Novel Method for Ultra-High-Resolution VR Display System

Hao Zhang, Lili Chen, Wenyu Li, Xuefeng Wang, Jinghua Miao
BOE Technology Group Co., Ltd., Beijing, China

Abstract

The purpose of this paper is to provide a novel solution for an ultra-high-resolution VR display system. This solution separates the rendering and transmission of fixed backgrounds and changing foregrounds, and combines it with gaze-based high and low definition rendering techniques, significantly reducing the consumption of SOC computing resources and bandwidth requirements for scene rendering. Additionally, by integrating display-side time warping technology, it avoids the black edges introduced by rapid head movements, offering a new path for the transmission and display of ultra-high-resolution VR systems.

Author Keywords

Foreground Rendering; Background Rendering; High-Low Resolution Rendering Technology; Ultra-High-definition VR System.

1. Introduction

With the rapid development of virtual reality technology, the demand for immersive experiences among users is growing. Against this backdrop, ultra-high-resolution VR display systems have become key to enhancing the user experience[1]. However,traditional full-scene rendering methods face significant computational and bandwidth challenges when confronted with high-resolution demands. System-on-Chips (SOC) need to process massive pixel data,which not only increases the computational burden but also puts higher demands on data transmission bandwidth.

To break through these limitations, this paper proposes a novel solution for an ultra-high-resolution VR display system. The core idea of this solution is to separately process the fixed backgrounds and changing foregrounds in VR scenes using a time-multiplexed rendering and transmission method, which significantly reduces the consumption of SOC computing resources for scene rendering. Combined with display-side time warping technology, it can effectively avoid the black edge phenomenon caused by rapid head movements. At the same time, foreground rendering combined with gaze-based high-low resolution rendering technology not only further reduces computational resource consumption but also greatly reduces the system's transmission bandwidth requirements[2-3].

2. Scene separation rendering transmission technology

We have developed the SSRT (Separate Scene Rendering Technology) technology, which is based on the core idea of processing fixed backgrounds and changing foregrounds in VR scenes using separate rendering and transmission techniques. As shown in Figure 1, when running application scenarios in the SOC, according to the application layer instructions, during the initialization of the application: Step 1, the fixed background image of the scene (here taken as a panoramic image) is first transmitted to the display module for storage; Step 2, the dynamically changing foreground content in the scene is rendered in real-time, and the left and right eye rendering images are obtained, where the pixel transparency of the foreground content in the rendering image is set to 1, and the pixel transparency of the rest of the content is set to 0; Step 3, an information line containing time information, pose information, display mode information, etc., is added to the left and right eye images, and then sent to the display end; Step 4, the display module parses the foreground images sent by the SOC in real-time, separating the image data and information line data; Step 5, based on the information line data, combined with the panoramic to planar conversion formula, the background image of the screen display moment is projected and mapped in the panoramic image; Step 6, based on the information line data, the distortion matrix is calculated to perform temporal distortion on the foreground image; Step 7, the background image and the foreground image are merged and then transmitted to the display for display.

The SSRT scheme has two main advantages: Advantage 1 is that the background image of the application scenario is transmitted to the display module during the initialization stage, ensuring that the SOC has enough resources to render the foreground in real-time, thereby ensuring the refresh rate of the ultra-high display resolution VR device. Advantage 2 is that placing the temporal distortion function on the display end can avoid the image black edge phenomenon introduced by rapid head movements.

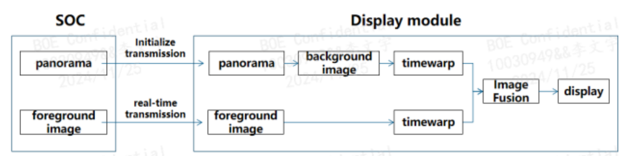

Figure 1. SSRT technology flowchart.

Figure 2 illustrates the image data outputted in real-time by the SOC, which includes foreground content and an information line. The information line stores pose data used for calculating the background image on the display end. The pixel Alpha channel of the foreground content in this image data is marked as 1, while the Alpha channel of the remaining pixels is marked as 0.

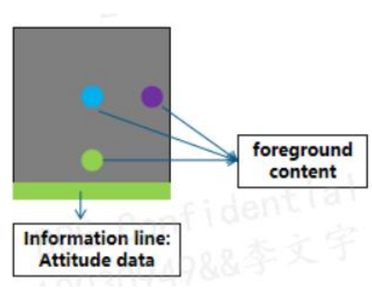

Figure 2. final image from SOC .

The conversion of a panoramic image to a background image is shown in Figure 3. At the startup of the application, the SOC first transmits the panoramic image serving as the background to the display module for storage, and then the SOC only needs to render the foreground content. The display module parses the image data transmitted by the SOC, separating the foreground image and the information line data. Based on the information line data, the display module projects and transforms the background image for the display moment from the panoramic image.

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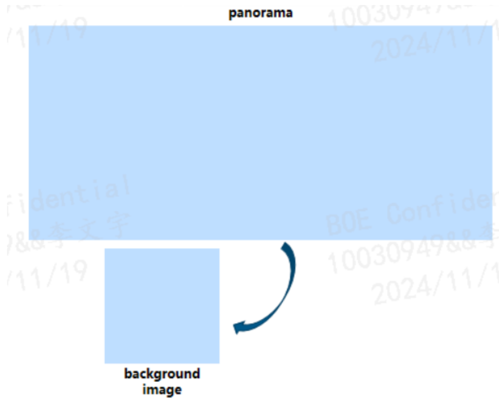

Figure 3. panorama and background image

The foreground image and background image are merged and ultimately transmitted to the display screen for presentation, as shown in Figure 4. The image blending process is primarily accomplished by determining whether the Alpha channel data of the foreground image is 0 or 1. If the Alpha channel value of a pixel in the foreground image is 1, then the RGB value at that position in the final displayed image is the RGB value of the foreground image; if the Alpha channel value is 0, then the RGB value at that position in the final displayed image is the RGB value of the background image.

Figure 4. Image Fusion.

For ultra-high-resolution VR systems, in addition to the high consumption of scene rendering resources, transmission bandwidth is also a significant bottleneck. As shown in Figure 5, by using foveated rendering technology, the SOC renders the area of focus with high definition and the entire field of view with low definition. It then stitches the high and low-resolution images together and writes the coordinates of the high-resolution image onto an information line. The SOC sends this composite image to the display module, which stretches the low-resolution image B to the screen resolution size and then replaces the corresponding positions in B1 with the high-resolution image A based on the coordinate information from the information line. The technical scheme in Figure 5, when combined with SSRT technology, can reduce the transmission bandwidth requirements while further reducing the rendering pressure on the SOC side.

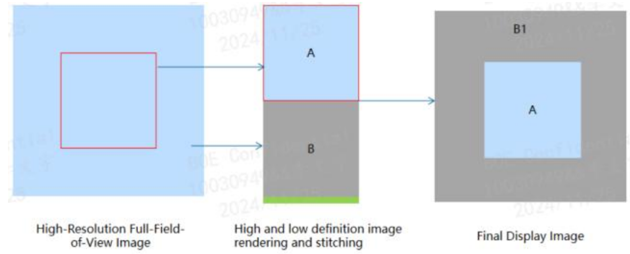

Figure 5. High-Low Definition Image Rendering and Transmission Display Technology

3. Interaction mode

This paper illustrates the solution with a VR system that has a single-eye screen resolution of 4k x 4k as an example. The scheme has developed multiple interactive display modes, allowing users to choose a suitable display mode based on their preferences and the complexity of the application. As shown in Figure 6, the display modes are mainly divided into two categories: conventional rendering mode and scene separation rendering transmission mode. Each category includes low-resolution rendering mode and high-low resolution rendering mode. In the high-low resolution rendering mode, there are two options for the size of high and low-resolution images, 1k x 1k and 2k x 2k (with the option to add more), and users can freely combine them according to their needs. It should be noted that in this scheme, the low-resolution image contains the full field of view content of the VR, while the high-resolution image only contains the content of the human eye's gaze area.

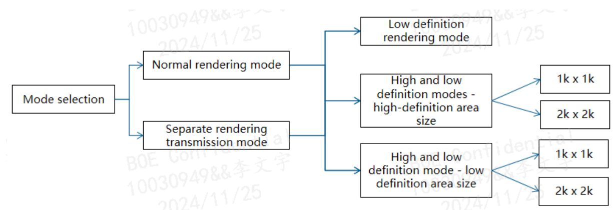

Figure 6. Multi display mode flowchart

Figure 7 illustrates the output flowchart for the low-resolution display mode, which only renders the low-resolution image and fills the high-resolution areas with black pixels, marking the low-resolution display mode in the information line. After this image is output to the display module, the display module separates the low-resolution image and stretches it to a 4k x 4k resolution size for display. This mode can greatly ensure the smoothness of the VR system and is suitable for more complex scenes or scenes in motion. Note that the maximum resolution of the low-resolution image designed in this scheme is 2k x 2k, and the minimum is 1k x 1k; in actual use, it can be modified according to needs.

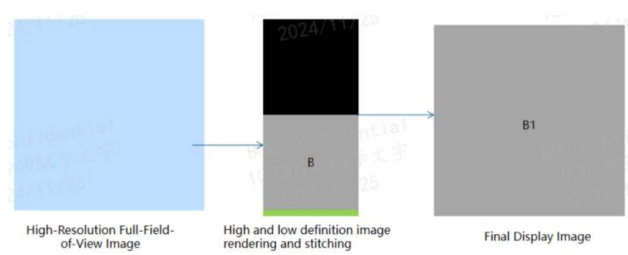

Figure 7. Low definition rendering mode

Figure 8 depicts the high-low resolution display mode 1, where both the high-resolution and low-resolution images are set to 2k x 2k. This mode strikes a balance between rendering speed and overall display clarity, ensuring the maximum extent of clarity in the overall display as well as the high-definition area coverage.

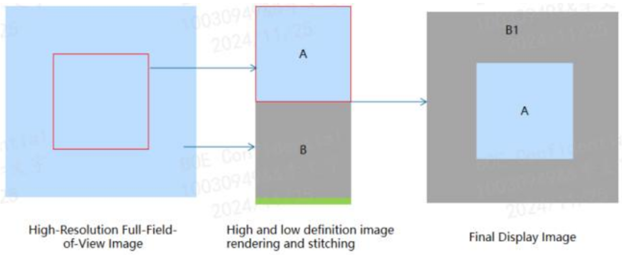

Figure 8. High and low definition mode1

Figure 9 illustrates the high-low resolution display mode 2, where both the high-resolution and low-resolution images are set to 1k x 1k. This mode ensures high-definition in the gaze area while significantly reducing the rendering pressure on the SOC, ensuring the frame rate of image rendering.

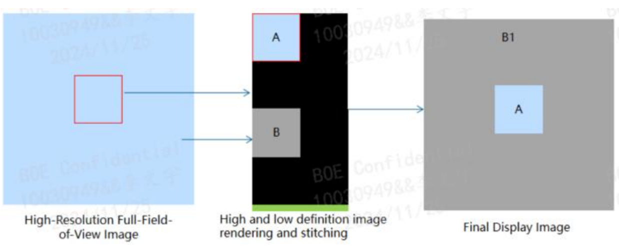

Figure 9. High and low definition mode2

Figure 10 represents high-low resolution display mode 3, where the high-resolution image has a resolution of 2k x 2k and the low-resolution image has a resolution of 1k x 1k. This mode increases the display area of the high-definition zone while reducing the clarity of the low-definition zone.

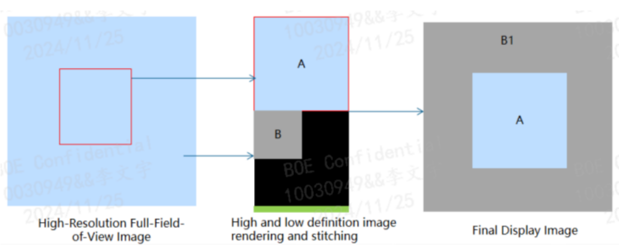

Figure 10. High and low definition mode3

Figure 11 illustrates high-low resolution display mode 4, where the high-resolution image is set at 1k x 1k and the low-resolution image is set at 2k x 2k. This mode reduces the display area of the high-definition zone while increasing the clarity of the low-definition zone.

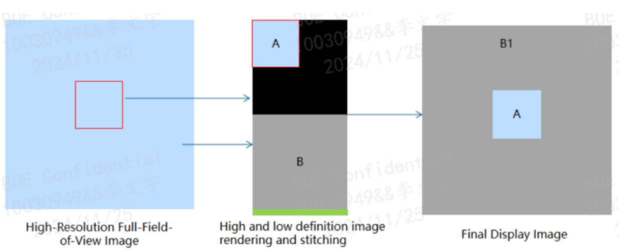

Figure 11. High and low definition mode4

Table 1 presents the ratio of rendering resources used by different display modes in the SOC to those used by the traditional real-resolution (4320*4320) rendering mode.

Table 1.GPU rendering resource testing

Mode	Proportion of rendering resources
low definition mode 1（1k1k）	47.7%
low definition mode 2（2k2k）	52.3%
High and low definition mode 1	77.3%
High and low definition mode 2	51.1%
High and low definition mode 3	60.2%
High and low definition mode 4	60.2%

4. Simulation verification

We conducted some simulation validations according to the SSRT (Separate Scene Rendering Technology) scheme. We built a simple VR panoramic spherical scene and rendered foreground objects such as spheres, cubes, and rectangular prisms within it. Figure 12 shows the panoramic image we used.

Figure 12. panorama.

Figure 13 is the VR monocular image rendered using the traditional method, which includes both the background (content of the panoramic image) and the foreground (spheres, cubes, and rectangular prisms).

Figure 13. Traditional rendering image.

Figure 14 depicts the final image output by the SOC simulated according to the SSRT technology, as well as the background image calculated on the display end. The final image output by the SOC includes the foreground content image and an information line. Using the information from the information line and the panoramic image, we have computed the background image.

Figure 14. SSRT technology image.

Based on whether the Alpha channel value of the foreground image pixels is 0 or 1, we blend the foreground image with the background image. The merged image in Figure 15 is consistent in content with the traditional rendering image in Figure 13. We compared the resource consumption of the SOC under both the traditional rendering method and our SSR rendering method in this scheme. In this scenario, our scheme can save nearly 43% of resource consumption. Of course, as the complexity of the foreground scene continues to increase, this figure will decrease.

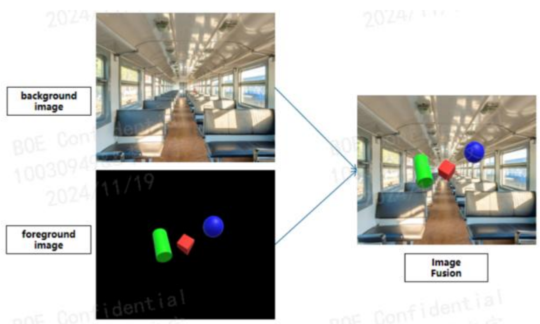

Figure 15. SSR technology verification.

5. Conclusion

This paper presents a novel solution for an ultra-high-resolution VR display system, aimed at reducing the rendering pressure on the SOC and increasing the rendering frame rate for complex scenes through the use of time-multiplexed rendering and transmission of distant and near-content. Additionally, by combining this technology with foveated rendering techniques, it further reduces the rendering pressure on the SOC and avoids transmission bandwidth limitations as much as possible. The paper has conducted extensive simulation tests of this technology on Windows and Android platforms, verifying its feasibility.

6. Acknowledgements

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7. References

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