

Global Illumination for Augmented Reality on Mobile Phones

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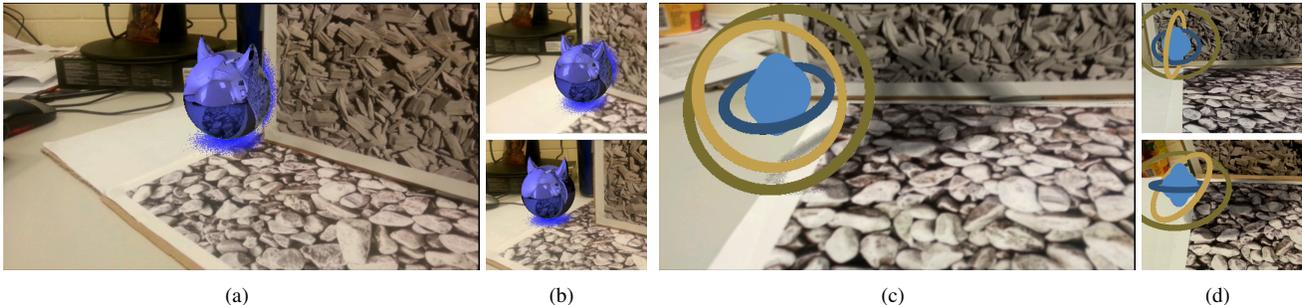


Figure 1: Our prototype achieves Global Illumination effects for Augmented Reality on mobile phones: (a) color bleeding (exaggerated) and environment reflections; (c) soft shadows. All effects are based on image-based lighting with a registered environment map, supporting moving objects (b,d).

ABSTRACT

The goal of our work is to create highly realistic graphics for Augmented Reality on mobile phones. One of the greatest challenges for this is to provide realistic lighting of the virtual objects that matches the real world lighting. This becomes even more difficult with the limited capabilities of mobile GPUs.

Our approach differs in the following important aspects compared to previous attempts: (1) most have relied on rasterizer approaches, while our approach is based on raytracing; (2) we perform distributed rendering in order to address the limited mobile GPU capabilities; (3) we use image-based lighting from a pre-captured panorama to incorporate real world lighting. We utilize two markers: one for object tracking and one for registering the panorama.

Our initial results are encouraging, as the visual quality resembles real objects and also the reference renderings which were created offline. However, we still need to validate our approach in human subject studies, especially with regards to the trade-off between latency of remote rendering and visual quality.

Index Terms: H.5.1. [Information Interfaces and Presentation]: Multimedia Information Systems—[Artificial, augmented and virtual realities] H.1.2. [Information Systems]: Models and Principles—[Human factors] I.3.2. [Computer Graphics]: Graphics Systems—[Distributed/Networked Graphics]

1 INTRODUCTION

The goal of our work is to create highly realistic graphics for Augmented Reality (AR) on mobile phones. One of the greatest challenges for this is to provide realistic lighting of the virtual objects. A large number of algorithms exist for implementing realistic lighting, commonly referred to as Global Illumination (GI). Several research projects have even achieved realtime GI, using a variety of different approaches [9]. Not surprisingly, several researchers have

applied these algorithms to AR: such as direct lightfield rendering [1], photon mapping [3], instant radiosity [4], and reflective shadow maps [5]. Our approach is similar to Kan and Kaufmann’s work by extending raytracing algorithms; however, ours is based on pathtracing [2].

A second crucial difference is that our target platform was a mobile phone, as opposed to desktop PCs in the aforementioned works. Based on the recent hype about renderers in the cloud [7, 6], we decided to go for this approach. Our distributed prototype first performs tracking on the mobile device, then sends the pose to a server, and finally receives the virtual content over the network for compositing with the video image.

Thirdly, to increase realism, our prototype does image-based lighting with a pre-captured panorama to apply real world lighting to virtual objects. We utilize two markers to create interactive dynamic lighting effects like soft shadows, color bleeding, and environment reflections.

Our initial results are encouraging, as visual quality resembles real objects and reference renderings that were created offline. Figures 2(a,b) show a comparison. However, we still need to validate our approach in human subject studies, especially with regards to the trade-off between latency for remote rendering and visual quality.

2 PROTOTYPE

Our prototype consists of a Samsung Galaxy S3 mobile phone and a desktop computer running Ubuntu 12.04 with 6 Gigabytes of RAM, an Intel i7 3.2GHz CPU, and a GeForce GTX 670. We utilize Qualcomm’s Vuforia¹ for tracking and Hugin² for stitching the panorama. In the following sections, we present details of our rendering component and the implementation of streaming from the desktop computer to the mobile phone.

2.1 Rendering

Pathtracing is based on the physics of light traversing through a scene, providing a way to compute GI. At each bounce, all incoming light (the illuminance) is integrated, arriving at a point on the surface of an object using Monte-Carlo methods. The incoming light is modulated by a surface reflectance function determining

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¹<https://developer.vuforia.com/>

²<http://hugin.sourceforge.net/>

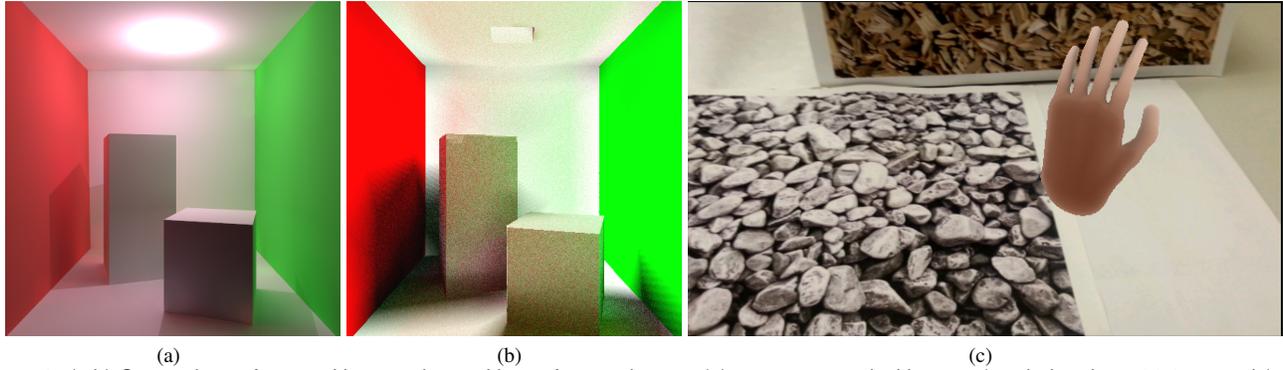


Figure 2: (a,b) Comparison of our realtime renderer with a reference image: (a) was generated with PBRT(rendering time: 86.8 seconds); (b) our prototype achieves a constant rendering time of 50 milliseconds with resembling visual quality. (c) Additional Global Illumination effects: subsurface scattering and ambient occlusion.

how much of it will be outgoing. This procedure is recursively repeated for every pixel. Effects that can be rendered include: diffuse interreflections (color bleeding) (Figure 1 a), environment reflection (Figure 1 a), soft shadows (Figure 1 c), and subsurface scattering (Figure 2 c) and ambient occlusion (Figure 2 c).

In order to perform the rendering in realtime, we have adopted Inigo Quilez’s approach [8], which implements a rendering pipeline on the GPU using Signed Distance Fields, which facilitate fast ray-object intersection calculations and visibility tests, which are essential for fast raytracing. We have extended Quilez’s approach by additionally generating bounding boxes around objects and geometry that are being affected by shadows and color bleeding, minimize rendering updates and network traffic. We extend Kan and Kaufmann’s [3] work on differential rendering for compositing with one-pass rendering of virtual and tracked objects. Our virtual objects can move freely through the scene while maintaining correct environmental lighting effects with the use of a second marker (Figure 1(b,d)).

Additionally, due to the noisy results from Global Illumination rendering techniques, mainly caused from the multiple secondary rays required for color bleeding calculations, on the client we apply a bilateral filter to our final rendering.

Figures 2(a,b) show renderings of the most commonly used GI test scene: the Cornell Box. While visual results resemble the reference rendering, our renderings are three orders of magnitude faster on the same computer.

2.2 Streaming

Streaming high quality graphics trades the bottleneck from the mobile device with the bandwidth and latency of transfer speeds. The commercial solutions mentioned in Section 1 have not yet been implemented on any AR systems.

For streaming to occur in realtime, while maintaining enough resources for the AR specific subsystems, we adopted the following compressions to reduce bytes transferred:

- Color coded single pass composition without alpha channel.
- Minimizing updates by bounding box tests.
- ZLIB compression.

3 CONCLUSIONS AND FUTURE WORK

In this paper, we have presented our prototype, which distributes rendering and computer vision between a desktop PC and mobile device to produce realistic GI on a mobile phone, providing a proof of concept for streaming visually high-quality AR on mobile devices. We believe that our work is the first to present GI for AR on a mobile phone. Our initial results are encouraging, as visual quality resembles real objects and also reference renderings that were created offline. However, there still remain two important areas of future work.

First, we still need to validate our approach in human subject studies, especially with regards to the trade-off between latency for remote rendering and visual quality. We plan to conduct studies similar to Steinecke and colleagues [10] to investigate the discriminability of real and virtual objects while varying latency and visual quality.

Second, our prototype can be improved in several ways. First of all, the computer graphics are still running too slowly in order to reach the commonly found 60Hz update rate on modern, possibly stereoscopic, mobile devices. In the future, instead of hardcoding environment lighting and material properties, we aim to obtain this information dynamically in the spirit of Jachnik and colleagues [1].

We believe that increasing the realism of virtual objects in AR scenes is crucial to achieve high-fidelity user interfaces, that can even trigger deep psychophysical responses, such as in our previous work BurnAR [11], where a high-quality virtual fire caused users to experience an involuntary heat sensation.

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