Short Paper

Hybrid XR collaborative and guided experiences in Cultural Heritage: Brancacci POV prototype

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Abstract

In this work, we present a research prototype of a hybrid XR experience for cultural tourism, accessible by any potential device, including immersive VR headsets. It has been designed to better answer visitors' expectations and to overcome the limitations offered by traditional Virtual Tours (VT). We present the conceptual model, prototype, applied case study and users survey. The overall result has shown how the development of a collaborative and guided experience, enhanced by the use of a gamified narrative, has produced an increased perception of authenticity of the VT.

CCS Concepts
*• **Human-centered computing** → Interaction design process and methods; **Empirical studies in interaction design**; • **Applied computing** → Arts and humanities*

1. Introduction

During the pandemic, many cultural institutions have tried to maintain the engagement with their audience, increasing their digital offer with VTs [Rep21], although their characteristics weren't completely answering tourists' expectations. Moreover, those digital solutions weren't considering the human aspects, in its threefold dimension: the personal dimension of users (the self), connected to others through social relations (the others) and immersed into a temporal and spatial environment (the world). The authors have devoted their research to extend these dimensions also to remote XR experiences, working to add a hybrid layer to virtual visits and to increase their perceived authenticity.

2. Research questions and prototype goals

In 2018, a study in the tourist sector identified the three main expectations visitors have, when planning and visiting cultural locations: authenticity, meaningfulness and memorability of the experience [CR18]. Are VTs offering "authentic" experiences? The authors believe that this is not the case. What can improve authenticity in virtual experiences? And how can we define in a more comprehensive way "authenticity"? Within a still ongoing study, we have identified the building bricks of authentic virtual experiences. We do not in fact consider authenticity as referring only to realism. In the literature about Virtual Environments, authenticity of the experience is connected with the "sense of presence", "interaction" and "immersivity" [WS, WJS, RWW]. But there have been attempts to extend this concept, as to include the user into a social or physical space [SG]. Our hypothesis is that authenticity should

be considered in all above-mentioned interconnected domains. In line with [Jasper 1919], we have adopted the following definition of "authenticity" in the design of Virtual Tours: "*Authenticity is what touches the deeper self of a person, transforming something distant into something familiar, through self-reflection and the relation with others and the world*". We have then designed a conceptual model that includes the following design strategies for VR experiences, involving all three dimensions of authenticity: 1) *self* identification and sense of belonging, curiosity-led storytelling; 2) *other* guidance, co-presence, exchange of thoughts; 3) *word* embodiment in 3d interactive immersive environment, physical presence. The model needed to be suited for two main user scenarios: (s1) an on-site experience, where visitors are together in a physical location (i.e. a museum or a class), and (s2) a remote experience, with visitors connected online from different locations (i.e. homes). These scenarios have several common design elements: (a) they are both mediated by a human guide, who story tells and invites users to action (tasks); (b) the story is designed to develop "historical empathy" [EB18], through re-appropriation and provocative questions; (c) the visitors starts the experience with an identification task (as choosing a personal element); (d) they share the same virtual space, (e) interact with the environment following the storyline and tasks and (f) also interact with each other, by sharing thoughts and collaborating. Due to the requirements, we would have needed to develop a prototype with cross-device capabilities (users should have freely chosen any visualisation device, such as smartphones, tablets, PC and also immersive VR headsets). We have therefore decided to use a web3d framework capable of such flexibility, open to be adjusted to the specific scenarios, not requiring any installa-

tion for the final user. The prototype was applied to a specific case study: Brancacci Point Of View (POV). Its objectives have been to improve the perception of authenticity along the three dimensions, and specifically: to develop social experiences (limiting isolation) stimulating physical encounters, exchange of ideas and interpretations; improve accessibility for users who cannot physically visit the cultural site.

3. State of the Art

During the pandemic, there was an increase of online visits in the range of 10% to 150% [Rep21]. In many cases, cultural institutions have included VTs among their online offerings. A Virtual Tour has been defined in several ways [CWF02, **?**, RDKP]. For the purpose of this study, we refer to Virtual Tours as interactive simulations of a location, such as a museum or a monument, accessible locally or remotely through a web interface, with hotspots, tags or layers that provide information, accessible using different devices and with different levels of interaction and immersivity.

Most of the online VTs platforms are based on customizable templates; some platforms provide 360° panorama only, some allow to move between hotspots and explore a 3d modelled space, others provide freedom in terms of movements, compatible with HMD [RDKP]. The tours are often augmented with multimedia content. Although the pandemic emergency seems over, interactive VTs are still considered of high interest for cultural institutions and for tourists. Moreover, the use of VR is reported to have an impact on the on-site travel [BRE19] and on post-travel experiences [MBV*]. In a recent survey, it emerged that VTs are fundamental when a site is not accessible, useful when planning to physically visit it, but they should include other elements: access to details and multimedia content, capacity to explore an architectural space and interact with it, possibility to have social interaction [RDKP]. Many of these requirements are missing in common VTs. Moreover, there is another aspect rarely considered: the tangible dimension and the physical role of bodies, key for the creation of embodiment and empathy. This aspect is instead fully considered in works related to hybrid experiences [BBBH05, LRS*]. On the other side, there is today the technological capabilities of answering to these needs, in the Web3D domain. Regarding immersive VR on the Web for instance, after the introduction of the first WebVR open specification [PHJ*17], the new WebXR API (https://immersiveweb.dev) allows users to consume immersive experiences through common web browsers [GZO19] using consumer-level 3-DoF (including cardboards) and 6-DoF HMDs (e.g. Meta Quest).

4. Concept model and prototype design

In line with the project objectives and requirements, we have developed a general concept model, aimed at enabling the development of prototypes for hybrid XR collaborative experiences in the Cultural Heritage context.

The model is structured in two main and parallel flows: one represents the experience of the visitors, the second of the guide/moderator (Fig. 1). It was designed to be used by both s1 and s2. The visitors take part in a VT together, in groups of 5 people (set
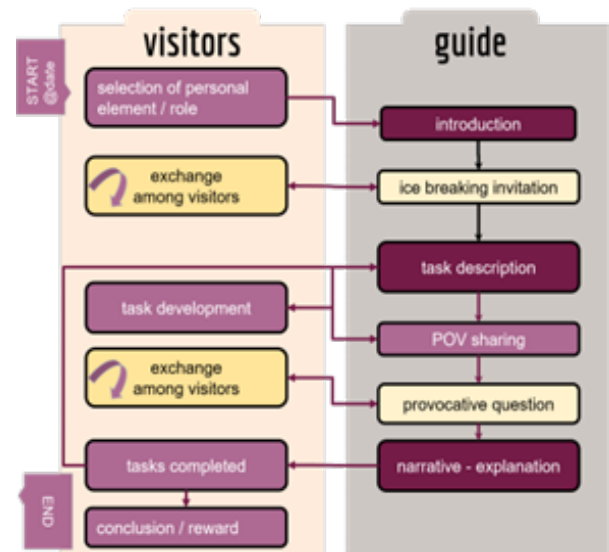

Figure 1: *The conceptual model of the authentic experience.*

as a maximum number that avoid complicating verbal exchanges). The participants start the visit by choosing a CH element, with the purpose of transforming the visit into something more personal and meaningful; they also increasingly develop their knowledge following a story self. The guide controls the experience, soliciting self-reflection through provocative questions, ideas exchange and collaboration through the assignment of tasks; when a participant cannot conclude a task, a "Point of View" is provided to all participants, allowing to synchronise visualisation and storytelling and to avoid exclusion other. The experience takes place in co-presence in a physical space and, at the same time, in a digital shared space world.

Based on this model, we have designed the first prototype that would have enabled an authentic on site XR experience of a CH site or museum. As planned, we have designed for a group of five users, who would have been accompanied by a human guide. The VT should have been carried out through a web-app and a shared logic, to allow the use of various types of devices (tablet, smartphone, desktop computer and Oculus), potentially both in presence and/or remotely. It was based on the ATON framework [FFD*21b] and made it possible to develop a specific UX and UI.

In this initial prototype, participants were invited to choose one visual object, by scanning a QRcode with a portable device. The selection was also used to connect users and to let them join a shared common virtual session, using the element. A specific UI and UX was developed for this type of user *Visitors*. The visit included the exploration of the 3d reconstruction of a monument, the exploration of semantic levels (visual and textual information and other multimedia content), discuss and solve a series of tasks. Through a distributed logic, the guide could influence what users see on their devices. Vice versa, visitors could communicate their progress to the guide through their interface. A second interface was developed for the *Guide*, who could control the experience and status of all participants through a control panel that was connect-

ing the narrative (and tasks), with the multimedia elements and 3d exploration, following a gamified approach meant also to limit distraction [PFF*] [PMP]. We have also planned to include an advanced type of user, who could join the session using a HMD *VisitorsHMD*. Even in this case an adapted UI and UX was developed. The concept behind the prototype follows the More Than Human Centred Design paradigm, as it proposes a network of relationships that goes beyond user/application interactions. We have implemented: User-User relations (verbal exchanges among visitors), User-Device relations (interaction with device interface involving navigation, querying and tasks solving) and Device-Device relations (access to the different instances of the same application). Once a Minimum Viable Product was completed, we applied the prototype to a real case study and tested it in real conditions in two temporary exhibitions.

5. Brancacci POV

The "Brancacci Chapel" is a masterpiece of the Renaissance in Florence (IT). In the second-half of the 15th century, it was owned by the Brancacci family, a rich family of merchants opposed to the Medici family. It has been painted by famous painters such as Masaccio, Masolino da Panicale and Filippino Lippi. Several restoration works have been carried out to try to maintain this treasure. Unfortunately, these frescos are fragile and delicate. In 2018, art conservators noticed some detachments of the pictorial layer, an alert was raised and a diagnostic campaign was started, led by CNR ISPC, in cooperation with Opificio and Florence Superintendence. Unfortunately, the importance of this monument is not considered by citizens and tourists, who often visit only main attractions, as the Uffizi museum. For these reasons, a Brancacci Chapel virtual experience could have been a particularly interesting case study. We have therefore decided to develop a specific application based on the prototype, naming it Brancacci POV (Point Of View), with the goal of providing an authentic experience to visitors interested to explore the monument collectively and accompanied by an expert.

BrancacciPOV 3D asset creation. To achieve this result, we have planned and carried out a 3D survey campaign, to be able to obtain a 3d model suited for the Web3D experience, as described in Figure 2. The 3D survey was performed using different image-based and range-based sensors (full frame camera and TOF laser scanner) and techniques, since an integrated approach was considered the best solution for an efficient acquisition and 3D representation of the building [REM], [FLB21]. Integration among image-based and range-based data were then computed through Reality Capture (RC) Software using a camera alignment approach which is based on synthetic images generated from the TLS registered point clouds. The obtained 3D model required further steps of processing to be used interactively through the web3D application. Therefore, the first step was to optimise the model. First, we had to remesh it with an automatic filter, both reorganising and decimating the polygon mesh that makes up the model. Then, the model was segmented into several parts according to the sections of the frescoes, and finally we proceeded to the most difficult part, which was the creation of the UV coordinates for the texture mapping. This process was manually optimised by organising the UV coordinates in the computer graphics software to have maximum control over

the result. In this way, it was possible to control the level of detail in pixels, i.e., the texture space allocated to the different parts of the model and to give higher priority to the areas of greater interest than others, such as the frescoes (weighted detail process), so that the user can see even the smallest details on the frescoes. This texture mapping was performed with both RGB and Ultraviolet textures to achieve a perfect match between the two layers, which can be experienced interactively within the application using a special tool (Ultraviolet Lens). The web application was realised using the framework ATON, which allowed the integration of the optimised 3D model of the Brancacci Chapel into the web-based virtual environment. For this case, a special technique was developed that provides more details about the frescoes depending on the user's viewing angle and position in the 3D space, and is suitable for standalone HMDs or mobile devices with limited resources.

Figure 2: *3D model of the Brancacci Chapel: 1) wireframe detail; 2) segmented model; 3) textured model; 4) RGB texture mapping a segment; 5) texture detail; 6) Ultra Violet texture*

BrancacciPOV application. As already anticipated, the Brancacci POV Web3D application is based on the open-source ATON framework [FFD*21b] developed by CNR ISPC. A first challenge to face was the detail required to visualise the frescoes: especially when targeting HMDs, a sufficient resolution is needed for an immersive exploration or close inspection. The main approach here was to adopt a multi-resolution structure per fresco-scene, allowing to load/unload high-resolution maps depending on user proximity and direction. A second challenge was related to the interactive discovery of invisible layers acquired with different instrumentation on the frescoes (as the Ultraviolet information). A tool was developed, available in specific stages of the experience, based on interactive lenses [TGK*] approach, and more specifically, on a previously developed model [FFD21a]. Previous literature did already prove and highlight the elegance, flexibility, and simplicity of interactive lenses applied to several fields and case studies. The third challenge was focused on the distributed logic of the application, including all the different participants' roles *guide, visitor, visitorHMD*. Different networked nodes needed to communicate in real-time, in a synchronous manner: the ATON framework offers all the building blocks for collaborative interaction (see [FFD*21b], section 3.7). The entire logic was thus developed on top of its collaborative component, that offers a simple API for custom event

broadcasting - with an additional filtering depending on participants' roles. Furthermore, the developed architecture for Brancacci POV, allows to create flexible networked setups, for instance combining both *guide* and *scoreboard* roles into a single node (machine) with participants using their own devices.

6. Brancacci POV experience and visitor survey

Brancacci POV experience was developed as a multi-user hybrid and collaborative VR experience that enables tourists to visit the Brancacci chapel, either remotely or in presence, together and while guided by an expert (Fig.3). UX involves one guide, who leads the experience through a control panel, used to both follow the narrative (explanation of the monument and its story), the tasks and the Point of Views (POVs). In order to also solicit social cohesion of the group [PBM], the guide also talks with the participants, prompts for action (tasks), makes provocative questions to solicit exchange, helps when needed and checks the status of each of the participants, verifying when they fulfil an assignment. When a visitor can not complete a task, he/she helps by sharing the same position in the 3D space (POV). This is received by all participants' devices, enabling them to observe the same viewpoint and perspective. The 5 "visitors" start the experience by choosing one among six characters depicted in the chapel. Then, they sit in a semicircle and in front of the guide and on a projected screen that works as the main visual reference for everybody. They share the same 3d space and interact with it and its semantic layers, while listening to the guide and discussing with the other visitors. At the end of the experience the visitors are asked to change roles and become a restorer, entering in the chapel with an Ultra-violet lamp and verifying what they have just learnt in the experience (Fig. 3, right).

Visitors Survey. A survey was undertaken in September and October 2022 at different venues in Florence (Italy), during public events. Visitors' perceptions, satisfaction and engagement with Brancacci POV experience were investigated through a questionnaire administered onsite after the experience and measured using items rated on a five-point Likert scale. Items were adapted from previous studies. A total of 107 questionnaires were completed. The large majority of respondents were Italian (81.3%), half of them based in Florence or Tuscany (53,3%). About half of the sample (51.4%) stated doing a physical visit to a cultural site more than 6 times a year; while about 47% declared to have never made a virtual visit to a site. The majority of respondents agreed that the Brancacci POV experience was unique (89%), authentic (88%), and meaningful (92%). Further, visitors' satisfaction with the hybrid experience resulted to be largely positive: almost the totality considered it useful (97%), found the information provided by Brancacci POV interesting (99%), and would recommend it to others (98%). Overall, 99% of respondents agreed to be satisfied with the experience. Respondents were also asked to indicate which aspect they enjoyed most and the concept of the experience as it was designed was indicated as the most enjoyable aspect (26%), followed by the possibility to have a guide (21%) and the mixed-use of different devices (16%). Finally, the findings support the role of this hybrid experience in promoting visitor engagement, with over 90% of respondents agreeing or strongly agreeing about the intention to learn more about the Brancacci Chapel (92.5%) and to physically visit it (or return) (96.3%).

7. Conclusions

In this research we have presented a concept model, prototype and application of an hybrid XR collaborative VT aimed at strengthening the perception of authenticity of a cultural experience. We have developed and tested our theory into a first prototype, Brancacci POV, designed to engage a group of visitors physically in the same location, guided by an expert. The results from the visitor survey suggests that this is the correct direction.

At the moment the on line version enable to access a simplified single user experience (https://brancaccipov.cnr.it). We are currently working on an advanced version that would fulfil the requirements of the second scenario (s2), enabling visitors to participate immersively and remotely to the experience. Moreover, we would like to extend and test it to classes of students, redesigning the experience with more than 5 participants.

Figure 3: *Brancacci POV experience: the guide (left), interacting visitors (centre), visitors with HMD (right).*

8. Acknowledgements

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