A Framework for Holographic Scene Representation and Image Synthesis

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1 Introduction

Traditionally, graphics objects or scenes have been represented through geometry and appearance. Most often, geometry is described by primitives such as triangles, points, basis functions, and others, while appearance is encoded in texture maps. Due to the difficulty of representing some real-world objects, such as fur, hair, or trees, with traditional techniques, research has also focused on image based rendering using light-fields, lumigraphs, reflectance fields, sprites, and other models. In all these graphics representations the treatment of light is motivated through ray optics, and rendering involves projection and rasterization, or ray tracing.

To the best of our knowledge, we present the first system using a hologram as a rendering primitive for a conventional, framebuffer-oriented graphics pipeline. Such holograms are elegant structures capturing the phase and amplitude of an object or scene wavefront as seen from all possible views through a window of given aperture. The major differences with lightfields, are the intrinsic wave optics that handle anti-aliasing implicitly, and the ability to reproduce object depth through phase. Thus, holograms overcome some of the inherent limitations of image based methods including defocus and compositing with conventional graphics scenes.

2 Overview

A hologram can be generated by either acquiring a *real object* using a CCD or by recording a *synthetic object* using computer generated holography (CGH). Furthermore, the hologram can be used as input to a holographic screen or as input for further processing leading to an output on a conventional display. This output requires a discrete reconstruction of the wavefront at the hologram, followed by a propagation of this wavefront to an arbitrarily placed virtual camera which provides the input to a conventional display.

The contributions of our work can be summarized as follows:

- Unlike previous work which was focusing on CGH [Schnars and Jüptner 2005] or holographic displays [Benton 2001], our work presents a novel way to conveniently compose holographic objects into conventional 3D graphics scenes and render them all together on a 2D display.
- To correctly compose different objects we designed a view dependent depth reconstruction of the propagated wavefront of the hologram. Our novel depth reconstruction from phase difference compensates for the influence of the lens and interference of multiple sources. This is a non-trivial operation and forms the very basis for correct hidden surface removal using the z-buffer.
- Furthermore we simulate a thin-lens camera model placed arbitrarily in space in order to evaluate the hologram in an image plane of an arbitrarily positioned and oriented virtual camera. This is essential for graphics image generation.

Undersampling of a high-frequency texture during the rasterization step in ray-based image generation can lead to severe aliasing artifacts whereas in a wave-based framework images are inherently aliasing free.

3 Results

Using our framework we are capable of rendering high quality images, while taking into account depth of field and refocusing of the scene by simply adjusting the aperture size or focal length as if a real camera would have been used. While holograms require a very high sampling rate in theory, our practical implementation computes high quality renderings from reasonably sized (1024^2 pixels) digital holograms. Creating a hologram of 1024^2 with double precision per primary color channel leads to a total size of 24MB. Even big objects with primitive count up to 300K (cf. Fig. 1 d-f) can be evaluated in a reasonable amount of time, due to usage of fragment shaders and angular spectrum propagation. All the images were generated on a Pentium 4 3.2GHz containing a NVidia GeForce 7800GT.

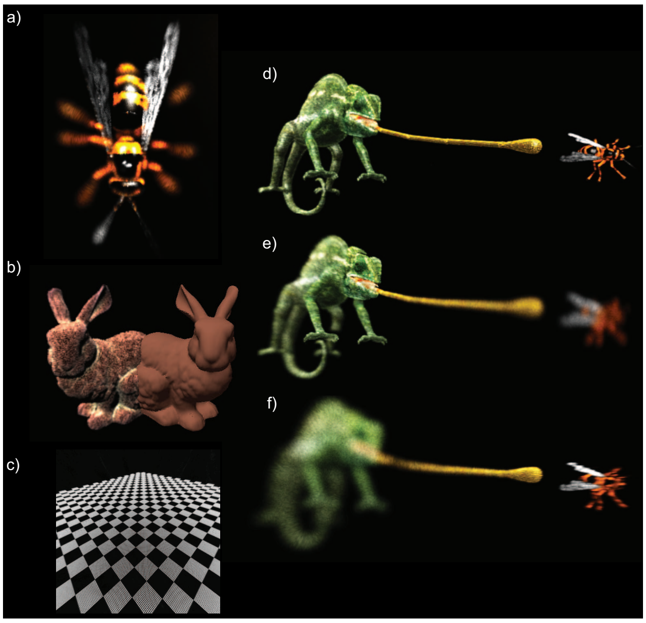

Figure 1: Simple modifications of the aperture and the focal distance lead to images with different depth of fields and different foci. b) emphasizes exact composition of a hologram with a triangular mesh while c) stresses the aliasing free nature of wave based image generation.

References

BENTON, S. 2001. *Selected Papers on Three-Dimensional Displays*. SPIE - Int'l Soc. for Optical Eng.

SCHNARS, U., AND JÜPTNER, W. 2005. *Digital Holography : digital hologram recording, numerical reconstruction, and related techniques*. Springer.