et al. 2014; European Commission 2019). Although main-

[5] https://stadia.dev/

[6] https://blogs.microsoft.com/blog/2018/10/08/project-xcloud-gaming-with-you-at-the-center/

[7] https://www.apple.com/uk/apple-arcade/

stream commercial solutions exist as per repositories of 3D models, characters and animations, these are mainly focused on gaming (ref to Unity marketplace, mixamo, turbosquid) and there is a huge gap in content relevant to historical sites and with some confidence level of historical accuracy. A solution such as EUROPEANA[8] (Isaac and Haslhofer 2013) that has been around since 2008 does not yet contain a large amount of content relevant to XR, for example culturally relevant 3D models of objects and personalities. Combined with the previous point about centralising the rendering on the network (MEC) and streaming the content to the user, one can realise that such approach opens the way to educational, cultural, heritage related, emotionally engaging applications that will disseminate history, traditions, culture and will engage and penetrate to a wider audience beyond the conventional museum user.

Furthermore, such heavily graphical based applications can be separated from the museum as a location and can work in any kind of environment. Especially where there is emotional value connected to the geolocation. For example, a 3D model of Colossus of Rhodes, or more recent example of statues smashed by ISIS in Mosul, Iraq, projected in an XR application within the boundaries of a museum will create much less impact than the same 3D model presented in the actual place it is thought to have been located. Same for points of interest that now do not exist for a variety of reasons (war, decay, natural disasters); XR can help recreate their virtual equivalents and preserve the emotional value connected to the place itself (Dumiak 2018; IEEE 2018).

Finally, to further increase the engagement of the user with the medium and content one should utilise well established mechanisms for such engagement, which is no other than games. Gamifying the use, other than the experience itself is a way to make users come back to the medium, engage them with the content and retain the knowledge objective (Huynh et al. 2016). XR apps for cultural heritage are a perfect application of gamification with geo-localisation in the lines of the very successful Pokemon Go game made by Nintendo (Sicart 2017). So apart from designing Serious Games relevant to VMs that would contain a game objective and utilise game mechanics to engage the user within unique sessions (gameplay), one can design an overarching framework to engage with gamification of XR apps. Building on the impact factor brought by the use of new technologies like AR, VR, MxR, the gamification element will provide the retention factor for the customer to return to the platform and further engage, explore, play, learn and have an emotionally engaging experience.

[8] https://www.europeana.eu/portal/en

6. Discussion: A Conceptual Framework

Considering current industry trends and the state-of-the-art in using XR and serious games in VMs and greater cultural heritage field, it is possible to identify great potential but also important challenges. This paper summarises the discussions into a three layered framework. These three layers are; Users, Technology and Content. Each of these layers presents unique challenges for the future of VMs. The discussion so far has presented previous approaches and also possible opportunities provided by the trends and advances in the technology and user-centric development. This section will discuss these in further detail.

Table 1 presents the summary of the challenges and the approaches and possible opportunities which could tackle them in our framework. As mentioned previously there are three layers of challenges identified in this framework. These layers are inter-related and the challenges in each would be dependent on other challenges in other layers, for example access to technology impacts user acceptance and user engagement. Similarly, the approaches and solutions could impact multiple challenges, especially in a user-centred approach. The complex dynamic relations of the framework have been conceptualised in Figure 1.

The challenges in the ***User*** layer are focused on the behaviour and preferences of the users towards cultural experiences. This layer is the core of a user-centred approach and impacts on all other aspects of the intended experience. The challenges in this layer are categorised into four topics;

Table 1. Challenges and Approaches in using XR and SGs for future user-centric VMs

Layer	Challenge	Approaches/Opportunities
Users	Acceptance	Personalisation
		XR
	Awareness	Serious Games & Gamification
		XR
		5G
	Software Usability	Serious Games & Gamification
		UX design
	Engagement	Serious Games & Gamification
		XR
Technology	Access to Technology	Accessible Devices
		5G
		Centralised rendering
	Device performance	5G
		Centralised rendering
	Software performance	5G
		Centralised rendering
Content	Creation	Community sourcing
		Centralised rendering
		Open Libraries
	Delivery	5G
		Centralised rendering
	Localisation	Geo-tagged content
		Community sourcing

User acceptance: This challenge focuses on personalising the experience of the user in order to create a memorable yet repeatable experience tailored to the needs and preferences of the user. As mentioned before visitors have different needs, expectations and abilities. Personalisation of the experience becomes a key factor in the success of any experience. Research shows that personalisation in games (both serious games and entertainment games) increases user acceptance and user engagement, even leading to better performance in achieving the goal of the game (Daylamani-Zad et al. 2016, 2018).

User Awareness: As previously mentioned, the uses need to be aware of the available services such as XR apps that can be acquired or the devices available at the museum. But this challenge goes beyond this simple awareness of facilities. The visitors should also be aware of the artefacts and the collections on exhibit in order to have a meaningful experience. Immersive experiences created using XR and also serious games that guide the visitor through the exhibit, allow the users to

have an enhanced experience designed beforehand for maximum experience. Such experiences of course would need to be personalised to the each visitor type and might have different goals and paths for different types of visitors.

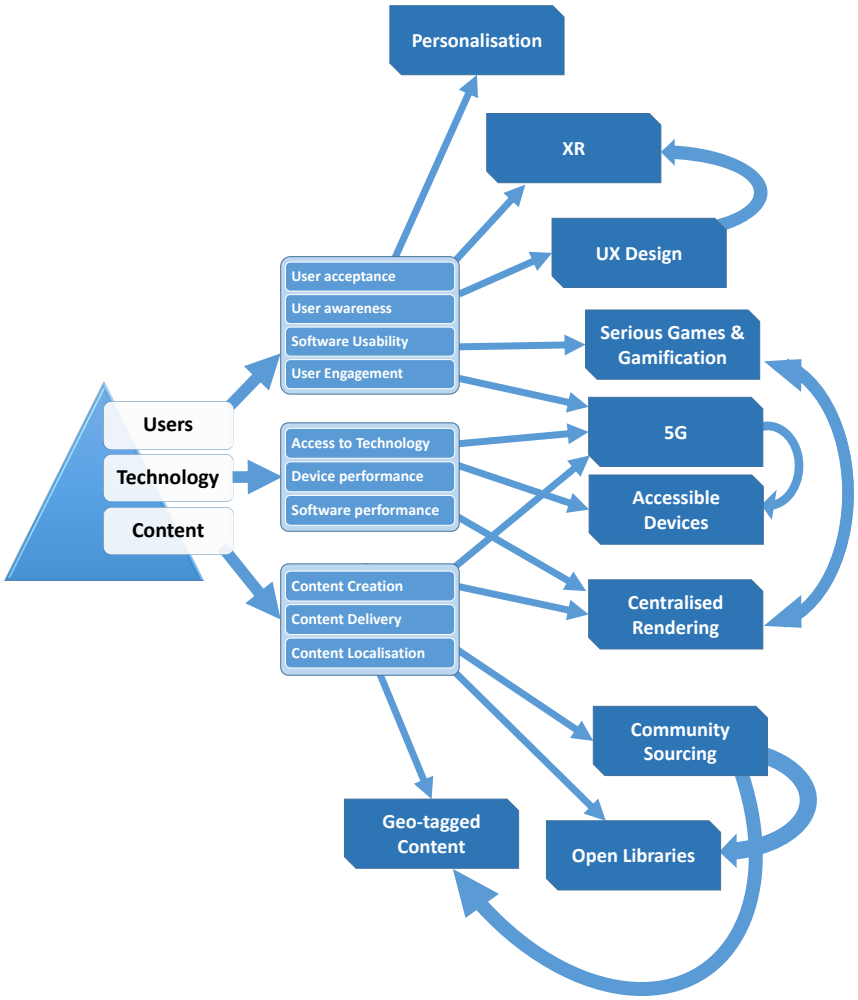

Figure 1. Conceptual framework of challenges, approaches, opportunities and their relattions

Software Usability: This challenges is concerned with creating an experience that is tailored to the users. Such software must be designed and developed with the users in mind. Suitable UX design greatly contributes to the success of an experience and has a direct impact on the acceptance of XR technology and the immersion of users in the VM.

User Engagement: The focus of this challenge is to engage visitors in the experience and get them involved and feel part of the experience. Serious games have shown clear positive impact in increasing engagement. There is also strong evidence that immersive experiences using XR technologies also contribute to increasing user engagement. They also show evidence of revisits because of the immersive experience that they create for the visitors. It is important to highlight that increased user engagement has a positive impact towards a number of approaches that would address other challenges. For example increased engagement would benefit community sourcing, geo-tagging content and content creation,

The challenges in the ***Technology*** layer relate to the issues regarding access and performance of hardware and software used. These are more technology dependant yet the challenges are related to creating a better experience for the users and reaching a wider range of users.

Access to Technology: As mentioned earlier, XR devices and SDKs are still not widely accessible to all users. Not all visitors would able or willing to install apps on their personal devices and finally not all users have devices that can perform well enough to support XR immersive experiences. Fortunately, the devices are becoming more accessible and affordable. The tech giants are producing more powerful and affordable devices. More importantly with the emergence of 5G technology, centralised rendering and fast content delivery will be soon possible even to devices that might not be suitable for the current state of XR technology. High speed streaming of pre-rendered content would allow even devices on the low-end of the performance spectrum to support immersive XR experiences.

Device Performance: This challenge related to the ability of current personal and professional devices for creating immersive XR experiences. Similar to the challenge of access, the devices are improving and becoming more wide-spread whilst centralised rendering and fast delivery through 5G would compensate for many of the current issues such as lags and incompatibilities. However there are other issues in the category such as limited FOVs which are already being addressed both by software developers and hardware manufacturers.

Software Performance: This challenge related to the compatibility and performance of XR apps. Similar to the previous points in this layer centralised rendering and fast delivery through 5G would be soon able to overcome many of the obstacles in this area.

The challenges in the ***Content*** layer relate to the issues regarding creation, delivery and localisation of suitable content for immersive XR cultural experiences. There are three challenges in this layer;

Content Creation: This challenge relates to the ever present challenge of content generation for XR experiences. This challenge becomes much more important in the cultural heritage domain as the content cannot be as easily sourced as other domains. The content has to be based on existing artefacts, descriptions and remnants. The challenge is further deepened in this domain as the content would also need to be updated as new discoveries could either change them or make them entirely inaccurate and obsolete. As mentioned earlier there are open libraries that actively seek to create more content. However a great approach to this problem could lie in community sourcing. By including users and visitors in the content creation process, not only more content is generated but also the visitors and users would be taking a more active role, leading to more engagement. Centralised rendering which would be possible through 5G technology would also be another factor here as content available on closed or licensed libraries could be used on a much more affordable basis.

Content Delivery: This challenge is concerned with the delivery of XR content to users. The content in XR apps, which includes 3D models, textures, materials, audio, video and text, can create large downloads. These can be preloaded to museum devices or be downloaded on demand by users as they progress through the experience. However, both scenarios would require large download bandwidths, low latency and rendering at the point of delivery. As per the previous challenges, centralised rendering and content streaming via 5G technology can be a great solution for addressing this challenge.

Content Localisation: This challenge is concerned with the localisation of content for cultural heritage experiences. From virtual and actual museums to real-life locations such as monuments and important locations, the localisation of XR experiences is of outmost importance. The users should be able to receive all relevant content to their physical/requested location. This can only be achieved with increased geo-tagged content. Creating geo tags for existing content is also a great challenge here which could be addressed through community sourcing and incorporation of user generated content. An intricate detail in this challenge is content that might be related to multiple locations, complicating the setup of current libraries. Knowledge graphs and graph databases have shown great potential in addressing such challenges (Tseng et al. 2013; Amirian et al. 2015).

7. Conclusion

In this chapter, a review of state-of-the-art for using XR technologies and Serious Games in Cultural heritage and virtual museums was presented. The presented work was discussed in detail and analysed based on their approach to a user-

centred design of solutions for VMs. The discussion was followed by identifying the current trends and challenges in the industry, highlighting potential opportunities and approaches currently focused-on in the industry. The results of these discussions were then summarised into a framework with three layers; Users, Technology and Content. The framework conceptualises the challenges, approaches and opportunities currently available towards creating immersive serious games in XR to enhance cultural heritage experiences through increasing user engagement and encouraging visitors to get involved, contribute and revisit. This framework is designed from 'lessons learned' that derive from state-of-the-art and past projects. It is expected to be used as a tool to inform design and ideation. In practise, designers can use this framework as a guide to create experiences which focus more on the user, exploit effectively the resources on hardware and software, to provide a compelling museum experience that has the user's needs and preferences at its core. Nonetheless, there are some limitations to the work presented here, as this framework is not an exhaustive audit of all the VM related projects that exist but rather a synthesis of findings from research projects that have applied key concepts of storytelling, narrative, mixed reality technologies and serious games. Finally, besides the mentioned concepts, others such as social interactions play important roles in the formation of an inclusive museum experience. Analysis in this area could extend the framework in the future supported by further empirical validation and evidence.

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