

# A Technical and Practical Comparison of Traditional and Neural Rendering Methods in Games

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**Abstract.** Rendering technology, a significant component of modern computer graphics, plays a vital role in the game field. With the growing demand for visual realism and real-time performance in game development, rendering technology has been continuously developed and optimized. This paper presents a comparative study of the three techniques - rasterization, ray tracing, and neural rendering- within an interactive gaming environment. By analysing their fundamental principles and practical applications in the gaming field, the analysis highlights each technique's respective advantages, limitations, and domains of applicability within the gaming field. Rasterization is widely adopted in real-time and small-scale games due to its high rendering efficiency and low hardware demands. Conversely, ray tracing provides a more realistic light simulation. This technology is increasingly used to develop games with high graphics quality requirements. Neural rendering leverages artificial intelligence (AI) techniques to balance rendering quality and efficiency, showing promising applications. Furthermore, this study raises expectations for the evolving convergence of multiple rendering techniques.

**Keywords:** Rendering; Rasterization; Ray Tracing; Neural Rendering; Game Field.

## 1. Introduction

Rendering, a computer graphics technology that converts a three-dimensional (3D) scene into a two-dimensional (2D) image, is applied across diverse fields, including gaming, film and television production, architecture, and medical visualization [1]. Among these, rendering plays a particularly critical role in the gaming industry. Rendering quality affects the visual performance, user interaction, and game immersion. Traditional rendering techniques, mainly rasterization and ray tracing, are widely applied in game development. However, as the demand for more sophisticated simulation of lighting and shadow effects and smoother real-time performance continues to rise, they both show their inadequacy. With the rapid development of AI technology, neural rendering, as a new technology using deep learning models, has emerged. It can reduce the computational load and enhance rendering efficiency. Therefore, it is significant to analyse and study the advantages and limitations of traditional and neural rendering technology and their applicability in the gaming field.

In recent years, research on rendering technology has mainly focused on optimizing traditional rendering technology. Nowadays, rasterization is still the most widely used rendering technique in the current gaming field. Rasterization has high rendering efficiency and is therefore well suited for games requiring a high frame rate and low latency. However, rasterization has a limited ability to simulate complex lighting scenes accurately. This makes the rendering results less realistic. Conversely, ray tracing is much more accurate and better at simulating lighting effects. However, its computational cost is too high and requires specialised high-performance hardware. Consequently, the gaming industry chooses to adopt the hybrid method rather than using ray tracing technology exclusively, thereby achieving a balance between graphical quality and efficiency. This is applied by allowing users to enable or disable ray tracing features, allowing for personalized adjustments based on individual hardware capabilities and visual preferences. Recently, with the rapid development of AI technology, integrating AI technologies with rendering technologies has led to the development of neural rendering technology [2]. It seeks to balance AI technology and traditional rendering technology to maintain high image quality while reducing computational cost. As one of the notable



practices, Deep Learning Super Sampling (DLSS) is developed by NVIDIA and represents a promising direction for future developments in game graphics [3].

This study aims to compare and analyse the applicability of traditional and neural rendering technology in the game field. By examining the fundamental principles of the three rendering approaches and game application examples, this paper analyses and evaluates their respective characteristics in various terms. Furthermore, the study discusses potential trends in the evolution of rendering technologies. Finally, it looks forward to the integration of future technology development.

## 2. Research Methodology

The main objective of this study is to provide a comprehensive comparative analysis of traditional rendering and neural rendering techniques in the context of modern game development. It seeks to analyse and evaluate each approach's technical strengths and practical limitations and provide an outlook on the future development of rendering techniques in the game domain. As shown in Fig. 1, this paper first outlines the fundamental principles and workflows of rasterization, ray tracing, and neural rendering. This is followed by comparing their rendering quality, computational performance, and cost-efficiency, supported by game application cases. In the final section, this paper summarises the above research content and discusses the technique's strengths, limitations, and applicability in gaming. In addition, this paper provides an outlook on the future development of integrating technologies.

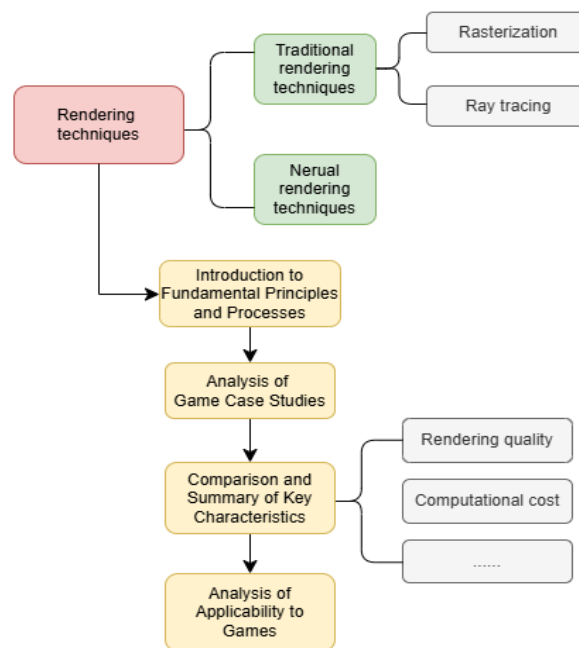


Fig. 1 Flow chart (Picture credit: Original).

### 2.1. Fundamental Principle and Workflow

Rasterization, ray tracing, and neural rendering are the three essential methods used in computer graphics to transform 3D scenes into 2D images. Rasterization and ray tracing are traditional techniques, while neural rendering has emerged more recently as a product of advancements in machine learning. This section outlines the fundamental principles and general workflows of these three methods.

Rasterization is one of the most essential rendering techniques in modern computer graphics. The core principle is to render a 3D scene onto a 2D surface by decomposing objects into a mesh of triangles or polygons. First, construct a network of triangles, then create objects on the screen from a mesh of virtual triangles or polygons. These triangles form the structural basis of 3D models, with each vertex defining its position, colour, and surface normal. The computer then converts these triangles into pixels

represented on a 2D screen. Further processing involves interpolating vertex attributes across each triangle's surface, followed by calculations for texture mapping, lighting, and shading to generate the final image.

Ray tracing is a rendering technique that determines the visibility of surfaces in the space of a 3D object by tracing rays of light from the camera into the scene. This technology can simulate real-world light behaviour to create highly realistic lighting effects [4]. Ray tracing generates a computer graphics image by tracing the path of light from the view camera, through the 2D view plane, out onto the 3D scene, and back to the light source [5]. Ray tracing technology can better simulate all aspects of the light source. It can generate shadows, reflections, refractions, and other effects produced by light in a 3D environment to achieve more realistic visual effects. However, the recursive calculation of each ray results in high computational costs and imposes significant hardware performance requirements. These led to the limitations of the practical application in the mid-1980s when hardware capabilities were insufficient to support its performance requirements. However, with the progress of computer hardware, especially the improvement of GPU performance, ray tracing has become a prominent area of research again. It has been gradually integrated into modern game engines to achieve more immersive visual experiences.

Neural rendering is an emerging approach in recent years that leverages deep learning techniques [6]. Its core principle is to employ neural network models to learn complex visual representations from real-world data. These models can simulate the complex lighting phenomena by training on large-scale datasets. This ability to render based on data training and knowledge allows neural rendering techniques to be more flexible in dealing with complex scenes and improves rendering accuracy. Moreover, with the support of the appropriate hardware, the rendering speed can be up to 200 FPS in some cases [7]. Overall, neural rendering provides a practical balance between visual fidelity and performance, improving rendering accuracy while maintaining better rendering speed.

## 2.2. Game Case Study

This chapter explores the practical application of rasterization, ray tracing, and neural rendering techniques in video games. By analysing relevant case studies, it provides a deeper insight into each technique's strengths and limitations in the gaming field.

The rasterization algorithm's relative simplicity allows it to render tasks quickly and efficiently. Its ability to deliver high frame rates makes it suitable for real-time, fast-paced games. For example, games like *League of Legends*, *Valorant*, and *Counter-Strike* all employ rasterization-based rendering pipelines [8, 9]. In these games, the rendering pipeline is optimised for fast vertex transforms and pixel shading, allowing players a smooth gaming experience even on mid or low-end hardware platforms.



**Fig. 2** League of Legends in-game screenshot (Picture credit: Original).

However, rasterization is limited in accurately simulating complex lighting phenomena. As shown in Fig. 2, the game scene's shadows, reflections, and refractions are not realistic enough. The light rendering on the character's attire is also less accurate. Thus, while rasterization has faster and better computational speed, it falls short in achieving high-fidelity lighting realism.

As previously discussed, while ray tracing can simulate more realistic lighting effects, it relies on high-performance hardware devices. Therefore, it was not until 2018 that this technology was gradually integrated into mainstream video games. In recent years, more and more games have adopted ray tracing technology, typically by providing the option to enable it in the game for players to choose and experience based on their hardware capabilities. For example, *Cyberpunk 2077*, *Watch Dogs: Legion*, and *Wuthering Wave* provide players with a more realistic visual experience with ray tracing enabled. Figs. 3 and 4 compare *Wuthering Wave* before and after turning on ray tracing. These clearly show the optimisation of image quality by ray tracing technology. As shown in Fig. 3, the shadows on the right are more natural and softer. The global lighting appears more realistic, and the sense of space is more pronounced. Furthermore, the details of object surface, such as rock surfaces and the surface of overhanging structures, are increased. The reflections on water surfaces also become more realistic with more light reflection details. As illustrated in Fig. 4, applying ray tracing markedly improves the accuracy of specular reflections. The character's reflection can be seen clearly in the right image. At the same time, the reflection on the left image is less defined and fails to capture the dynamic variations in the light source.



**Fig. 3** Comparison image (1) before and after enabling ray tracing in *Wuthering Wave* [10].



**Fig. 4** Comparison image (2) before and after enabling ray tracing in *Wuthering Wave* [10].

In summary, ray tracing technology enhances the realism of dynamic lighting and environmental effects, improving players' visual immersion. However, it comes with a higher computational cost and requires more powerful hardware support. The ray tracing method on low-end hardware devices may lead to a low frame rate and affect the player's gameplay experience.

Neural rendering in gaming is still in the early exploration and gradual penetration stage, but it has already demonstrated considerable potential for future development. A representative example is

NVIDIA's Deep Learning Super Sampling (DLSS), which uses AI to increase frame rates, reduce latency, and improve image quality. The fourth generation of DLSS (DLSS 4) has been implemented in some games, such as Black Myth: Wukong, FragPunk, and *Dune: Awakening*. Fig. 5 shows that by adopting neural rendering technology, the image quality of the games is significantly improved, which is more similar to the lighting effect of the display. Fig. 6 shows that with DLSS4's Multi Frame Generation, Frame Generation, and other neural rendering techniques, games can maintain a frame rate of 200 FPS and above. Nevertheless, implementing neural rendering technology depends on specific hardware platforms and requires separate support during game development.



**Fig. 5** Comparison image before and after enabling neural rendering in Cyberpunk 2077 [11].



**Fig. 6** In-game Screenshot of Black Myth: Wukong After Enabling Neural Rendering [12].

### 3. Discussion

Following the preceding analysis of the fundamental principles and representative game applications of rasterization, ray tracing, and neural rendering, this section compares the characteristics of these three techniques and evaluates their suitability for use in the gaming field.

The primary advantages of rasterization are its high efficiency, high real-time performance, and low hardware requirements. In addition, it benefits from a mature rendering pipeline and tool ecosystem, making it highly accessible for developers. However, there are obvious deficiencies in complex lighting simulation, and the light simulation for shadows, reflections, and global lighting is relatively rough [13]. Despite these shortcomings, rasterization is sufficient to meet the needs of most real-time battles or lightweight games. Consequently, rasterization remains the most widely used traditional rendering method in game development.

Ray tracing, on the other hand, has a significant advantage in realism and light reproduction, and can more accurately simulate real-world lighting effects such as reflections, refractions, and shadows. Ray tracing is more flexible than rasterization, and it can compute the light needed for specific effects more accurately, while rasterization is limited in what it can compute efficiently [14]. Ray tracing algorithms require a significant computational overhead, which is very demanding on hardware. High-performance GPUs frequently come with a high price tag, which may impact the player experience. Game developers must strike a balance between visual effects and hardware requirements. Consequently, many games offer ray tracing as an option for high-end gamers and large-scale AAA games that seek an immersive experience.

Neural Rendering represents an advanced rendering technique developed by combining knowledge from the field of AI. DLSS technology is one of its prominent implementations. The core advantage of neural rendering is improving performance while enhancing image quality. Using AI-driven models effectively enhances frame rates and reduces latency. However, the computational demands of neural rendering remain considerable. Apart from professional gamers, the high price of hardware will dissuade a large portion of ordinary players. As a result, there are still fewer games that adopt Neural Rendering, and most of them are AAA games. Nevertheless, with the future development of computer hardware equipment, the broader application of neural rendering in games is anticipated [15].

In summary, rasterization suits most hardware and scenarios, real-time games with low image quality requirements, and smaller-scale game development. Ray tracing is ideal for high-budget game projects that require the ultimate visual experience. Neural rendering provides a promising balance between performance and image quality and is gradually expanding its application in high-frame-rate games and games with high visual performance requirements. This technology holds significant potential for future gaming experiences.

#### **4. Conclusion**

This study examines three essential computer graphics rendering techniques: rasterization, ray tracing, and neural rendering. These techniques are analysed regarding their respective principles, processes, and applications in the game domain. The objective of this study is to explore the applicability of these rendering methods in the gaming field. By integrating theoretical principles with real-world game case studies, this paper assesses the strengths and limitations of each rendering method. Rasterization remains the predominant choice for real-time interactive and smaller-scale games due to its computational efficiency and relatively low hardware requirements. Although computationally intensive, ray tracing significantly improves lighting realism and is increasingly being incorporated into AAA games that utilize high-performance GPUs. While still evolving, neural rendering balances computational overhead and rendering effectiveness, indicating a strong potential for future development. In the future, the research will focus on integrating these three techniques, emphasizing a balance between realistic lighting simulations and real-time performance. It is hypothesized that by incorporating the strengths of these three technologies, a more advanced rendering approach will emerge, which will profoundly impact the gaming field.

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