Vegetation Depiction Modes and Performance Testing on Various Virtual Reality Headsets

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Introduction

As virtual reality technology keeps being utilized in various fields, the demand for immersive environments keeps growing. Still, it is particularly challenging to provide high-fidelity solutions for standalone headsets due to hardware limitations, especially if it is necessary to visualize different types of vegetation. While there are improvements in next generation headsets regarding computational power, still it is a challenge to render intricate virtual environments. Previous studies that compare virtual reality headsets rarely focus on standalone headsets and prefer to use simpler geometries for testing purposes.

The aim of this study is to evaluate performance of multiple vegetation types with differing depiction modes, such as high-polygon 3D models, use of level of detail (LOD) and billboards, on standalone VR headsets – Meta Quest 2 and Meta Quest 3.

Materials and Methods

A three-dimensional scene consisting of skybox, 20 m x 20 m floor and eight observation points was created using Unreal Engine 5.3. Three different types of vegetation – plumeria rubra, camellia and bilberry - were modelled using SpeedTree software. LOD was generated using Unreal Engine, but billboard textures were created in Blender 4.5. Plants were placed in a grid structure using hierarchical instanced static mesh component (HISM), covering the floor and their planting distances were set to represent real life scenario, which resulted in 2025 instances of bilberries, 36 instances of camellias and 16 instances of plumeria rubra.

Tests for each vegetation type were conducted separately – firstly, a test with high-polygon meshes was run, where vegetation was observed from 40 meters to five meters, frames per second captured each five meters, then test was repeated with LOD and LOD, where last model is replaced by a billboard.

Results

The gained data shows that the use of high polygon meshes yields the least optimal results for both headsets. Meta Quest 2 could not reach the recommended number of frames in none of the cases, while Meta Quest 3 had optimal performance of 72 frames per second from 25 to 40-meter observation points with plumeria rubra and camellia. Both headsets had very poor results (under 10 frames per second) with bilberry plant, which had 2025 instances, planted 45 centimeters apart.

Improved performance for plumeria rubra and camellia was noted when LOD was applied to the plants. Meta Quest 2 had 72 frames per second from 25 to 40-meter distance, Meta Quest 3 – from 10 to 40-meter distance. Tests with bilberry plants could not reach the optimal threshold, but on average Quest 2 had 3 times the frame rate it had with high-polygon model, Quest 3 – 4.2 times.

The best results were observed with billboards, especially with bilberry plants, where both headsets reached optimal performance in all distances. For plumeria rubra results were almost identical to the previous test. Camellia had less than optimal performance in distances closer than 15 meters.

Discussion

Results show that while high polygon meshes provide the best visual fidelity, their rendering is often unfeasible. The newer generation headset Meta Quest 3 was capable of providing an improved performance in all cases when compared to Meta Quest 2, yet when it came to densely planted vegetation, optimal performance proved to be unachievable. The use of LOD helped to improve framerate in all the cases and combined with billboards further improvements were noted. While the billboards proved to be useful when it comes to optimization, they could only visualize one angle of the tree, which could break the illusion of realism. It is possible that the complexity of the materials (bark, leaves, flowers) could have also impacted the results. Future research should explore user perception and immersion when experiencing different modes of depiction.

Conclusion

The tests conducted show that Meta Quest 3 has a better performance in all cases, especially when LOD and billboards are applied. While the billboards showed the best performance, they can cause a loss of immersion in close distances. Authors propose a hybrid approach, where full 3D meshes are displayed near the player, while LOD and billboards are used for more distant objects.

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Keywords

virtual reality, standalone headsets, billboards, level of detail