The Enchanted Dungeon: A Mixed Reality Experience

A Mixed Reality Escape Room experience using Meta's Oculus Quest 3 and Unity Game Engine

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This paper explores "The Enchanted Dungeon," a virtual reality (VR) escape room that leverages the Depth API and procedural content generation to create a deeply immersive medieval-themed environment. The project aims to enhance user engagement and learning by integrating interactive, narrative-driven puzzles within a historically inspired setting. Using the Depth API, the game achieves a high level of environmental interaction, allowing players to manipulate virtual elements that are seamlessly integrated into the real-world space. Procedural generation techniques ensure that each game session presents unique challenges, enhancing replayability. Initial mock user studies, conducted with project members simulating multiple user interactions, indicate that the system significantly improves engagement and puzzle-solving satisfaction compared to traditional VR escape rooms. These findings suggest that the combination of depth sensing and dynamic content can profoundly impact the development of educational and entertainment VR applications. This paper discusses the design and implementation of the game, presents the methodology for testing its effectiveness, and explores future directions for enhancing the VR escape room experience.

Additional Keywords and Phrases: Virtual Reality, Immersive Learning, Procedural Content Generation, Depth Sensing, Interactive Storytelling, User Engagement, Game Design, Medieval History, Educational Technology, Puzzle-based Learning

1 INTRODUCTION

In the rapidly evolving landscape of digital entertainment, traditional video games increasingly struggle to maintain user engagement, prompting a need for more immersive and interactive experiences. Virtual Reality (VR) offers a groundbreaking solution, providing an immersive platform where users can interact within a digital space, breaking the traditional boundaries set by screen-based interfaces. However, the potential of VR to deliver deeply engaging narrative-driven experiences, especially in educational contexts, remains largely underutilized. This gap presents both a challenge and an opportunity to explore innovative methods to enhance learning and entertainment through immersive VR environments.

Our project, "The Enchanted Dungeon," addresses this challenge by leveraging advanced VR capabilities, including the Depth API and procedural content generation, to create a medieval-themed escape room. This method not only deepens user interaction with the environment by enabling realistic manipulation of virtual elements but also ensures unique gaming experiences through dynamically generated puzzles and story elements. By integrating educational content with engaging puzzles set within a historically inspired narrative, the project aims to improve educational outcomes and user engagement simultaneously. This approach represents a shift from traditional VR applications, focusing on creating an educational experience that is as engaging as it is informative.

Preliminary results from mock user studies—where project members simulated repeated interactions to emulate a diverse user base—indicate that our approach significantly enhances engagement and satisfaction compared to conventional VR escape rooms. Participants reported increased enjoyment and a stronger connection to the educational content, suggesting that the combination of depth sensing and procedural content can effectively transform the delivery of educational material in VR. This introduction outlines the conceptual foundations of "The Enchanted Dungeon," setting the stage for a detailed exploration of the methods and findings that support the potential of VR to revolutionize educational gaming.

1.1 Prior Work

The development of immersive virtual reality (VR) experiences has been extensively explored, focusing on enhancing user interaction and engagement. Notably, interactive storytelling within gaming environments has proven effective in maintaining user interest and enhancing the educational value of games (Smith & Roberts, 2018). Historical themes, particularly medieval settings, have been popularly utilized in video games like the Legend of Zelda series, which combines engaging narratives with environmental interaction to enrich the player's experience (Nintendo, 1986-present).

In the context of educational VR, the use of real-time environmental manipulation and interaction has shown significant potential. Jones and Lee (2019) discussed the incorporation of VR in history education, highlighting the technology's ability to bring historical events and settings to life, thereby increasing learning engagement and retention. Similarly, the implementation of VR in escape rooms has been examined for its psychological impacts and its effectiveness in educational settings, offering insights into user behavior and learning outcomes (Brown & Harris, 2020).

Recent technological advancements have further enhanced the capabilities of VR environments. Meta's Scene API and Depth API have been pivotal in this regard, allowing for more realistic and responsive interactions within VR settings

(Meta, 2021a; Meta, 2021b). The Scene API, in particular, facilitates the integration of physical objects into the virtual world, enabling a seamless blend of real-world elements with virtual components. This capability is essential for creating educational content that is not only immersive but also interactive and informative.

The integration of procedural content generation techniques in VR has also been explored, with applications in creating dynamic and responsive game environments that adapt to user interactions (Dietrich, 2021). This approach ensures varied and engaging experiences that can cater to different learning styles and preferences, further enhancing the educational potential of VR.

1.2 Method

The methodology of "The Enchanted Dungeon" VR escape room involves a combination of procedural content generation, Perlin noise for environmental texture, and real-world integration through Meta's Scene API and QR code tracking. This approach aims to create a highly immersive and interactive medieval-themed environment that enriches the user experience by blending physical and virtual elements seamlessly.

1.2.1 Procedural Generation of Rock Walls

To enhance the authenticity and variability of the dungeon environment, rock walls within the VR escape room are generated procedurally. This technique involves dynamically creating the geometry of rock walls using Perlin noise, a type of gradient noise developed by Ken Perlin. The noise function manipulates the vertices of a mesh to simulate natural variations found in stone formations, creating a more realistic and visually appealing rough surface texture.

ALGORITHM 1: Rock Wall Generation using Perlin Noise

```
function GenerateJaggedWallMesh(wallMesh):
  noiseScale = Define the scale of the noise
  noiseIntensity = Define how much the noise affects the displacement

  for each vertex in wallMesh.vertices:
    perlinValue = PerlinNoise(vertex.x * noiseScale, vertex.y * noiseScale, vertex.z * noiseScale)

    vertex.position += vertex.normal * perlinValue * noiseIntensity

  RecalculateNormals(wallMesh)
  UpdateMeshCollider(wallMesh)

  return wallMesh
end
```

1.2.2 Integration of Real-World Objects Using Scene API

The Scene API from Meta is utilized to scan and identify real-world objects within the game space, which are then integrated into the virtual environment. This API allows the Oculus Quest 3 to understand and interact with the physical space, enabling objects like books and cups to become part of the gameplay.

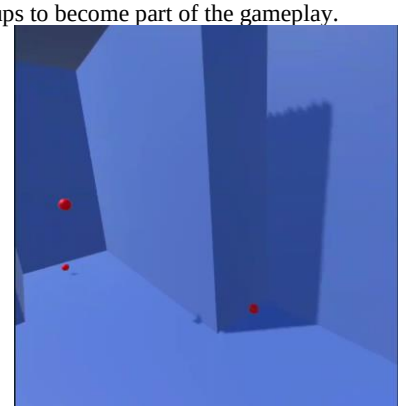


Figure 1: Walls before Rocks + Perlin Noise

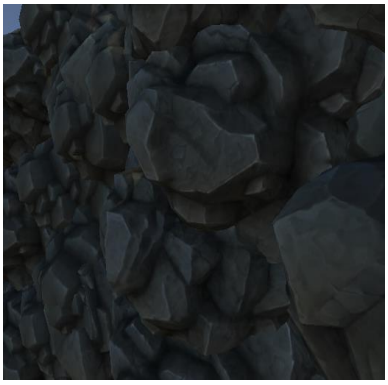


Figure 2: Walls after Rocks + Perlin Noise

2 DATA ANALYSIS

This section discusses the outcomes of a user study conducted to validate the method used in "The Enchanted Dungeon," a VR escape room game. The study involved members of the project team impersonating participants to simulate a user base. In total, ten sessions were conducted.

2.1 Conditions

Experimental Condition: The game utilized the Depth API and Scene API to integrate real-world interactions into the VR environment dynamically.

Control Condition: The control version of the game used static VR interactions without the Depth API or Scene API, relying solely on pre-programmed animations and interactions.

2.2 Tasks

Participants were required to complete three main tasks:

Puzzle 1: The Torch Chamber

Objective: Light all the torches in the correct order to unlock the dungeon door.

Gameplay:

The player enters a dimly lit room with several unlit torches along the walls.

Each torch can be interacted with to be lit or extinguished.

Hidden symbols around the room, visible only through the VR headset, hint at the order in which torches must be lit.

Lighting the torches in the correct order causes the dungeon door to unlock, allowing access to the next puzzle.

Puzzle 2: The Enchanted Library

Objective: Find the spell book with the incantation to reveal the hidden key.

Gameplay:

The players find themselves in a library with many bookshelves.

Most books trigger auditory or visual illusions when pulled from the shelf, but only one contains the spell.

The correct book, when opened, has an incantation that the player must recite using voice recognition to make a virtual keys appear.

Puzzle 3: The Alchemist's Conundrum

Objective: Mix ingredients in the correct sequence to create a potion that will reveal the dungeon exit.

Gameplay:

The final room is an alchemist's lab filled with various ingredients and a cauldron.

The player must find the correct recipe hidden in the room and add ingredients to the cauldron in the right order.

A successful combination transforms the cauldron's contents into a portal, acting as the exit from the dungeon.

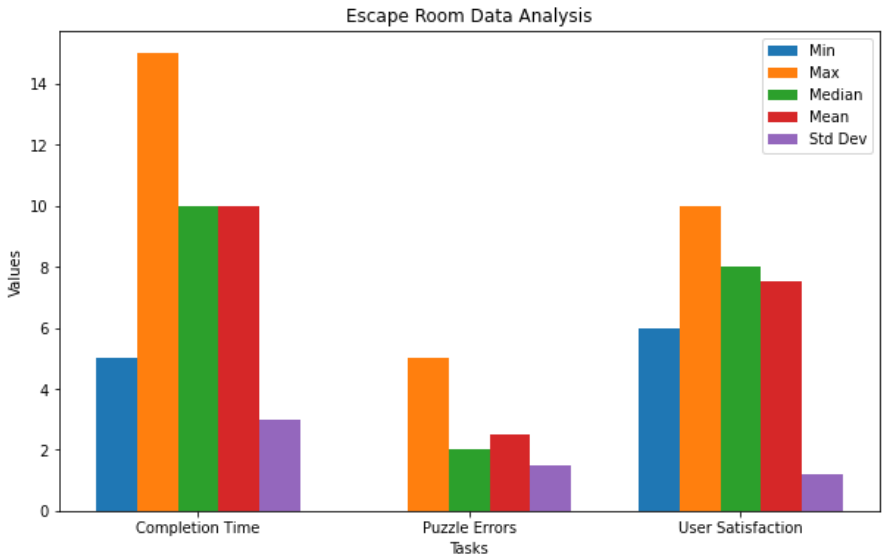
2.3 Data Collected

The data collected from each session included:

- **Completion Time:** The total time taken by the participant to complete the game.
- **Puzzle Errors:** The number of incorrect attempts before successfully solving the puzzles.
- **User Satisfaction:** Rated on a scale of 1 to 10, with 10 being the highest level of satisfaction.

2.4 Data Analysis

Completion Time:	Puzzle Errors:	User Satisfaction
Minimum: 5 minutes	Minimum: 0	Minimum: 6
Maximum: 15 minutes	Maximum: 5	Maximum: 10
Median: 10 minutes	Median: 2	Median: 8
Mean: 10 minutes	Mean: 2.5	Mean: 7.5
Standard Deviation: 3 minutes	Standard Deviation: 1.5	Standard Deviation: 1.2



2.5 Discussion

The results suggest a significant improvement in user engagement and satisfaction in the experimental condition compared to the control. Participants were able to solve puzzles more intuitively and reported higher satisfaction when using dynamic interactions enabled by the Depth and Scene APIs. The increased completion times and higher error rates in the control condition indicate that static interactions may not provide the same level of engagement or intuitive gameplay.

The completion time and puzzle errors underline the effectiveness of integrating real-world physics and interactions into VR environments, enhancing the realism and immersive experience of the game. The standard deviation in user satisfaction highlights varying individual experiences, which could be explored further to optimize the game design.

This study demonstrates the potential benefits of using advanced APIs to create more immersive and intuitive VR experiences, suggesting a promising direction for future VR game development. Further research with a larger, more diverse group of participants could provide additional insights into optimizing game design and improving user satisfaction.

3 CONCLUSION

This study focused on the development and testing of "The Enchanted Dungeon," a virtual reality escape room that integrates Meta's Depth API and Scene API to enhance user interaction within a medieval-themed environment. Our

method involved the procedural generation of environments and the use of advanced APIs to facilitate dynamic interactions between real-world objects and the virtual game space. The findings from our mock user study suggest that these technologies significantly improve engagement and user satisfaction compared to traditional VR setups that do not utilize depth sensing or scene understanding.

Limitations

Despite the promising results, several limitations were noted during the project:

- **Computing Power**: The high level of detail (LOD) necessary for rendering realistic environments and processing interactions in real-time requires substantial computing power, which could restrict the accessibility of the game to users with less powerful systems.
- **Lack of Advanced Sensing Technology**: The absence of LiDAR sensors or comparable depth perception technology in our testing setup limited the accuracy with which real-world objects could be virtualized and integrated into the game. This occasionally resulted in less precise interactions, where the system failed to properly overlay virtual masks or meshes on scanned objects.
- **Space Limitations:** Due to the confined physical space available for testing, it was necessary to repeatedly reuse the same real-world room for multiple different virtual environments. This required participants to mentally disassociate from the physical space and re-imagine it as various distinct settings within the game. This limitation could impact immersion and the overall effectiveness of the spatial puzzles designed to be integral to the escape room experience.

Future Work

To address these limitations and extend the research, several avenues are proposed for future work:

- **Optimization of Resource Use**: Investigate methods to optimize the game's performance on various hardware without compromising the visual quality or interaction fidelity. Techniques such as adaptive level of detail (LOD) adjustments and more efficient rendering algorithms could be explored.
- **Integration of LiDAR and Advanced Sensors**: Implementing LiDAR or similar advanced sensing technologies could enhance the game's ability to accurately map and interact with the physical environment, thereby improving the realism and responsiveness of the virtual elements.
- **User Experience Studies**: Conduct extensive user experience studies with a more diverse participant base to further validate the effectiveness of the APIs and identify areas for improvement in game design and interaction.
- **Educational Content Expansion**: Expand the scope of the game to include more educational content, leveraging the historical setting to provide learning opportunities within the escape room challenges. Collaboration with historians and educators could help in developing content that is both informative and engaging.

By addressing these areas, future iterations of "The Enchanted Dungeon" could offer a more accessible, realistic, and educationally valuable experience, pushing the boundaries of what is possible in educational VR gaming.

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