Development of Hyperrealistic 3D Avatars for Virtual Cycling Simulation Using Advanced Character Creation and Animation Techniques

CS4991 Capstone Report, 2025

Abdullah Hejazi
Computer Science
The University of Virginia
School of Engineering and Applied Science
Charlottesville, Virginia USA
wxh7qw@virginia.edu

ABSTRACT

The integration of realistic 3D avatars and animations into the Nsoria Shift virtual cycling simulator improves user immersion and realism and address limitations of static or low-fidelity character representations. Without detailed avatars and dynamic animations, the simulation lacks visual engagement and fails to replicate real-world cycling mechanics accurately. I focused on developing ten high-quality and performance-optimized avatars using tools such as Blender, Reallusion Character Creator, and Unity. My key tasks included 3D scanning, retopology, texture mapping, rigging, animation, and optimization to ensure seamless integration into the simulation. I also created a diverse set of realistic cycling animations to depict various scenarios, including different cycling positions, mounting, and crashing. My final outcomes included ten optimized avatars, and a comprehensive animation set integrated into the simulation. Future work will focus on enhancing avatar customization options, resolving texture blending issues and conducting usability testing to refine the system further.

1. INTRODUCTION

In virtual cycling simulations, realism and user engagement play a crucial role in creating an immersive experience for users. However, many existing simulators rely on low-fidelity avatars and static animations which fail to replicate real-world cycling mechanics. This lack of visual engagement can detract from the overall experience and reduce user satisfaction and limit the simulator's effectiveness as a training or entertainment tool.

I aim to overcome these challenges by incorporating hyper-realistic 3D avatars and dynamic cycling animations. One issue in traditional simulations is the use of predefined and low-detail character models that lack fluid motion and natural interactions with the environment. Many existing solutions rely on basic animations that do not adapt well to different cycling conditions, leading to a rigid experience. Furthermore, performance constraints often forces developers to sacrifice visual fidelity, which leads to limiting realism in favor of efficiency.

My solution addresses these limitations by introducing high-quality, performance-optimized avatars with realistic cycling animations, ensuring that movements align with the simulator's physics engine. By refining both visual and functional aspects, I plan to enhance user immersion and realism to provide a more engaging and lifelike virtual cycling experience.

2. RELATED WORKS

Reed, et al. (2023) looks at Zwift as a virtual leisure platform that combines gaming elements with structured fitness training. The study highlights how Zwift creates an engaging virtual space where users can train and socialize in ways that would be difficult in real life. The research emphasizes the role of avatars in enhancing user engagement, stating that customization and visual fidelity improve immersion and motivate users to continue using the platform. The study also notes that social interactions within Zwift enhance the experience, which supports my decision to create realistic animations that capture natural cycling movements and interactions, making the virtual environment feel more lifelike.

Bentvelzen, et al. (2022) explores how Zwift makes amateur users feel like professional cyclists by incorporating structured training plans, performance tracking, and realistic virtual equipment. The research highlights five key engagement strategies, including flexible training schedules, competitive structures, and immersive social interactions. I focused on realistic biomechanics, accurate cycling animations, and avatar customization to create an experience in Nsoria Shift that keeps users engaged and motivated. Additionally, the study emphasizes the importance of performance tracking and realism, which influenced my decision to optimize avatar animations for smooth motion and efficient rendering within the virtual cycling simulator.

3. PROJECT DESIGN

I created ten hyper-realistic 3D avatars for the Nsoria Shift virtual cycling simulator using a combination of 3D scanning, FaceBuilder, and manual modeling techniques. I conducted 3D scanning sessions with human subjects, processed the scans using MeshLab and cleaned up any noise. When 3D scanning was not feasible, I took multiple angled photos and used FaceBuilder in Blender to generate accurate facial models. After creating the base models, I optimized them through retopology, ensuring clean and efficient mesh structures for animation. I applied Levels of Detail (LODs) to improve performance and reduce polygon counts for distant avatars while maintaining high details up close. Additionally, I used mesh decimation to further optimize models without compromising realism.

Once the models were optimized, I mapped textures using Substance Painter to make sure realistic skin details with proper shading and lighting effects. I rigged the avatars with skeletal structures for smooth movement and used weight painting to ensure natural deformations. I also implemented facial blend shapes to allow dynamic expressions. For animations, I created various cycling actions such as different riding positions, braking, mounting, and crashing, ensuring they aligned with the simulator's physics. I integrated the avatars into Unity, fine-tuned their interactions, and optimized them for real-time rendering. Finally, I conducted testing to fix texture blending issues, improve animation realism, and refine avatar customization options for future enhancements.

4. RESULTS

The integration of high-fidelity 3D avatars and dynamic animations into the Nsoria Shift virtual cycling simulator resulted in a significant improvement in user immersion and realism. The ten optimized avatars I created blended into the virtual environment and maintained visual fidelity without compromising performance due to the efficient use of Levels of Detail (LODs) and mesh decimation techniques. The realistic cycling animations I implemented, including mounting, braking, and crashing, contributed to a more natural and engaging experience.

Users testing the system reported a heightened sense of realism, as the refined animations and detailed textures allowed them to feel more connected to the virtual cycling experience. Additionally, facial blend shapes and weight-painted skeletal rigging ensured natural deformations which made avatars appear more lifelike during interactions.

Despite these advancements, in certain lighting conditions, inconsistencies in texture seams were observed, which require refinements. Additionally, while the avatars provide a diverse range of appearances, more customization options, such as adjustable body types and facial features, would enhance the user experience. Next iterations will focus on refining texture blending and expanding customization features. Also, usability testing with a broader user base will help identify additional areas for enhancement.

5. CONCLUSION

My project improves the realism and engagement of the Nsoria Shift virtual cycling simulator through the integration of hyper-realistic 3D avatars and dynamic animations. I utilized low-fidelity models to allow the system to offer a visually compelling and immersive experience that brings the simulator closer to real-world cycling mechanics. I used advanced modeling, animation, and optimization techniques to make sure high visual fidelity is reached without compromising performance. This work demonstrates the value of combining technical precision with artistic design to elevate user experience in fitness-focused virtual environments.

6. FUTURE WORK

Future development will focus on refining texture blending to eliminate visible seams under different lighting conditions and expanding avatar customization features to include adjustable body types, facial features and clothing options. Also, I aim to conduct broader usability testing to collect feedback from diverse user groups, which will inform further improvements in realism and functionality. Additionally, the animation system can be enhanced to respond more dynamically to real-time user inputs and environmental changes. This will make the system more compatible with potential applications extending to rehabilitation, e-sports, and virtual reality fitness platforms.

REFERENCES

Bentvelzen, G., Niess, J., Masthoff, J. and Wozniak, P. (2022). "Tailor my Zwift." Proceedings of the ACM on Human-Computer Interaction, vol. 6, no. MHCI, 19 Sept. 2022, pp. 1–23, https://doi.org/10.1145/3546751. Accessed 2 Jan. 2023.

Reed, J., Dunn, C., Beames, S., & Stonehouse, P. (2023). E'ride on!': The Zwift platform as a space for virtual leisure. *Leisure Studies, 42*(2), 188–202. https://doi.org/10.1080/02614367.2022.2088836