Foveated Real-Time Ray Tracing for Virtual Reality Headset

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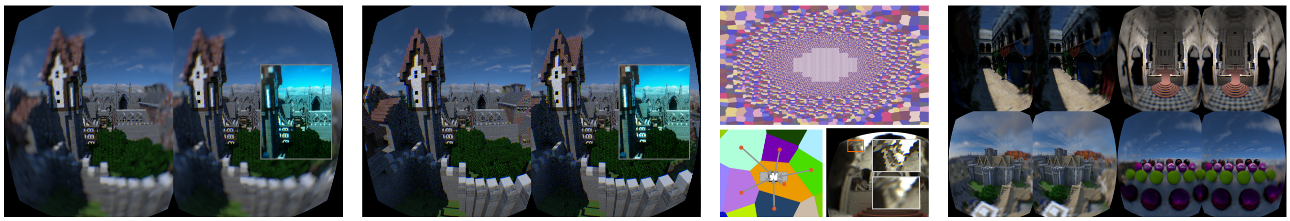

(a) 77 fps (13ms), 32 IBL rays per sample (b) 25 fps (39ms), 32 IBL rays per sample (c) Foveated sampling (d) Other rendering results

Figure 1: *(a) Our method with 6.7M triangles Rungholt scene. 55K shaded samples. Inset picture was taken through the lens of the Oculus Rift HMD. (b) Naïve ray tracing. 1M shaded samples. Visual quality in our method is equivalent to the one produced by the naïve method when seen through the HMD. (c) Our foveated sampling pattern and k-NN filtering method. Each cell corresponds to a sampling point. Real-time rendering over 60 fps is achieved with the OpenCL™ ray tracer, running on four Radeon™ R9 290X GPUs.*

1 Introduction

Emerging commodity high frame rate, wide angle head mounted display(HMD) VR Headsets, especially the Oculus Rift[Ocu 2013], opens the possibility of providing immersive virtual reality experience into widespread consumers. **Fast, low latency, smooth and realistic rendering methods** are vital for such a VR device.

Since the human eye is not sensitive to its surrounding environment[Deering 2005], it is natural to render pixels finely in the center of the wide angle HMD screen, and coarsely for the outer area[Guenter et al. 2012].

Considering these characteristics, we invented a new foveated rendering technique based on ray tracing. By nature, ray tracing allows flexible sampling control over the image and is extremely suitable for foveated rendering. Ray tracing also has a unified way to produce high quality shadows, reflection, etc which are important factors for immersive VR experiences.

2 Our Approach

Foveated sampling Sampling points are approximately distributed over the image plane according to $\theta^{(-2/3)}$, where θ is the distance from the center of the image. In the center of the image itself(roughly $1/15$ the area of the whole image), samples are uniformly distributed to get better shading coherency, as shown in Fig 1 (c) above.

Smooth shading For every pixel in the image, k-nearest neighbor sampling points are calculated, and its weight according to the distance to the pixel is computed. At rendering time, each pixel color is computed by taking a weighted average of the shading results from these k-NN samples to get a smoother shading result, as shown in Fig. 1 (c) bottom. For each shading sample, we trace a minimum of 16 rays. Otherwise spatial and temporal luminance popping/noise artifacts appear at high frame rates, which makes it distracting for the observer.

Stereo rendering As shown in Fig. 2, the projection used by the Oculus Rift is parallel in both the left and right images. Many pixels are the same for L and R images if the scene scale is large enough. Our implementation takes advantage of this property to save the number of rays and for smooth stereo rendering. We render a single wider image from a single point of view, then split it into both L and R images during the post processing phase. Precise parallax correction is required by further research, but this can also be solved with ray tracing and will not significantly increase the number of additional rays.

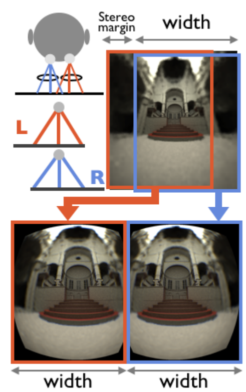

Figure 2: *Our stereo rendering pipeline.*

Parallel OpenCL ray tracer High performance and scalability are achieved by an OpenCL ray tracer designed to take advantage of multiple OpenCL devices. Since low latency is important for VR, every frame's computation is split across devices rather than alternate frame rendering. We developed a load balancing method computing screen split dynamically for each frame by taking the computational power of devices, image area, number of sampling points, and computational cost of samples into consideration. As all of those factors are evaluated on the fly, it can use any combination of devices without any precomputation. Sampling points which are computed by a device is selected by the k-NN information stored for each pixel in parallel.

Results Figure 1 illustrates our results. The OpenCL ray tracer was tested with Oculus Rift DK1 HMD (1280x800@60Hz). Our technique effectively reduces the number of pixels to shade by 1/20, achieving more than 75 fps while preserving the same visual quality.

Acknowledgements Rungholt scene ©kescha. Sibenik ©Marko Dabrovic. Crytek ©Frank Meinl. IBL map from Smart IBL.

References

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