Optimization of VR Application Mahakarya Vokasi Land Using Level of Detail (LOD) Technique

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Article Info

Article history:

Received Jun 12th, 2023
Revised Jul 20th, 2023
Accepted Jul 26th, 2023

Keyword:

VR Exhibition Application

Level of Detail

VR Application optimation

Mahakarya Vocation Land

ABSTRACT

The development of the VR exhibition application for vocational land masterpieces using Level of Detail (LOD) is the focus of this research. LOD allows for adjusting the detail of 3D objects based on the user's viewing distance, reducing computational load, and improving application performance. LOD Groups are used to categorize objects based oncomplexity levels and dynamically adjust the level of detail. The research results indicate that the use of LOD successfully increased FPS by 284% and reduced memory usage in several important parameters such as setPass Calls, draw calls, batches, triangles, vertices, used textures, render textures, and shadow casters. Although some parameters did not show a significant improvement in FPS, it is important to monitor and optimize them. The useof LOD can be an effective strategy to improve the performance of VR exhibition applications by reducing rendering and memory load, creating a smoother and more responsive VR experience.

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1. INTRODUCTION

In the rapid development of information and communication technology, virtual reality (VR) applications are becoming increasingly popular and used in various fields, including virtual exhibitions [1]. VR exhibition applications allow users to experience engaging and interactive virtual environments, including viewing artworks, products, or other exhibitions. In relation to this, the Ministry of Education, Culture, Research, and Technology launched a VR exhibition application called "Mahakarya Vokasi Land" in 2022. Through this application, visitors can experience the beauty of Indonesia using virtual reality (VR) technology. Within this platform, visitors can explore various locations and discover various student-made products from vocational education institutions. This application has been implemented in various national events [2,3].

However, the development of VR exhibition applications often faces challenges in terms of performance optimization. The use of complex and detailed 3D graphics in virtual environments can impact application performance, especially when used on devices with limited capabilities, such as mobile devices [42].

One approach used in optimizing VR exhibition applications is Level of Detail (LOD) [5]. LOD is a technique that allows adjusting the detail of 3D objects based on the user's viewing distance. By implementing LOD, objects that are far from the user's view can be simplified in terms of geometry, texture, or other levels of detail, thereby reducing computational load and improving application performance.

This research aims to optimize a VR exhibition application using Level of Detail (LOD) Groups. By implementing LOD Groups, objects within the virtual environment will be grouped based on their complexity levels, and the level of detail will be dynamically adjusted based on the user's viewing distance [6]. This is expected to improve the performance of the VR exhibition application while still providing a satisfying visual experience.

In this study, an analysis of the optimal LOD Group method will be conducted, along with its implementation in the VR exhibition application. Testing and evaluation will be carried out to measure the performance of the application by comparing it with a non-optimized VR exhibition application. The results of this research are expected to contribute to the development of more efficient and responsive VR exhibition applications, thereby enhancing the user experience and attractiveness of virtual exhibitions [7].

2. RESEARCH METHOD

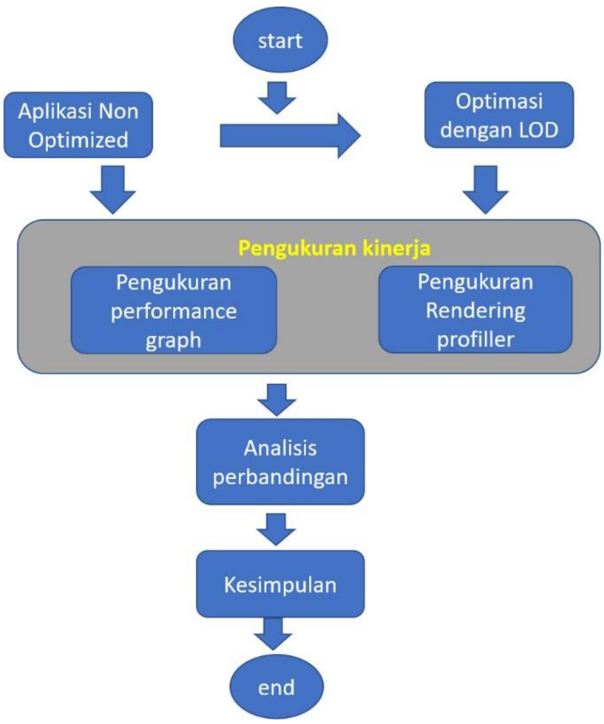


Figure 1 research method

2.1 LOD Group

LOD (Level Of Detail) is a technique used in Unity to control the level of detail of objects in a 3D environment [8]. Meanwhile, LOD Group groups objects with different levels of detail based on the distance from the observer.

e-ISSN: 2548-6853

The goal of the LOD Group is to optimize the performance of graphic applications by reducing the load on graphic processing. In a 3D environment, some objects may not be clearly visible to the observer due to their distance. By implementing LOD Group, these objects can be rendered with lower levels of detail [9], which means that the number of polygons or textures used to represent these objects is reduced (Figure 2).

The appropriate level of detail selection for objects within an LOD (Level of Detail) Group is based on the distance from the observer. The farther an object is from the observer, the lower the level of detail applied. This way, objects that are far from the observer do not need to be rendered with high levels of detail, reducing processing load and improving graphics application performance.

The implementation of LOD Group can help create a smoother and more realistic visual experience in VR applications. By adjusting the level of detail of objects based on the viewer's distance, LOD Groupaids in optimizing the utilization of computational resources and improving the overall performance of graphical applications.

2.2 Frame Per Second (FPS) pada performance graph

Frames per second (FPS) refers to the number of images that are updated every second on the screen. Each image represents a frame [10]. A fast projection of images creates an illusion of motion to the human eye. Therefore, the higher the number of frames or image projections per second, the smoother the movement [11].

Target FPS= 1000/time per frame (ms) .... (1)

2.3 Profiler untuk pengukuran aspek rendering

Profiler is a tool in Unity used to monitor the performance of an application, including rendering, scripts, physics, and more. In terms of rendering, the parameters observed are batch count, set pass calls count, batches, triangles count, vertices count, used textures, render textures, render texture changes, used buffers, vertex buffers upload in frame, and shadow casters [12].

- Batch Count: The total number of objects rendered in a single batch. Having a high batch count indicates potential optimization opportunities by combining those objects into a single batch.
- SetPass Calls Count: The total number of SetPass function calls during rendering. Each SetPass call results in a material change and having a high count can impact performance.
- Batches: The total number of batches executed in a single frame. If the number is high, it may indicate a possibility for more efficient batch separation.
- Triangles Count: The total number of triangles rendered in a single frame. Optimizing the triangle count can help improve rendering performance.
- Vertices Count: The total number of vertex points rendered in a single frame. Reducing the vertex count can help improve rendering performance.
- Used Texture: The number of textures used in a single frame. A high count can impact performance, so it's important to minimize the use of unnecessary textures.
- Render Textures: The number of render textures used in a single frame. Having a high count can impact performance, so it should be carefully considered.
- Render Texture Changes: The number of render texture changes in a single frame. If the count is high, it may indicate unnecessary changes that affect performance.
- Used Buffers: The number of buffers used in a single frame. Excessive buffer usage can impact performance, so optimization is required.
- Vertex Buffers Upload in Frame: The amount of vertex data uploaded in a single frame. Reducing the amount of vertex data uploads can help improve performance.
- Shadow Caster: The number of objects casting shadows in a single frame. If the count is high, it can affect shadow rendering performance.

3. RESULTS AND ANALYSIS

3.1 Hardware specification

PC Specification	VR Specification
Intel Xeon W-1290P CPU @3.70Ghz (20CPUs)	HTC VIVE Pro 2
RAM 32 GB	2448 x 2448 Pixels Per Eye
VGA Quadro RTX 4000 8 GB	120Hz Refresh Rate
	120-degree horizontal FOV
	Hi-Res certified headphones
	Integrated dual microphones
	Bluetooth & USB-C Connectivity
	Steam VR Tracking V2.0

3.2 VR Performance Graph

Below is the result of the VR Performance Graph when playing the Mahakarya application, where the VR player's position captured is the same.

Figure 2. LOD Perfomance

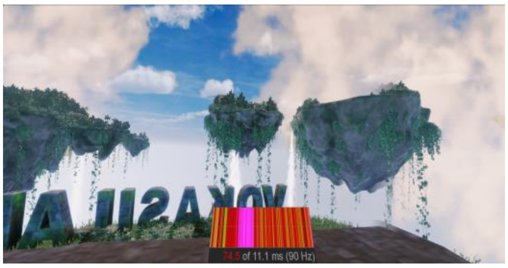
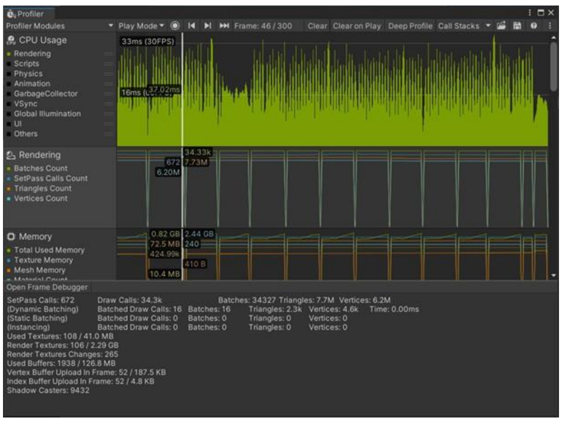


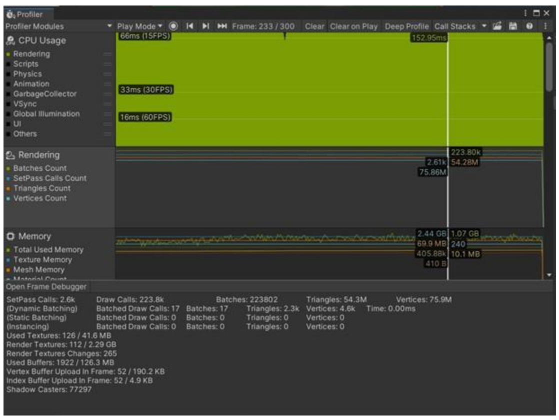
Figure 3. Non Optimized performance

The VR Performance Graph shows a time per frame of 11.1 (90 Hz). This means that the time required to achieve 90 frames per second (FPS) is 11.1 milliseconds. If the time per frame exceeds 11.1 ms, frame drops will occur [13]. The result for LOD is 51.54 FPS, and for Non Optimized it is 13.42 FPS.

3.3. Profiler (rendering) perfomance

Below is the result of the Profiler for each application during gameplay. It can be seen that the rendering graphics have different spikes, indicating that the rendering process consumes a high CPU usage. We can also see that the rendering yields different results. This rendering data can be observed in section (3.4), where the data will be compared.





e-ISSN: 2548-6853

Figure 4. LOD rendering

Figure 5. Non Optimized rendering

3.4 Analysis

Variable	Optimized LOD	Non Optimized
Setpass calls	672	2.2k
Draw calls	34.3 k	233.8 k
Batches	34.3 k	233.8 k
Triangles	7.7 M	54.3 M
Vertices	6.2 M	75.9 M
Used texture	108/41.0 MB	126/41.6 MB
Render texture	106/2.29 GB	112/2.29 GB
Render texture changes	265	265
Used Buffers	1938/126.8 M	1922/126.3 M
Vertex Buffer Upload In Frame	52/187.5 KB	52/190.2 KB
Index Buffer Upload In Frame	52/4.8 KB	52/4.9KB
Shadow Caster	9432	77.297
FPS	52.54 FPS	13.42 FPS

Based on the data above, the LOD method successfully increased FPS by 284%. This method managed to reduce memory usage for setPass Calls by 74.15%, draw calls by 84.67%, batches by 84.67%, triangles by 85.81%, vertices by 91.83%, used textures by 14.2%, render textures by 5.3%, and shadow casters by 87.7%. In this method, the parameters that are not significant in improving FPS are render textureschanges (remains the same), used buffers (-0.8%), vertex buffer upload in frame (remains the same), and index buffer upload in frame (remains the same).

4. CONCLUSION

The use of Level of Detail (LOD) method significantly improves the FPS (Frames per Second) performance. This method also successfully reduces memory usage drastically on several parameters, namely setPass Calls, draw calls, batches, triangles, vertices, used textures, render textures, and shadow casters. However, there are some parameters that do not show a significant increase in FPS. Render textures changes, used buffers, vertex buffer upload in frame, and index buffer upload in frame have constant or minimal decrease values. Although they do not contribute significantly to the increase in FPS, it is still important to monitor and optimize these parameters to ensure overall application performance remains optimal. By using the LOD method, the application manages to achieve a significant increase in FPS while reducing memory usage on several important parameters. This indicates that the use of LOD can be an effective strategy in improving application performance by reducing rendering load and memory, thereby creating a smoother and more responsive VR experience.

ACKNOWLEDGEMENTS

The writer expresses gratitude to the Ministry of Education, Culture, Research, and Technology, the Director General of Vocational Education, Batam State Polytechnic, Digiars Studios, ISBI Bandung, and RUS Kudus Vocational School for their assistance in terms of collaboration, trust, funding, and facilities in this research.

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