Perceptually-Based Foveated Virtual Reality

Anjul Patney* Joohwan Kim Marco Salvi Anton Kaplanyan Chris Wyman Nir Benty
Aaron Lefohn David Luebke

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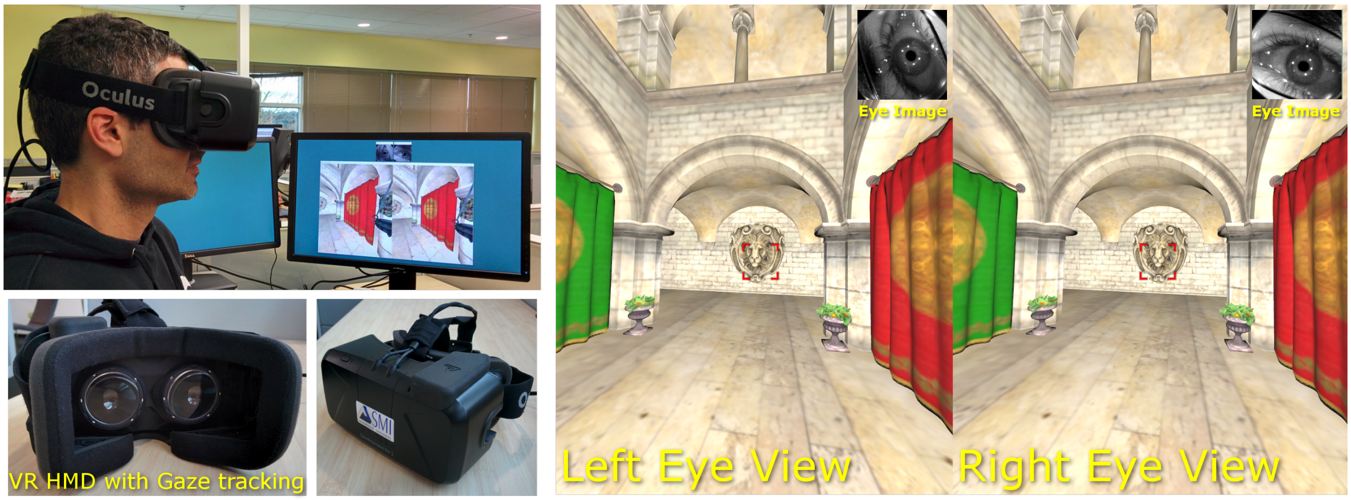

Figure 1: *Our installation demonstrates perceptually-based quality improvements for foveated rendering in virtual reality environments. A virtual-reality headset combined with a high-speed eye tracker enables practical and efficient foveated rendering, which optimizes performance by reducing image quality in the viewer's peripheral vision. Our perceptually-motivated techniques offer a better image quality than existing algorithms.*

Abstract

Humans have two distinct vision systems: foveal and peripheral vision. Foveal vision is sharp and detailed, while peripheral vision lacks fidelity. The difference in characteristics of the two systems enable recently popular *foveated rendering* systems, which seek to increase rendering performance by lowering image quality in the periphery.

We present a set of perceptually-based methods for improving foveated rendering running on a prototype virtual reality headset with an integrated eye tracker. Foveated rendering has previously been demonstrated in conventional displays, but has recently become an especially attractive prospect in virtual reality (VR) and augmented reality (AR) display settings with a large field-of-view (FOV) and high frame rate requirements. Investigating prior work on foveated rendering, we find that some previous quality-reduction techniques can create objectionable artifacts like temporal instability and contrast loss. Our emerging technologies installation demonstrates these techniques running live in a head-mounted display and we will compare them against our new perceptually-based foveated techniques. Our new foveation techniques enable significant reduction in rendering cost but have no discernible difference in visual quality. We show how such techniques can fulfill these requirements with potentially large reductions in rendering cost.

Keywords: foveated rendering, perceptually-based, virtual reality, augmented reality

Concepts: • **Computing methodologies** → **Perception;** *Rendering;*

*e-mail:apatney@nvidia.com

1 Overview

Despite tremendous improvements to graphics hardware, the computational needs of real-time rendering applications continue to grow. Rapidly evolving VR and AR displays demand significantly higher display resolutions, multiple views, and much higher frame rates. In order to provide compelling experiences in these new devices, approaches that reduce cost in imperceptible ways are becoming more important.

A significant reduction in human visual acuity occurs between images forming on the center of the retina (the fovea) and those outside the fovea (the periphery). Various optical and neural factors combine to cause this quality degradation, which increases with distance from the fovea, and is known as *foveation* [Guenter et al. 2012]. Foveated rendering algorithms exploit this phenomenon to improve performance. These algorithms decrease rendering complexity and quality in the periphery while maintaining high fidelity in the fovea. In conjunction with high-quality and low-latency eye

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tracking, foveated rendering is an attractive way to drive upcoming VR and AR displays.

Our review of vision science literature suggests that while attractive and applicable, foveated rendering must be carefully implemented. Peripheral vision plays a critical role in helping us understand our surroundings without active study, and alerts us to changes and motion outside our current gaze. Maintaining this sense of presence is an important goal for foveated rendering. Existing techniques often improve performance but they can introduce objectionable artifacts such as temporal aliasing or a sense of tunnel vision due to excessive peripheral blur. We show several perceptually-based methods for foveated rendering, and demonstrate their advantages over existing techniques.

2 Overview of Demonstration

Our demonstration consists of a fully functional foveated VR rendering system. Using our setup, we will provide SIGGRAPH attendees a unique experience of real-time gaze-tracked foveated rendering in a virtual reality environment. We will show them how different algorithms for foveated rendering influence perceived image quality, demonstrating the advantages of temporally stable and contrast-preserving techniques.

3 Hardware

Virtual Reality Display As shown in Figure 1, we use a commodity head-mounted display as our base hardware. Our demonstration is compatible with any modern virtual reality setup. Our gaze-tracking prototype uses an Oculus Rift Development Kit 2 (DK2).

High-speed Gaze Tracker Our head-mounted display has been retrofitted with a high-speed gaze tracker manufactured and installed by SensoMotoric Instruments (SMI). Our gaze tracker runs at a frequency of 250 Hz and has a response latency of 6.5 ms.

4 Software

Our software infrastructure consists of a real-time rendering testbed which we have built using OpenGL and GLSL. Our testbed renders images of 3D scenes in stereo at 75 Hz (refresh frequency of Oculus DK2 display), and uses live data from the gaze tracker to implement foveated rendering using several existing and proposed methods.

Our proposed techniques improve the perceptual experience of foveated rendering by ensuring that they suppress artifacts (e.g. aliasing) that are visible in peripheral vision.

Our testbed uses high-quality anti-aliasing techniques to ensure temporal stability in foveated rendering. We enable 8× multisample anti-aliasing (MSAA) and have implemented a TAA algorithm inspired by Unreal Engine 4 [Karis 2014], modified to work with all of the above techniques.

5 Acknowledgment

We would like to thank SMI for providing us with Oculus DK2 HMDs integrated with high-speed gaze tracking hardware.

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