Proceedings of CONF-MLA 2025 Symposium: Intelligent Systems and Automation: AI Models, IoT, and Robotic Algorithms
DOI: 10.54254/2755-2721/2025.LD28109

Optimizing Atmospheric Effects and Collider Design for Immersion in Unity-Based Virtual Reality

Fengyuan Liu

Donald Bren School of Information and Computer Sciences, University of California Irvine, Irvine, USA
fengyl8@uci.edu

Abstract. Virtual Reality (VR) research increasingly highlights how seemingly small design decisions can have significant effects on user perception, presence, and interaction quality. Technical elements such as rendering methods or collider structures are not merely implementation details but active factors shaping the overall immersive experience. This study investigates these aspects through controlled experimentation in Unity, focusing on the VR narrative environment Wires and Wildflowers. The research examines how technical design choices in Unity influence immersion and controllability in virtual reality environments. Using Wires and Wildflowers, a VR narrative experience, two experiments were conducted with twelve participants. The first compared atmospheric rendering techniques: particle-based fog, procedural noise, and a hybrid combination. Results indicated that particle-only and procedural noise individually enhanced immersion, while the hybrid method reduced coherence and presence. The second experiment compared capsule and human-shaped colliders within shelter and wheat field environments. Capsule colliders consistently supported smoother navigation, whereas the human-shaped collider introduced complexity that disrupted immersion in confined spaces. The findings demonstrate that design consistency and technical simplicity enhance VR experiences more effectively than detailed or hybridized methods.

Keywords: Unity, Virtual Reality, Particle System, Immersion, Collider Design

1. Introduction

The global video game industry has become one of the fastest-growing sectors in the creative economy, generating approximately USD 187.7 billion in revenue in 2024 and contributing significantly to employment and GDP in multiple countries [1]. In addition to entertainment, games increasingly influence cultural trends, social interaction, and even training and education. Within this landscape, Unity has emerged as a leading cross-platform development engine. It is widely used due to its real-time rendering abilities, flexible asset integration, and compatibility with over 25 target platforms, including mobile devices, consoles, VR/AR systems, and the web. These features enable developers to deploy a single codebase across multiple platforms, which reduces production costs and expands audience reach [2].

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2025.LD28109

Unity's technical versatility has enabled the creation of numerous acclaimed titles across diverse genres. Examples include Pokémon Go, Monument Valley, Beat Saber, Ori and the Blind Forest, Hollow Knight, and Subnautica. These projects demonstrate the engine's capacity to support high-quality visual design, immersive narrative delivery, and engaging interactivity in both indie and large-scale productions. Beyond gaming, Unity's advanced rendering pipelines (HDRP, URP), dynamic lighting, and complex shaders have also found application in film, architectural visualization, industrial simulation, and immersive training [3]. In addition to these applications, Unity's particle system has been widely studied for its ability to enhance visual richness and user engagement. Particle systems allow developers to generate and animate thousands of small objects such as sparks, smoke, or water droplets in real time, each with independent lifespans and rendering processes. This capability not only improves the aesthetic quality of games but also contributes to immersive gameplay experiences by simulating natural phenomena. As research of Particle System in Unity note, particle systems can add a crucial layer of "pizzazz" that makes game environments more dynamic and realistic, while remaining computationally efficient [4].

Although Unity's potential for enhancing immersion is well documented, the effectiveness of specific design choices in early gameplay, such as environmental effects, player perspective, and collision geometry remains unexplored. In real-time 3D environments, collision detection between high-polygon mesh models is computationally expensive, typically increasing quadratically with the triangle count. To reduce this overhead and maintain real-time performance, most game engines, including Unity, approximate complex meshes using primitive colliders such as spheres, cubes, or capsules. The capsule collider is commonly used in first- and third-person controllers because its rounded ends prevent snagging on small obstacles and its vertical form supports natural posture and movement. Despite their efficiency and versatility, capsule colliders may not always provide the most accurate approximation for all gameplay interactions [5]. Therefore, this study aims to explore how subtle design adjustments like replacing generic particle-based fog with higher-fidelity textures, incorporating noise-based shaders for more natural atmospheric rendering, and experimenting with alternative collider shapes, it can influence navigation, spatial awareness, and player immersion.

2. Method

2.1. Narrative background and group collaboration

The project Wires and Wildflowers is a virtual reality narrative experience developed in Unity, designed as an immersive game and story environment for VR. The narrative is set in a speculative post-apocalyptic future and centers on Moss, a humanoid robot who has lived alongside his human master since childhood. Because robots outlive humans, Moss has witnessed his master's entire life, from youth to old age, against the backdrop of an interstellar war. After the war ended, the master passed away, leaving Moss alone. The narrative encourages players to reflect on ecological collapse, memory, and the meaning of post-human identity.

The original story concept was inspired by a poem with the same name, from the music video Wires and Wildflowers. Since the original storyline spans a long timeline, directly showing the full progression of time would reduce immersion in VR. Therefore, focusing on a single ordinary day following the old man's death, allow the player to experience the story through subtle details and atmosphere without breaking immersion.

The main responsibility was to implement the project in Unity, constructing the full virtual scenes, integrating imported assets into coherent environments, designing interaction systems, and ensuring that visual storytelling remained consistent with the narrative goals.

DOI: 10.54254/2755-2721/2025.LD28109

2.2. Scene construction process

The work began with importing and organizing the resources provided online, including Blender models and assets selected from the Unity Asset Store [6-8]. These resources were arranged across two main environments, the underground shelter and the outdoor wheat field. To ensure narrative consistency, carefully adjusted the scale, position, and alignment of each object is needed so that they reflect the emotional tone of decay and serenity. In adapting the spatial design, moving what was originally a house setting in the story into an underground space, transforming it into a shelter is necessary. This change avoided making the wooden house appear visually abrupt in the outdoor wheat field and also reinforced the realism of the narrative. Placing both environments within a single map and linking them through a teleportation script further reduced loading delays and enhanced immersion by simulating seamless movement between rooms.



Figure 1. A view of the sense of underground shelter (picture credit: original)

As seen in Figure 1, In the underground shelter, there is furniture, radios, televisions, and photographs to represent remnants of human life. The layout was intentionally cluttered yet believable, strengthening the sense of abandonment. Lighting design played a crucial role in shaping the atmosphere. This paper deliberately kept the shelter dim and oppressive, relying on a few light bulbs and flickering screens to cast sharp but uneven illumination. These lights did not simply serve a functional purpose but also acted as narrative cues, drawing the player's attention toward interactive objects while reinforcing the sense of claustrophobia. To heighten the mood, this paper layered subtle fog effects and particle-based dust simulations, which created the impression of stale air in a sealed, decaying space.

The wheat field environment was designed with a completely different approach which shown in Figure 2. It was built a wide-open terrain and populated it with wheat models to form a natural, expansive landscape. A massive biomechanical spaceship was suspended in the sky to establish spatial scale and evoke megalophobia like in Figure 3, while a modest grave in the center of the field acted as a narrative focal point. Unlike the shelter, this environment was meant to feel open and contemplative. It experimented with Unity's particle system to simulate drifting mist, ambient dust, and slow-moving clouds, which softened the scene and created a surreal atmosphere. The lighting setup here required several iterations: like using a combination of directional sunlight, ambient warm tones, and long dynamic shadows to capture the impression of dusk. This contrast with the underground shelter symbolized a transition from confinement to release, and from despair to resolution.

DOI: 10.54254/2755-2721/2025.LD28109

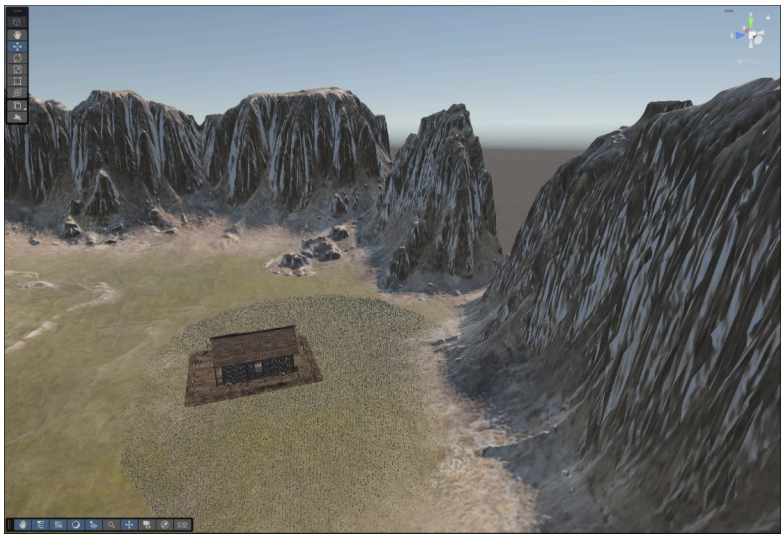

Figure 2. A view of the sense of wheat field and hub (picture credit: original)



Figure 3. Bio-mechanical spaceship creating a sense of megalophobia (picture credit: original)

Player interactivity was implemented through colliders, trigger zones, and custom scripts. For example, interacting with radios or screens triggered war broadcasts and personal messages that gradually revealed fragments of the backstory. A teleportation system was scripted to connect the two environments seamlessly. To enhance immersion further, environmental animations such as doors that opened automatically, radios that turned on when approached, and lights that responded dynamically to the player's position have been added shown in Figure 4.

Special attention was given to the design of the first-person perspective and collision effects. implementing capsule colliders for the player character to prevent clipping through walls or objects, while still allowing smooth navigation through tight spaces. The collider height and radius were adjusted repeatedly to ensure that the player could move naturally without snagging on small details. These adjustments were critical in the underground shelter, where cluttered layouts could easily lead to awkward movement or immersion-breaking collisions. Testing also revealed issues such as the player camera intersecting with low ceilings or furniture, which is resolved by refining collider shapes and repositioning interactive objects.

Throughout the construction process, the project was frequently tested the environments in Unity's Play mode, refining object placement, light intensity, particle density, and the timing of

DOI: 10.54254/2755-2721/2025.LD28109

triggers. Iterative testing allowed the sense to balance performance with visual fidelity, ensuring that the particle effects and dynamic lighting enhanced the experience without introducing lag or frame drops in VR. This optimization process was essential for maintaining immersion, as even small technical disruptions can undermine the narrative impact in a virtual reality context.

Overall, the construction process in Unity was not limited to assembling assets but involved continuous decision-making that tied technical implementation to narrative and emotional goals. Each element like lighting, colliders, particle effects, and interactive triggers. It was designed to function in service of the story. Through careful alignment of technical design with narrative intent, the environments were constructed to convey the themes of Wires and Wildflowers, focusing on loss, memory, and discovery.



Figure 4. Light beams guiding player interaction and navigation (picture credit: original)

2.3. Research focus

During the construction of the environments in Unity, the project identified two key limitations that directly define the focus of the experimental research.

The first is the rendering of fog and atmospheric effects. In this part, it primarily relied on Unity's particle system to simulate mist and drifting clouds as shown in Figure 5. While this approach added visual layering, it was not sufficient to create the overwhelming sense of scale, especially in relation to the massive biomechanical spaceship. The "giant-object" atmosphere remained only partially realized. The experimental study will therefore investigate improved methods of fog and cloud rendering, such as volumetric fog techniques or shader-driven cloud systems, to achieve a more convincing sense of scale and immersion.

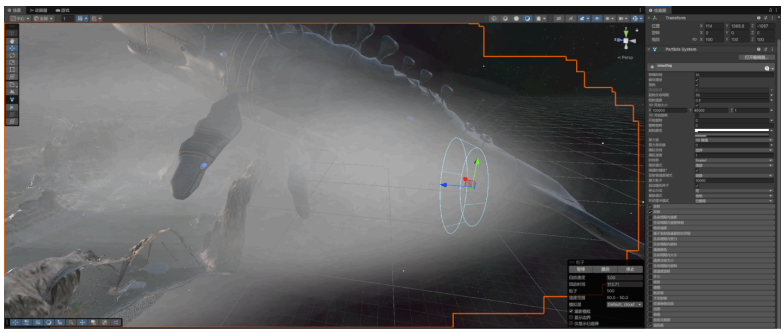

Figure 5. Particle system generating fog effects (picture credit: original)

DOI: 10.54254/2755-2721/2025.LD28109

The second issue concerns the design of the player's camera and collider. The current first-person controller, which uses a capsule collider, sometimes causes jittering or snagging when navigating crowded environments like the underground shelter. These disruptions broke the smoothness of movement and weakened immersion. In addition, the default field of view was not always effective in emphasizing the contrast between confined and expansive spaces. The research will focus on exploring optimized collider shapes and camera binding, including adaptive collision detection, to identify the most effective configurations for fluid navigation and immersive storytelling.

2.4. Questionnaire

A questionnaire-based evaluation was conducted with 12 participants aged 16 to 22, most of whom were students with little prior exposure to VR or Unity scene construction, which made their judgments of immersion and controllability more natural. The experiment was divided into two parts. In the first part, participants experienced the wheat field scene under three different atmospheric conditions: one version used only particle emitters to generate natural mist, another version employed procedurally generated cloud shapes with layered textures and noise-based shaders like in Figure 6, and a hybrid version combined the two methods, where procedural clouds established large-scale forms and particle effects added fine details and local motion.

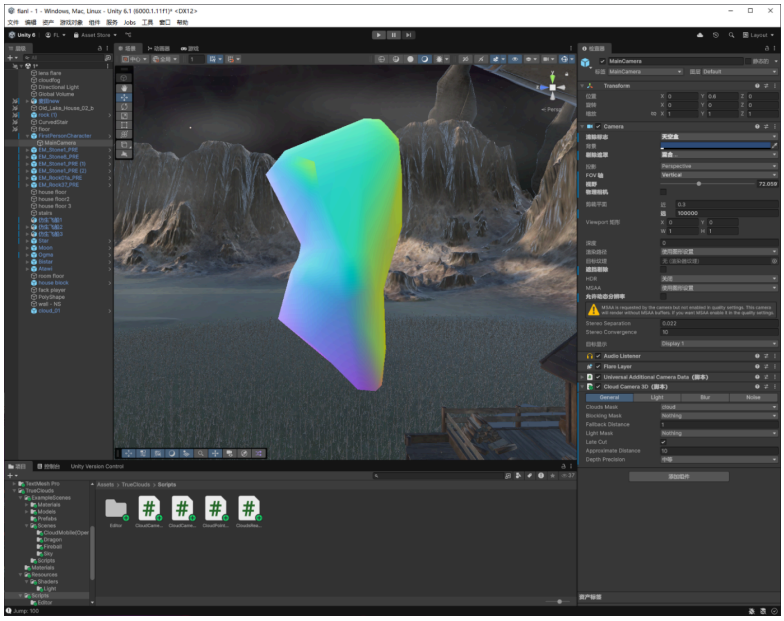

Figure 6. A cloud shape mode with layered textures and noise-based shaders (picture credit: original)

After completing each version, participants rated their sense of immersion on a 1–10 scale, from no presence to very strong presence. In the second part, participants tested two first-person controller setups in identical environments: one using the standard capsule collider and another using a more complex human-like composite collider. After each trial, instead of giving a single overall rating, participants provided two separate scores of controllability, one for their experience in the underground shelter and another for their experience in the wheat field. Both ratings were based on a 1–10 scale, where 1 indicated the character could not be operated properly and 10 indicated highly natural and responsive control. Each participant completed five trials in total, with each run lasting approximately 30–50 minutes, and immediately after the session they filled out a short paper questionnaire since the number of items was small.

DOI: 10.54254/2755-2721/2025.LD28109

3. Results and discussion

Table 1. Evaluation scores for particle, procedural noise, and hybrid methods

Participant	Particle Only	Procedural Noise	Hybrid Combined
Example 1	8	8	6
Example 2	8	7	6
Example 3	10	10	9
Example 4	9	8	6
Example 5	8	7	6
Example 6	8	8	6
Example 7	9	8	6
Example 8	10	7	4
Example 9	8	9	6
Example 10	9	8	9
Example 11	8	8	7
Example 12	8	7	3

Table 1 presents the immersion scores given by 12 participants across the three cloud conditions. The particle-only condition achieved the highest ratings, with most scores clustered around 8 or 9. The procedural noise condition also performed well, although the ratings were slightly more variable, ranging from 7 to 9. In contrast, the hybrid condition consistently received the lowest scores, with several participants rating immersion as low as 3. On average, particle-only clouds were judged the most immersive, procedural noise was moderately immersive, and the hybrid combination was least effective.

These results suggest that while both particle effects and procedural noise can successfully create convincing atmospheric immersion on their own, combining the two methods may have introduced visual inconsistency or distraction. Participants may have perceived the hybrid clouds as less natural, since the overlay of particle wisps and noise-based textures produced conflicting visual cues. Instead of enhancing realism, the combination reduced coherence, which weakened the overall sense of presence.

This outcome highlights the importance of consistency in atmospheric design for VR immersion. The finding that hybrid methods underperformed points directly to the research focus of this study: improving cloud and fog rendering techniques. By exploring alternative blending strategies or volumetric approaches, future iterations may better achieve the “giant-object” atmosphere that was not fully realized in this experiment.

DOI: 10.54254/2755-2721/2025.LD28109

Table 2. Evaluation scores of models under shelter and wheatfield environments

Participant	Capsule Shelter	Capsule Wheat	Human Shelter	Hybrid Combined
Example 1	8	9	4	5
Example 2	7	8	4	4
Example 3	7	9	5	5
Example 4	8	8	2	5
Example 5	8	8	3	6
Example 6	8	9	7	7
Example 7	8	9	9	8
Example 8	8	9	6	5
Example 9	7	8	6	8
Example 10	7	8	3	6
Example 11	8	9	4	7
Example 12	8	9	4	5

Table 2 shows the controllability ratings under different collider configurations. Across all participants, the capsule collider consistently outperformed the human-like composite collider. Capsule conditions generally received high scores, especially in the wheat field environment, where ratings were mostly 8 or 9. In the underground shelter, capsule collider ratings were slightly lower, but still remained above 7 for nearly all participants. By contrast, the human collider conditions were rated much lower overall, with several participants giving scores of only 2 or 3 in the shelter. Even in the wheat field, where open space reduced collision issues, scores for the human collider rarely exceeded 7.

These results suggest that the capsule collider provided smoother and more reliable movement in both environments, whereas the human-like collider introduced unnecessary complexity. In the underground shelter, the cluttered and narrow layout made the human collider particularly problematic, as the additional body-like collision points often caused snagging or jittering. This explains why the human collider scores were lowest in the shelter conditions. In the wheat field, where space was open and unobstructed, participants still found the capsule collider easier to control, while the human collider produced only moderate improvements compared to its performance in the shelter. Overall, the findings indicate that while the human collider may theoretically provide more realism, it reduces playability and immersion in practice.

In summary, the results of both experiments highlight the importance of design consistency in immersive VR experiences. For atmospheric effects, participants preferred either particle-based or procedural clouds individually, while the hybrid method was least effective due to visual incoherence. For controllability, the capsule collider consistently outperformed the human-shaped collider, particularly in confined environments, where excessive complexity disrupted smooth navigation. Overall, these findings suggest that achieving immersion does not always require the most precise or highly realistic models. Simplified solutions such as capsule colliders and particle-based fog can effectively deliver presence and controllability, whereas forcing together mismatched resources or overly detailed colliders may distract players and diminish immersion.

DOI: 10.54254/2755-2721/2025.LD28109

4. Conclusion

The research demonstrates that immersion in virtual reality does not depend on maximal realism but rather on coherent and efficient design. Atmospheric experiments revealed that particle-based and procedural methods individually sustain presence, whereas hybrid combinations create visual inconsistency that weakens immersion. Collider evaluations confirmed that capsule colliders, though simplified, outperform human-shaped colliders in both confined and open environments by ensuring smoother and more reliable navigation. Overall, the results emphasize that achieving immersion requires prioritizing consistency, usability, and narrative alignment instead of pursuing unnecessary complexity. Streamlined yet optimized solutions enable virtual reality development to maintain performance and strengthen player engagement while supporting narrative integrity.

References

[1] Newzoo. (2024). Global games market will reach $187.7 billion in 2024 [Blog post]. Newzoo. https://newzoo.com/resources/blog/global-games-market-revenue-estimates-and-forecasts-in-2024 Newzoo+3Newzoo+3Newzoo+3
[2] Lee, K. (2024). Unity, a 2D and 3D Game Engine. In N. Lee (Ed.), Encyclopedia of Computer Graphics and Games (pp. 1942–1944). Springer.
[3] Hussain, A., Mkpojiogu, E. O. C., & Kamal, F. M. (2020). Unity game development engine: A technical survey. University of Sindh Journal of Information and Communication Technology, 4(2), 73–81.
[4] Imam, R., & Areeb, Q. M. (2021). Game effect based on particle system in Unity 3D. Academic Letters.
[5] Snyder, C., Gungormusler, A., Allen, A., Ayvazov, A., & Yordanov, D. (2019). Approximating 3D poly mesh virtual objects with primitive shape colliders. Technical Disclosure Commons, Defensive Publications Series. https://www.tdcommons.org/dpubs_series/2633 reddit.com+4ResearchGate+4ResearchGate+4
[6] Hess, R. (2013). Blender foundations: The essential guide to learning blender 2.5. Routledge.
[7] Hess, R. (2007). The essential Blender: guide to 3D creation with the open source suite Blender. No Starch Press.
[8] Ball, D. (2022). Artists as Assets: Labor and Capital in the Unity Asset Store.