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Developing a VR Game Featuring Optical Illusion Challenges to Support Cultural Heritage - A Progress Report

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Figure 1: A view of a hidden room featuring the 6th century mosaic of Panayia Aggeloktisti church

Abstract

This paper presents the development state of a Virtual Reality game to support cultural heritage through puzzle-based optical illusion gaming challenges. It is an immersive escape room type of game focusing on the cultural heritage of Cyprus, where players must complete a series of optical illusion challenges to progress, while learning historical information about key landmarks, monuments and objects of significant heritage to the Cypriot community. The main project objective is to bring together various archaeological artefacts in a virtual space and providing an immersive gaming experience to its users/visitors. The paper highlights the need for investigating the topic of VR gaming to support cultural heritage. It presents the development progress to date, including information on the digitisation process, environment design, and the mechanics of the VR game. Some of the future directions of the project are also presented.

CCS Concepts

• **Computing methodologies** → **Virtual reality; Mesh models;** • **Applied computing** → **Interactive learning environments;**

1. Introduction

The latest technological innovations in the field of Virtual Reality (VR) have significantly contributed towards fostering the digital transformation of a plethora of domains. Cultural Heritage is one of the fields that has been directly benefited from advancements in VR, especially as a technological method to visualise and interact with tangible and intangible heritage. VR and computer graphics have drawn significant attention and interest for creating virtual versions of heritage, enabling users to access and experience some

of the world's most famous heritage sites from the comforts of their own home, and to explore history or sites that may even no longer exist [NAB20]. VR is increasingly used by cultural heritage organisations through applications, such as virtual museums, VR tours, storytelling etc., and lately through games for educational and entertainment purposes. Recent projects utilize VR games to develop interactive experiences, however, research is still at its infancy and it lacks adequate understanding of its benefits and drawbacks in the domain of cultural heritage [TA22]. The wide implementation of

VR has brought new challenges in technological, industrial and societal perspectives [TA22], and it is important to develop in-depth understanding of the affordances and opportunities of VR gaming to support education and promotion of cultural heritage. This paper presents the current state of development of a VR game aiming to support Cypriot cultural heritage through optical illusion gaming mechanisms, challenging players to complete puzzles and experience heritage in immersive ways.

2. Background and Context

Cultural Heritage is the cornerstone of our identities and social cultures, and its preservation and dissemination is of paramount importance to protect our history [Bou03; NAB20]. Cultural heritage goes beyond locations, objects, languages and symbols of historical importance, as these are products of cultures, and it is imperative to be able to understand and perceive intangible heritage such as religions, traditions, cultures, and social norms [Bou03]. Cultural heritage organisations are constantly seeking of ways to engage the audience through the use of digital technologies such as VR, AR and Mixed Realities, IoT, even robots, among a plethora of other emerging technologies [NAB20], fostering the concept of Digital Cultural Heritage (DCH). DCH seeks to integrate digital technologies in traditional cultural heritage practices and support the collection, preservation, reconstruction, visualisation and dissemination of heritage through innovative ways [MML*20]. Experimentation with VR in particular has given rise to interactive applications capable of providing engaging experiences to users i.e. virtual museums [FFP*20]. Increasing interest is further shown in technology mediated game based learning and gamified educational approaches in DCH [MD17]. In fact, games and gamification approaches to support DCH through Serious Games are successfully used to engage and educate people with great success over the years [KG21]. These are digital games designed for non-entertainment purposes (i.e. training, education etc.), where the players develop knowledge and skills through completing tasks and obtaining rewards in the process [JLDV17]. Serious games have been successfully used to support and increase engagement with very positive results [CB20; TA22], and their efficacy and impact in the DCH context has been the focus of extensive research for the past 20 years. However, a relatively unexplored domain which research is still young is the use of VR video games for cultural heritage [Cha20].

2.1. Video Games in Cultural Heritage

The success of the video games industry has found its way into DCH, providing new and entertaining ways of experiencing and disseminating heritage [FFP*20]. Over the recent years, many examples of successful projects are produced by cultural heritage organisations, educational institutions, heritage experts, and even entertainment game studios which have developed games that were either historically accurate or imaginary representations of settings, scenarios and storylines, or both [FFP*20]. For example, Assassins Creed I developed by Ubisoft have been studied from its cultural perspective, enabling players to experience examples of social culture in Middle East, customs, and attitudes, and to develop emotional connections with locations through the gameplay, the storyline, the visual and character design, and narratives [SANM08].

The Assassins Creed game series is one of many examples of such games, featuring realistic and accurate reconstructions of historical monuments such as Hagia Sofia in Constantinople, the Notre Dam Cathedral, the Parthenon, the Pyramids of Giza and other, embedding them in the storyline and into the gameplay. There are also recent attempts combining entertainment games with education, for example, the project SAGA that aims to bridge the gap between serious and entertainment video games by considering history and facts for entertainment, historical accuracy and playability [LA22] among others.

The field of VR gaming is drawing development attention recently. A recent study conducted by [TA22] identifies a number of VR game genres implemented in cultural heritage, and categorises them in serious games, interactive story telling, escape/puzzles, quest games, beat-them-up, and multiplayer games. Puzzle games is a genre which interests players, and in particular optical illusion puzzles are drawing attention [WXW*21]. Optical illusions such as colour perception illusions (Munker illusion), parallel lines looking askew (Zöllner illusion) and others have been used in games and integrated into gameplay as a way to challenge players [WXW*21]. One of the most well known video games implementing optical illusions is 'Superliminal' (www.pillowcastlegames.com) enabling the player to experience optical illusions as the core game mechanic, i.e. manipulating objects in size and converting real into forced perspective, viewer and dimension perspectives of how things look differently from different angles and other [Han20]. 'Monument Valley' (www.monumentvalleygame.com) and 'Manifold Garden' (manifold.garden) are also highly anticipated games that enable the player to experience optical illusions, manipulate impossible architectures and spatial arrangements, with great commercial success, among others [Bon21]. To implement optical illusion challenges in videogames, [WXW*21] proposes a detailed workflow to guide game designers on how to illusionise their games through a comprehensive database of optical illusions. Optical illusions have also been drawing research attention, for instance, [CKM*22] presented an example project of an educational escape room game focusing on educating users about arts and artists, which some of the game challenges include optical illusions.

3. VR Game Prototype

The game described in this paper is a prototype under development by researchers and students at the University of Central Lancashire, Cyprus (UCLan Cyprus). The aim of the game is to raise awareness about Cyprus cultural heritage by enabling players to visualise and learn important historical information while challenged through puzzles in an interactive learning experience. Optical illusion challenges are implemented to offer an engaging way of ensuring that the players will explore the VR setting, study, and interact with the immersive exhibits for completing the challenges to progress. The game targets the younger generation of users who are influenced by their exposure to video games, VR, high fidelity 3D graphics, smart devices, and other modern entertainment and social networking technologies, to provide them with an interactive method to experience and be educated about Cypriot cultural

heritage. The game is developed using Unreal Engine 4, and configured for Meta Quest 2 VR headset.

3.1. Game Mechanics and Level Design

The game is an escape room puzzle environment, where in order to progress through the different rooms, the player must complete optical illusion puzzles by interacting with objects to translate their size, move them around, insert or remove them from trigger points, manipulate gravity, and through other interactions. The key puzzle mechanics implemented to support the gameplay are based on the concept of ‘misleading’ and ‘swapping realities’ optical illusions as defined by [WXW*21]. Misleading illusions refer to specific challenges that appear to be one thing, but actually represent something else, and are implemented to increase the difficulty of the task. Swapping realities illusions focus on alternating between an environment with no illusions, to an environment filled with illusions. For instance, the game features challenges where the objects required to resolve them are slightly obscured, masked or hidden in the environment, and are not immediately noticeable or understandable at first glance. Such challenges require the player to solve riddles, observe, explore, and/or interact with the environment, understand visual cues, and also to rely on their perceptions to figure out the way to resolve them.

Several optical illusion challenges have been employed. Forced perspective resizing techniques, where the size of an object is manipulated in real time and matches the viewport perspective of the player have been implemented. For example, in a particular room featuring historical information and 3D models from Panayia Aggeloktisti church, the player encounters a riddle which prompts to explore the environment and identify a particular object which needs to be picked up, resized, and placed at a dedicated trigger space to unlock a secret passage to a room featuring the famous 6th century mosaic of the church (Figure 2). View perspective challenges require the player to explore a room (Figure 3a), identify and focus on texture materials projected in the environment from a particular angle (Figure 3b), for the illusion mechanics to convert the textures to an object then to be used for solving the puzzle and progress (Figure 3c). A gravity based illusion challenge that requires the player to interact with a room in which gravity must be manipulated to complete the puzzle and progress is implemented (Figure 4a). A deception challenge is also implemented (Figures 4b and 4c), making the player to believe that there is a hallway with an object of interest at the end of a corridor (Figure 4b), but once the player gets closer, it is a 2D image (Figure 4c).

The difficulty of the game is increased as the player progresses through the rooms. This is implemented by introducing new and combinations of challenges, riddles are harder to solve, challenges require multiple tasks to be completed, and less clues are provided to the players. The key game mechanics were developed by the second author of this paper as part of the requirements for his undergraduate degree final year project, under the supervision and guidance from the first author.



Figure 2: Inserting a resized cube into a trigger box unlocks a hidden room showcasing the famous 6th-century wall mosaic in Aggeloktisti.

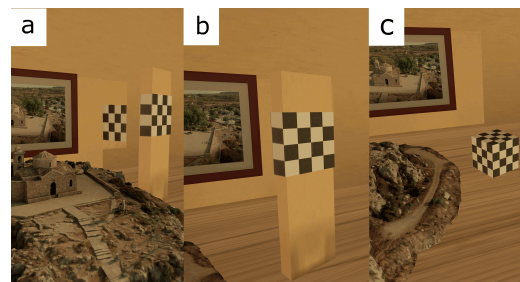


Figure 3: Perceived visual angle illusion, converting a 2D texture (a, b) into a 3D cube (c).

3.2. VR Environment Design

To design the DCH aspect of the environment, several important archaeological artefacts have been digitised. A team of undergraduate students studying Computer Games Development at UCLan Cyprus, under the guidance of the lead author of this paper have visited, captured and digitised them to develop a game that will aim to bring them all into a single interactive VR experience. The game currently features the church of Panayia Aggeloktisti including its unique 6th century mosaic (Figures 1 and 2) and wooden paintings, the church of Prophet Elias (Figure 3), and the ruins of Aghios Mamas church in Aghios Sozomenos deserted village among other exhibits (Figure 4a). Data was captured using drones equipped with high-definition cameras, high-quality digital

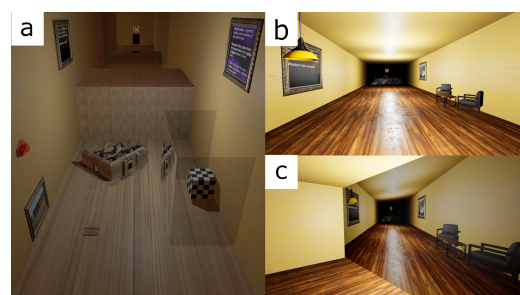


Figure 4: Gravity (a) and deception (b, c) optical illusions.

cameras, and mobile phones. The collected photographic data was processed through Zephyr 3D (www.3dflow.net) photogrammetry software that uses a range of complex computing algorithms to convert the captured data into detailed 3D models. The initially generated models were further processed through a chain of Computer Aided Design (CAD) software to enhance and optimise their performance by reducing geometry in ways that would keep the original shape and texture quality of the models intact, but make them efficient for implementation in CAD software, Game Engines and eventually in VR. Tools such as the Agisoft De-Lighter (www.agisoft.com) software to remove shadows from textures, Instant Meshes (github.com/wjakob/instant-meshes) for mesh retopology through converting high polygon 3D assets into reduced polygon count models, and Blender (www.blender.org) for UV unwrapping, texture baking and for general modeling purposes have been used. This manual process was necessary to ensure that the 3D models would have been optimized in terms of size and triangle count before imported in the VR environment, to improve loading times and rendering costs of the VR scene. The development team aims at around 400-600 draw calls and a triangle budget between 750k - 1 million per frame as suggested by Meta Quest 2 performance and optimisation guides [Met].

4. Conclusions and Further Work

The purpose of this paper is to present the initial efforts in the development of a VR game aiming to support the Cyprus cultural heritage through puzzle based optical illusion challenges. The development team is currently experimenting with the mechanics, applicability and effectiveness of optical illusion challenges, exploring their level of difficulty, usability, issues pertaining VR sickness when interacting with them during gameplay, and evaluating the players' overall experience. The team is also working on optimisation techniques to improve graphics rendering and memory management. Future work will focus on additional gaming functionalities, structured educational materials, designing scenarios combining the illusion challenges with the storyline of the game, replacing the current primitives used in the illusion mechanics with digitised heritage objects, and to further digitise additional heritage artefacts. Experimental protocols for a series of user evaluation studies investigating the players experience from multiple perspectives, such as educational, enjoyment, challenge and usability perspectives are also under preparation.

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