

Preservation and Dissemination of Historical Architecture Based on Unreal Engine: A Case Study of the Design of the Macao Ruins of St. Paul's Block Game

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Abstract:

With the rapid development of information technology, digital technology has become an important means of protecting and disseminating cultural heritage. Although traditional methods of cultural heritage protection, such as cultural relic restoration, displays, and museum exhibitions, have made significant contributions, they lack interactivity and modernity, making it difficult to attract the active participation of young viewers, nor is it conducive to its sustainable preservation and value dissemination of cultural heritage. At the same time, looking globally, cultural heritage is facing threats from natural disasters, time erosion, and man-made destruction due to various subjective and objective factors. Some historical buildings have suffered significant damage or even disappeared altogether. Video games, as an important branch of current digital technology, can not only restore the real details of historical buildings with high precision but also greatly enhance the sense of immersion and participation while interacting with virtual objects to improve the effectiveness of cultural dissemination. Therefore, game content design has great potential to explore the digital protection and dissemination of cultural heritage. This research focuses on the ruins of St. Paul's, a historic building in Macau, by developing a building block game using Unreal Engine to explore the role of digital technology in the preservation and dissemination of historical architecture.

Keywords:

Historical Buildings, Unreal Engine, Game Design, Ruins of St. Paul's

1. Introduction

1.1. Gamification Design in the dissemination of cultural heritage

Gamification design holds immense potential in exploring the digital preservation and dissemination of cultural heritage. It refers to a design methodology that incorporates the strategic use of game elements in non-game contexts to enhance user engagement through mechanisms such as challenges, rewards, and interactive features.

By creating a seamless flow in the user experience, gamification design not only focuses on external motivation but also taps into intrinsic motivation, resulting in a more captivating user experience through both internal and external effects. Research has demonstrated that combining interactive and entertaining games with the promotion of cultural heritage can significantly increase users' interest and participation, effectively attracting younger audiences' attention while fostering the protection and inheritance of cultural heritage. For instance, "Black Myth:Wukong," an exceptional AAA game released on August 20th this year (2024), showcases historical architecture and sculptural art from various regions like Shanxi, Chongqing, Shandong, Fujian through meticulously designed scenes, authentic restoration of ancient buildings, and engaging storylines. This immersive gaming experience ignites players' curiosity about ancient Chinese architecture and cultural sites presented within the game. The success of "Black Myth:Wukong" exemplifies how games have transcended their role as mere entertainment tools to become powerful mediums for disseminating tangible and intangible cultural heritage. They play a crucial role in capturing people's attention towards traditional culture while showcasing the unique charm of Chinese civilization—a testament to China's confidence in its rich cultural legacy.

The game's mission objective guidance and the accurate reproduction of artifacts by the game Engine contribute to players' understanding of the cultural and historical significance behind the building. For instance, Unreal Engine utilizes advanced graphics processing features such as Nanite and Lumen technology to ensure optimal computer performance. This significantly enhances screen precision and visual effects, faithfully restoring intricate details of the building. As a result, players can smoothly immerse themselves in the game content while effectively integrating technological advancements with artistic elements.

The Unreal Engine blueprint system also offers designers a visual scripting tool, enabling creators without programming experience to effortlessly develop game logic and interactive effects through the simple act of dragging and dropping function nodes. This significantly reduces the barriers for individuals entering game development, facilitating the realization of creative ideas.

1.2. Ruins of St. Paul's

Macau, as an important city where Eastern and Western cultures converge, boasts an abundance of historical edifices, among which the Ruins of St. Paul's stands as one of Macao's iconic landmarks. Originally serving as the frontal wall of St. Paul's Cathedral, it suffered destruction from three fires, leaving only the church facade, part of its foundation, and the stone steps in front. The "archway" embodies elements of Italian Baroque architectural style. The incorporation of diverse cultural elements within the church structure, such as Japanese chrysanthemum carvings and traditional Chinese carvings, epitomizes the integration and development of various cultures (Figure 1). This building was inscribed on UNESCO's World Heritage List in 2005. The archway, standing at a height of 25.5 meters, is constructed entirely from granite and is comprised of five distinct layers. The first layer features three doors, flanked on either side by a total of ten Ionian pillars that serve both as supports and decorative elements for the walls. Positioned in the center is the main door, adorned with Latin inscriptions reading "MATER DEI," which translates to "Mother of God." This inscription signifies the church's dedication to the Virgin Mary. The door lintels on either side display three uppercase letters: "I," "H," and "S," which are the

abbreviation for the Latin phrase “Jesus Hominum Salvator,” meaning “Jesus, Savior of Mankind,” and also the emblem of the Jesuits. The second level contains four bronze statues, supported by ten Corinthian columns, and includes three windows, with the lintels adorned with seven rose flower reliefs, symbolizing holiness and love in Catholicism. The theme of the second level is “The Mission of the Apostles.” The third level is the most richly decorated, themed “The Compassion of the Virgin,” showcasing the loving image of the Virgin Mary and her significant role in Catholicism through abundant religious patterns and sculptures. The fourth level is themed “The Redemption of Humanity”, with Jesus at the center, emphasizing the redemptive spirit of Jesus Christ, flanked by reliefs of the instruments of Christ’s Passion, symbolizing the suffering endured by Jesus. The theme of the fifth level is “God Creates the Universe”, presented in a triangular shape, with a dove at the center representing the Holy Spirit, surrounded by carvings of the sun, moon, and stars, symbolizing the horizon, and topped with a cross.



Figure 1. The purple Ruins of St. Paul's on the 20 Macau Pataca banknote.

The Ruins of St. Paul's serves as a symbol of the fusion between Chinese and Western cultures, epitomizing Macao's pivotal role in global history and cultural exchange. It stands as a “witness” to the transformative historical shifts that have taken place in Macao, possessing profound cultural significance.

The humid and rainy climate in Macao readily leads to stone weathering and structural corrosion. Moreover, the post-epidemic surge in tourist numbers will inevitably result in irreversible deterioration of the stone walls and pillars. Consequently, over time, the Ruins of St. Paul's faces a risk of damage, making it imperative to explore digital technology as an urgent means to achieve cultural heritage preservation and dissemination.

1.3. Research Target

Based on the aforementioned background, this research explores how to develop a brick-building game centered on the Ruins of St. Paul's in Macau using the Unreal Engine. Through gamification design, the architectural details and the historical and cultural background of the Ruins of St. Paul's are incorporated into the brick-building process, enabling players to reconstitute historical buildings and restore their former appearance through interactive experiences with virtual brick blocks. Thus, players can acquire historical knowledge and architectural styles in a pleasant atmosphere, achieving the goal of understanding the cultural connotation of the Ruins of St. Paul's (Figure 2). This study not only pays attention to the digital reproduction of the Ruins of St. Paul's but also aspires to offer an innovative solution for the protection and dissemination of cultural heritage through game design.

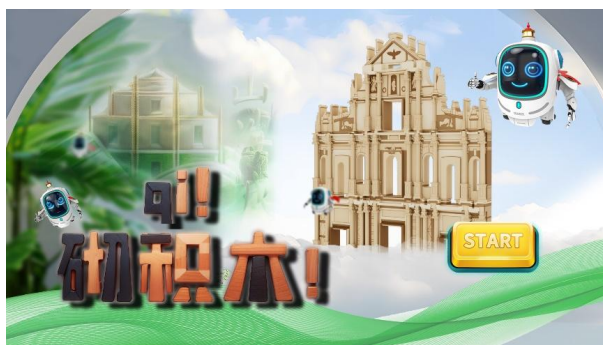


Figure 2. Game Start UI Interface.

2. Overview of Related Research and Technology

2.1. Gamification Design and Cultural Communication

Game-based design has gradually become a crucial tool for cultural dissemination and education. Through the interactivity, entertainment, and immersion of games, complex contents of cultural heritage can be conveyed to the public, particularly the younger generation, in an innovative manner. Jane McGonigal, the renowned game designer, has pointed out that games are not merely entertainment tools but also effective means of learning. Games can meet with the human's desire for "play" through practical operations, making players to focus more on the content itself and helping them understand historical and cultural contents more profoundly. For instance, in the game series *Assassin's Creed: Unity*, the meticulous recreation of the Notre Dame Cathedral scene allows players to unconsciously acquire historical knowledge related during gameplay. In April 2019, Notre Dame Cathedral was tragically destroyed by fire. Ubisoft Studio, the production company of *Assassin's Creed: Unity*, provided reference blueprints for the restoration work of Notre Dame to the French Government. Interactive and immersive experiences are conducive to enhancing users' cultural learning experiences. Minecraft is a sandbox video game where players freely create various buildings and artistic styles in a three-dimensional space. Through a simple construction mechanism, players are able to build architectures they are interested in, so creativity is cultivated. Some players have even created real-world buildings such as the West Gate of Peking University and Boya Pagoda for others to visit in a virtual campus which sets a good example for the digitization of historical buildings.

2.2. The Application and Potential of Block-Based Game Design

Digital building block games draw upon the gameplay of traditional children's block games. Through modular design, complex architectural structures are disassembled into simple blocks. Players can assemble the blocks in accordance with a certain logic and gradually construct a specific architectural style from numerous scattered components. This design offers players greater flexibility and efficiency. During the game, players not only enjoy the pleasure of creation but also gain an in-depth understanding of the structure and cultural background of architecture. The building block game in this study also employs a similar approach. In the process of assembling under the established mechanisms in the game of *Ruins of St. Paul's*, players deepen their memory and understanding of the architectural features of the Ruins of St. Paul's.

2.3. Analysis of Relevant Domestic and International Cases

The project “Zhu Di Builds the Forbidden City” initiated by the Palace Museum in China offers experiential visitors an immersive experience of the entire process, from proposal to completion, of constructing the Palace Museum during the Yongle period of the Ming Dynasty through cutting-edge virtual reality technology. Visitors actively engage with and interact within a virtual environment, resulting in a strong sense of presence. In 2022, Florence developed a heritage data system funded by the Italian Ministry of Culture to recreate the historical town scene using advanced 3D modeling and virtual reality technology. Users can fully immerse themselves to explore and appreciate the medieval architectural art in this virtual environment by wearing virtual reality helmets. Through the utilization of digital technology, users’ perspective is expanded beyond individual buildings to encompass the entirety of the historic downtown area and its urban cultural landscape. Through comprehensive and multi-faceted data collection and analysis, a more extensive and multi-level information can be provided, thereby enhancing the scientific and systematic approach to cultural heritage protection. These cases exemplify the potential of digital technology and gamification design in safeguarding and disseminating cultural heritage, while also offering valuable insights for this study.

3. Technical Implementation of the Ruins of St. Paul’s Block Game

With its advanced virtual geometry technology and dynamic global illumination, Unreal Engine empowers this project to meticulously recreate the architectural structure of the Ruins of St. Paul’s in a virtual environment, while elevating user interaction through the utilization of building blocks. The primary objective of the game is to captivate players by enabling them to reconstruct the archway's visual representation within the virtual world using these building blocks.

3.1. Overview of the Game

The game is set on an elevated platform with a backdrop of the deep blue sea. The primary objective for players is to accurately replicate the architectural structure of the Ruins of St. Paul’s by selecting from a range of ten blocks and placing them in their correct positions to earn points. Only upon completing all tasks can players unlock the next level. This game comprises three levels, progressively transitioning from simple initial tasks to a free-building mode that allows players to gain a comprehensive understanding and vivid recollection of the Ruins of St. Paul's appearance and architectural intricacies (Figure 3).



Figure 3. The Ruins of St. Paul's on the high platform.

3.1.1. Level One: Beginner Teaching

This level is primarily designed to familiarize the player with the game's controls and must be completed within a time limit of 240 seconds. The player interacts with the scene using either a game controller or keyboard and mouse (Figure 4). Upon entering the game, an operation guide is displayed on the screen to assist the player in interacting with the blocks. A fully assembled model of the Ruins of St. Paul's is placed on the left side of the platform as a reference for the player. When combining building blocks, players are required to proceed to the central area of the workspace and follow prompts to fill ten purple boxes with blocks, gradually assembling them into the structure of the Ruins of St. Paul's. Each box corresponds to a unique position. Upon correct placement of the blocks, the system will emit a distinct sound signal as a reminder for players to assess their score. Additionally, players can also view their score through the UI located on the top right corner of the viewport.



Figure 4. Two interaction modes available for players.

If the blocks are placed incorrectly, the system will emit a dull prompt tone to alert players of their misplacement. Once all blocks have been placed, the game ends and the system interface will display the construction results. Incorrectly placed blocks will be highlighted in purple, while correctly placed blocks will be shown in light yellow. Additionally, a final score will be calculated. The system provides instant feedback to assist players in enhancing their accuracy during subsequent operations.

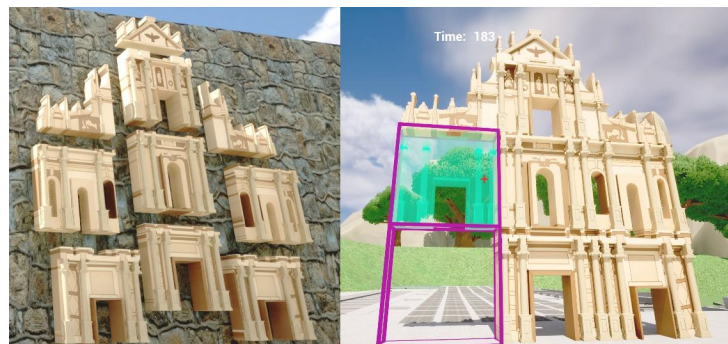


Figure 5. Ten Ruins of St. Paul's building blocks.

3.1.2. Level Two: Random Challenge Level

The winning mechanism for the player in this level remains similar to the first level, with the only difference being that the building block types will now appear in a randomized order. Additionally, the play time has been reduced to 60 seconds in order to enhance the difficulty. The players have the option to discard unwanted blocks at any point during the game by right-clicking the mouse (or the B button on the controller), until a suitable block emerges and can be strategically placed in its

designated position for scoring. The clearance conditions mandate that the player correctly position all ten blocks prior to advancing to level three. Should any block be misplaced, the system will prompt the player to restart until all blocks are properly positioned and unlock the next level. (Figure 6)

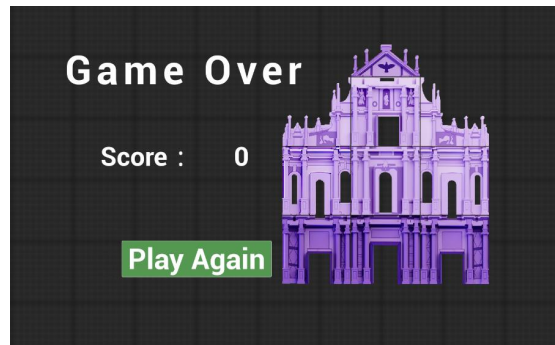


Figure 6. The UI prompts the player to restart.

3.1.3. Level Three: Free Building

The player is granted to build freely without any time constraints or mission limitations. In this expanded mobile area, players have the opportunity to reconstruct the damaged inner rooms and tower sections behind the Ruins of the St. Paul's, unleashing their imagination as they freely combine building blocks and explore a multitude of construction possibilities. Upon completion of the level, players can capture screenshots to preserve their architectural achievements and experience a profound sense of accomplishment.

3.2. Technical Implementation

3.2.1. 3D Modeling and Texture

The archway of the Ruins of St. Paul's in the game is divided into ten squares, each representing distinct architectural elements such as arches, columns, triangular roofs, etc. (refer to Figure 7). Through this segmented design, players can randomly select blocks and construct personalized architectural structures of it, thereby enhancing the interaction.

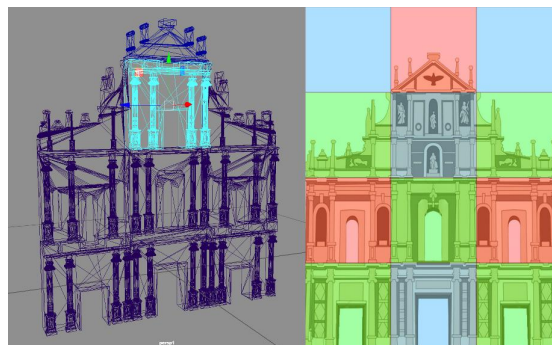


Figure 7. 3D Design of the Ruins of St. Paul's.

The 3D modeling software SketchUp and Maya were utilized to create detailed models of the archway, with specific attention given to redesigning complex components for enhanced visibility and clarity during gameplay. The model's texture is created in Photoshop, and it consists of two main types: color map and texture map. In order to enhance the game's difficulty, several minor adjustments were made to the

arch texture design for the Ruins of the St. Paul's archway, resulting in a certain level of similarity among the arches. This design aims to challenge players' observation and judgment to increase the game's difficulty and enjoyment. The finalized models and textures are imported into Unreal Engine to achieve the interactive experience of the game (Figure 8).



Figure 8. 3D Rendering of the Ruins of St. Paul's.

3.2.2. Game Level Design and Interactive Feedback

The game's level design employs a progressive mode, transitioning from easy to difficult, in order to facilitate the player's learning process and gradually increase the challenge as they become more acquainted with the mechanics. The initial level serves as an instructional guide, featuring a low difficulty setting aimed at helping players master the fundamentals. The guide interface displays the model of the Ruins of the St. Paul's and provides operation tips, allowing players to interact with scene objects using either a game controller or keyboard and mouse. By correctly matching blocks, players progressively unlock additional details while receiving instant feedback to ensure a smooth gaming experience.

The second level enhances the randomness of the blocks, requiring players to assess the suitability of selected squares and place them accordingly in corresponding positions. The system provides real-time feedback on matching results, while auditory and visual cues effectively heighten player immersion and engagement. The system will automatically flag any errors in the match and provide the correct answer at the end of the game to assist players in enhancing their accuracy in completing each level.



Figure 9. Players freely combine block components to construct a variety of architectural structures.

The third level offers a free build mode. The system enables players to exercise their creativity by freely combining block components in order to construct diverse architectural structures. It introduces the inner chambers and towers of the damaged sections of the Ruins of the St. Paul's, requiring players to exercise their imagination

in creating the missing components of the structure. It not only grants players' freedom within the game, but also affords them increased opportunities for exploration and education in architectural design. Through the progression of these three levels, players can gain a comprehensive understanding of the architectural style, cultural significance, and historical stories surrounding the Ruins of the St. Paul's, (Figure 9).

3.2.3. Technical Advantages of Unreal Engine in Block Game Development

The Unreal Engine played a pivotal role in the development of this game, leveraging its robust modular design and advanced graphical rendering capabilities to flawlessly replicate the architectural intricacies of the Ruins of St. Paul's. The Nanite technology integrated into the engine enables automatic processing of high-precision models and optimization of operational efficiency, thereby ensuring the game runs smoothly even with high polygon models. Additionally, Unreal Engine's Lumen global lighting system offers a realistic dynamic lighting environment without the necessity for specialized ray tracing hardware. It enables real-time generation of light and shadow effects, resulting in a more authentic representation of the Ruins of the St. Paul's building under various lighting conditions. This significantly enhances the visual impact and overall appeal of the game. The blueprint system of Unreal Engine offers a convenient approach to game design and development. Serving as a visual programming tool, blueprints enable developers to effortlessly write game logic and design interactive functions by simply dragging and dropping nodes, eliminating the need for complex coding in other programming languages. This remarkable feature significantly reduces the technical barriers associated with game development, allowing individuals without prior programming experience to actively engage in the design and development process.

4. Significance and Future Prospects of the Research

Through the implementation of building block game development for the Ruins of the St. Paul's in Macao, this study substantiates the significant value of gamification design in preserving and disseminating cultural heritage. Throughout the developmental process, building block games have demonstrated their innovative potential in cultural heritage dissemination through their simplicity, adaptability, and creative engagement. By actively participating in interactive construction, players not only acquire knowledge about the architectural structure of the Ruins of the St. Paul's but also gain a profound understanding of its historical and cultural significance. This amalgamation of digital technology and interactive dissemination methods presents a novel solution for preserving and promoting cultural heritage in Macao as well as other regions.

4.1. Significance of the Study

Through the integration of virtual reality technology and gamification design, the project offers an immersive, dynamic, and educational experience for promoting Macau's rich architectural heritage. Within a relaxed and enjoyable environment, players will have the opportunity to engage with the Ruins of the St. Paul's profound cultural legacy through interactive games. The implementation of gamification design transcends the constraints of traditional cultural exhibitions by captivating younger audiences in a more flexible manner while stimulating their interest in history and culture. By utilizing building blocks, players not only gain firsthand experience of

Macao's significant historical value as a convergence point between Chinese and Western cultures but also enhance the effectiveness of cultural heritage transmission while expanding the application of digital technology within the cultural domain.

4.2. Future Prospects of the Research

With the continuous advancement of technology, there is an increasing expectation for gamification design to promote more complex architectural structures and the historical culture they embody. The development of digital technology software and hardware will provide more innovative channels for cultural heritage protection. Through immersive experiences, historical buildings and intangible cultural heritage will be brought to life in a vivid and 3D manner, reaching players worldwide. This project not only offers an innovative perspective on the cultural communication of the Ruins of the St. Paul's in Macau, but also proposes a practical direction for digitally preserving and communicating other cultural heritages. In the future, the combination of gamified design and cultural content will continue to drive innovation in disseminating cultural heritage, enabling individuals to deeply experience history and inherit culture through interactive experiences.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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