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A Comparison of Gamified, Immersive VR Curation Methods for Enhanced Presence and Human-computer Interaction in Digital Humanities

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Abstract:
Gamification of virtual reality (VR) experiences is a topic of research that has been particularly intensified with the advent or recent VR h/w, such as, low-cost, high field-of-view head-mounted displays (HMDs). The main novelty of this work lies in the investigation and comparison of different s/w human-computer interaction methodologies for real-time VR simulation of both tangible and intangible digital heritage sites and the creation of dedicated, immersive, gamified curation experiences. Important conclusions are drawn since for the first time, VR is finally becoming a mass consumer product that will be delivering more and more convincing interactive experiences with elevated feeling of Presence for Digital Humanities. Based on recent specific software 3D platforms and 3D content creation pipelines, digital heritage environments can benefit immensely from such versatile, efficient and robust prototyping VR human-computer interaction methodologies.
1. INTRODUCTION

Gamification connects to a sizeable body of existing concepts and research, both in human-computer interaction as well as game studies, including serious games, simulations, pervasive games, alternate reality games and playful design. It is defined as “the use of game design elements in non-game contexts” [1]. Whereas “serious games” describe the design of full-fledged games for non-entertainment purposes, “gamified” applications incorporate elements of games. In this work we aim to investigate the use of gamification for novel VR human-computer interactive experiences featuring high levels of Presence [8], [9], [17] specifically tailored for digital heritage curation applications. Digital curation of heritage sites, involves the presentation to the visitor of both tangible as well as intangible 3D and multimedia heritage elements. Our main research involves the following forward-looking research questions: a) are novel, low-cost, modern HMDs suitable as complete VR platforms? b) What are the most appropriate s/w platforms and 3D content creation pipeline tools needed to realize such VR digital heritage gamified experiences for digital humanities? In Section 2 we describe the previous work in this area and the two different archaeological sites that were simulated with our methodologies, namely the Roman Agora (Forum) in Thessaloniki, Greece and the site of Knossos, Heraklion, Greece as shown in the following figures 1-4.
In Section 3 we give a brief overview of the two VR frameworks and their VR and multimedia capabilities harnessed in our two applications, namely the proprietary Unity3D [14] engine and our own, open-source glGA [2]. Section 4 describes in detail our tangible (static 3D building reconstructions) heritage content creation as our intangible heritage simulations (animated virtual characters capable of reenacting plays, customs and stories) were described in [3]. In Section 5 we present the actual gamified heritage site curation for both archaeological sites, using the previously two described frameworks based on the single3D content-creation pipeline. We summarize the main answers to our research questions in Section 6 and we provide conclusions in Section 7.

2. PREVIOUS WORK

VR games [16], [10] are able to elude one’s cognitive system and produce the sense of being physically present in the real as well as the virtual gaming world. This “sense of being there” is also known as presence [17], [24], [25]. Presence is considered as a paramount factor when using VR environments, especially considering digital heritage settings, since it gives an indication of whereas the virtual scenario has the ability to drain the subject into it, as a “trip to the past” [9], [18], [26]. In this way, the level of presence is fundamental to understanding the extension of which the subject perceives the scenario as a real world experience, even though the origin and nature of this variable is still not clear. Virtual reality alone (the one component of Mixed Reality (MR) since Augmented Reality (AR) is the other) has increased its role.
in the last few years as a consumer gaming product. However, even today very few VR-game products exist and even fewer are originating from the mainstream game industry [11], [19], and those existing do not take advantage of latest VR gamification technologies, despite the fact that there is a significant market need. VR Games are unique in their ability to motivate and stimulate people. Indeed, gamers often surprise themselves and are capable of much more than expected. The concept of Serious Games (SGs) is based on taking advantage of these game assets to motivate students and ease their learning process [20], [27]. Games also promote active pedagogy by placing learners in the position of central actor, thus providing them with a sense of power and control over their learning activities and curriculum [21]. Recent 3D heritage visualization technologies [7] do not focus particularly in VR, HMD-based immersive gamified experiences, hence leaving this new area relatively unexplored.

2.1 Ancient Agora of Thessaloniki – Roman Forum

The Ancient Agora – Roman Forum [6], the administrative center of ancient Thessaloniki, occupied an area about two hectares in the heart of the city. Its construction began at the end of the 2nd century A.D. on the site of an older forum dating from early Imperial times (real and virtual parts are illustrated in the figure below).

Figure 5 Aerial view of the Site of the Roman Agora, Thessaloniki, Greece (left) and the 3D reconstructed Stoa (right)

The complex was arranged around a rectangular paved square. There were stoas on three sides, each of which consisted of a double row of columns and provided direct access to a surrounding zone of public buildings. The southern stoa stood on a vaulted substructure (cryptoporticus) - a double arcade which lay partly underground, making use of the natural slope of the land. To the south, along the whole of the cryptoporticus, lay a row of shops fronting the ancient shopping street which ran along the north side of present-day Philippou St. Off this street lay minor entrances to the square, while the latter opened north, to the present-day Olympou St. In the middle of the east wing, on the site of an earlier council - chamber, a building for public performances was erected, which, on the basis of the
inscription and the statues of Muses found there, must have functioned as an Odeon.

All the 3D reconstruction information was provided by the IST Ephorate. Currently there is a modern museum on-site and the Ephorate is actively exploring with this work modern VR, immersive technologies as novel curation enhancements for the site visitors.

2.2 The Great Palace of Knossos

The palace of Knossos was a political and ceremonial center of the Minoan civilization [5], built between 1700BC and 1400BC. Its total size reached twenty four thousand squares meters and it was consisted of one thousand three hundred rooms, all connected with a variety of different corridors (parts are illustrated in the figure below).

![Figure 6 3D virtual reconstructions of the site of ancient Knossos, Heraklion, Greece](image)

In more detail, in the center of the Great palace was the Central Court which connected all the different wings of the palace. At that time it was a very common setup among all the Minoan palaces. In the west side there were the West Facade and Porch. The most famous part of the palace is the Throne Room. Its name originated from the stone seat found in the room behind the antechamber. It is a late addition, created during the period of Mycenaean occupation. South of the Throne Room there is a shrine which was called “Tripartite Shrine” from the archaeologist Arthur Evans. Most of the credits, for what it is known nowadays about Knossos, is attributed to the archaeologist Arthur Evans. For us, all basic 3D reconstruction data were collected from [5] as well as our own data collection via on-site visits.

3. IMMERSIVE VR FRAMEWORKS CURATION CAPABILITIES

To realize virtual reality games, we employed the Oculus Rift HMD DK-1 and DK-2 devices and associated SDKs via two different s/w 3D simulation frameworks, the commercial Unity3D game engine and our own, GPU-powered, teaching computer graphics open-source giGA framework [2], [3], [6]. In this work we compare the process of utilizing
both frameworks with the same 3D content, based on interchangeable, standard 3D formats and content creation pipelines, both for the tangible (static 3D edifices) as well as the intangible heritage (animated 3d characters and storytelling-based site curation).

Regarding Unity, all Oculus VR camera utilities (OVR) are created from the Oculus team explicitly for this game engine. What is needed is to download the specific files from the Oculus support site and insert them into the Assets folder in the Unity’s project. There are two prefabs for the camera. The first one is only static, leaving the developer write the scripts for the camera’s manipulation. The second one is a Player Controller and it is the same camera, with first person, in terms of rotation and movement, scripts attached. Since our game is from the player’s perspective we chose the second prefab. With one simple drag and drop GUI motion we have VR camera with First Person point of view. For easier movement in our Virtual Environments (VEs) we added translation into Y axis as well, even if it is not possible for a human to do so. Since the user will not be able to see the keyboard, and focusing only on convenience, camera’s vertical translation occurs with the movement of the mouse. In Unity the OVR offers many more to suit any type of game. Crosshair, camera’s rigid body and Head Up Displays (HUD) are implemented, so the user can simply make any change he wants in the particular script instead of creating them from scratch.

In our own glGA in order to create the camera, we implemented into our framework as a plugin, support for the SDK v2.5c in C++11. In our glGA VR game, we went right from the start for a free look camera. In the main loop, the Oculus_getOrientation () function is called and returns the HMD orientation which is casted to a Mat4 matrix. This is convenient for us in order to multiply it with the camera’s View Matrix so that using the HMD and the user-controlled mouse the user can perform freely navigation using his/her orientation and mouse/keyboard control keys. Both Unity and glGA support also modern 2D multimedia presentation capabilities, such as displaying video-textures, images, text and sounds all directly in the 3D virtual environment. We heavily utilized them in the presented games, as shown latest in Section 5.

4. CONTENT CREATION OF TANGIBLE AND INTANGIBLE DIGITAL HERITAGE SITES

4.1 3D tangible digital heritage authoring pipeline

4.1.1 Roman Forum 3D reconstruction

In the Roman Forum, also known as ancient agora, we focused on the eastern entrance and the non-existing today Stoai (portico) as the IST Ephorate was particularly interested in simulating this part in VR, in order to evaluate various hypotheses regarding its form.
In terms of visual information, we relied on the sketch provided by the IST Ephorate showing a proposition by the archaeologists. The creation tool for this environment was Google SketchUp and after its completion was subsequently exported as Collada 3D file and shown in Figure 7. Regarding the intangible digital heritage content creation that we followed, the reader can refer to [2], [3].

4.1.2 Palace of Knossos 3D reconstruction

As a virtual environment, we created the whole palace of Knossos in its currently physical reconstruction by Evans [5] as shown in the figure below. As emphasis was put into real-time VR simulation, we employed similar tools and sources as in the previous Agora reconstruction.

5. GAMIFICATION OF DIGITAL HERITAGE SITES CURATION

5.1 Roman Agora site gamified curation

In the Roman Forum of Thessalonica [4] we focused mainly on the east Entrance Stoa and this results to a small VE for us to stage a proper curation game. So we created one single suite of mini VR games: In the first one, the player is far away from the entrance and his goal is to reach it. In his/her way there are three ancient Roman characters, with one challenge each blocking his way. To proceed forward he/she must complete successfully certain challenges:
a) First one is about a gamified memory challenge - Three boxes move independently for three rounds and at the end of each one the user must type the order of their movement.

b) The second challenge has to do with speed. The player starts with a small amount of life. He faces three rows against him with each one having bombs and coins. These are thrown at him for a specific amount of time. If in the end of this challenge his life is more than zero, then he will be able to proceed to the final mini-game.

c) The last one tests the player’s knowledge about the site. Three questions appear (all of them have to do with the Roman Forum) and he must answer at least one correctly. If everything goes well, the user will be able to see freely the entrance. At the end there is a Multimedia Corner where all presentations are hosted there. The user can enable or disable them with the left mouse button. These are briefly shown in the figures below (dual screens are due to stereoscopic imaging for each eye in the Oculus DK1 HMD)

Figure 9 Roman Agora suite of VR mini-game shells in our giGA framework

Figure 10 Knossos site gamified curation in Unity

5.2 Knossos site gamified curation

The palace of Knossos is a vast environment. So we were able to create a mini adventure-exploring-type of game. Throughout this game there are ten coins that the user needs to collect. Also four strange boxes are scattered around hiding tiny robots in them, Portal style, waiting for the player to step into them. By doing that the box fades away and the little robot asks a question about Knossos. The user’s task is obviously to find the answer. Around the area, there are hidden various multimedia presentations containing information about the palace. The figure below illustrates examples of our results.
6. IMMERSIVE VR FRAMEWORKS CURATION CAPABILITIES

When we commenced creating VR games using the novel Oculus Rift DK1 HMD, our main goal was to investigate an open 3D content creation game pipeline for a gamified curation specifically tailored for VR immersive experiences with enhanced presence. Thus we achieved a single such pipeline and then tested it with two different s/w 3D game simulation frameworks. From this comparison and pipeline, the following novel results were obtained:

• Oculus Rift DK1 by itself is not yet a minimum VR platform. Head and hand tracking (rotations including translations) should be coupled to the underlying s/w framework as also found in [11] in order to avoid “breaks in presence”. Recent RGB-D based algorithms and open frameworks from FORTH provide such ready-to-be integrated solutions [22], [23] and we are currently in the process of integrating them. Instrumental to this approach is having complete source code support and usage of C++11, thus our own glGA framework has a clear advantage to this process, rather than other commercial frameworks.

• Unity provided an easy to use, fast rapid prototyping environment with high visual 3D realism (shadow-mapped point lights as well as HDR area lights and skyboxes). The forthcoming Unity 5 with global-illumination for real-time will be an interesting, multi-platform solution to further explore. However, our current VR games have so far indicated (we have not finalized yet a formal user study) that a coherent, low-realism 3D world can lead to higher presence by the participants: If you’re targeting a visually realistic environment, it is more likely to generate breaks in presence [10]. This is because human brain will expect many things that we are not yet able to achieve technically: perfect physics, sound, force feedback so that your hand doesn’t penetrate an object, objects breaking in pieces, etc. Having a lower-realistic environment lowers user expectations that all world should be perfectly simulated, resulting in a more consistent presence feeling.

• Oculomotor (avoiding eye strain) and bodily comfort (e.g. asking the user to sit to prevent feelings of disorientation and nausea) are key factors to provide a Positive user VR experience. In order to maintain as much as possible VR immersion from the start till finish of the VR game, a challenging tasks that requires multiple s/w and h/w parameters has to be constantly re-evaluated and adjusted. As a good starting point we found out that the Oculus Best
practice guidelines [10], [11], [12] as well as other similar guidelines from other researchers [13] allow adjustment and intensification of the VR experience.

6. CONCLUSIONS AND FUTURE WORK

VR is an immersive medium that finally is providing a sea change in entertainment [15]. It creates the sensation of being entirely transported into a virtual (or real, but digitally reproduced) three-dimensional world, and it can provide a far more visceral experience than screen-based media. Enabling the mind’s continual suspension of disbelief requires particular attention to detail. It can be compared to the difference between looking through a framed window into a room, versus walking through the door into the room and freely moving around.

The Oculus Rift is the first VR system of its kind: an affordable, high-quality device with a wide field of view and minimal lag. Until now, access to VR has been limited primarily to research labs, governments, and corporations with deep pockets. With the Oculus Rift, developers, designers, and artists are now leading the way toward delivering imaginative realms to a global audience.

If VR experiences ignore fundamental best practices, they can lead to simulator sickness—a combination of symptoms clustered around eyestrain, disorientation, and nausea. Historically, many of these problems have been attributed to sub-optimal VR hardware variables, such as system latency. The Oculus Rift represents a new generation of VR devices, one that resolves many issues of earlier systems. But even with a flawless hardware implementation, improperly designed content can still lead to an uncomfortable experience.

Because VR has been a fairly esoteric and specialized discipline, there are still aspects of it that haven’t been studied enough for us to make authoritative statements. In these cases, we put forward informed theories and observations and indicate them as such. User testing is absolutely crucial for designing engaging, comfortable experiences; VR as a popular medium is still too young to have established conventions on which we can rely. Although we have user-studies underway, there is only so much we can study at a time. Versatile 3D game engines and open-source 3D frameworks need to fully support such VR hardware and complement it with necessary tracking and VR specific content-creation pipelines.

Once HMD h/w improves in the next two years, we expect to witness even more elevated presence in VR simulations such as cultural heritage reconstructed sites and their gamified curation.
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