Digital HPO Hologram Rendering Pipeline

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Abstract

This paper describes a rendering pipeline for digital hologram synthesis. The pipeline is capable of handling triangle meshes, directional light sources, texture coordinates, and advanced illumination models. Due to the huge computational requirements of hologram synthesis only the HPO holograms are considered.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Raytracing; Hidden line/surface removal; Color, shading, shadowing, and texture

1. Introduction

Holographic displays are very close to their practical utilization. However, the holographic displays need holograms as an input and holograms have to be either obtained optically or synthesized numerically. The numerical synthesis is addressed in this paper.

The holograms are complex diffraction gratings with very large spatial frequencies comparable with a frequency of diffracted light, which is in a case of visible light approximately 5 MHz. Capturing of such frequency without aliasing needs a lots of samples. This fact makes synthesis very computationally intensive and must be therefore implemented as efficiently as possible.

The presented approach is fast because it avoids costly functions, e.g. the square root function, and performs preprocessing wherever it is possible to speed up the synthesis. Although it is fast it is also capable of handling textures and advanced illumination models. It consumes exactly the same input as the classical rendering pipeline and therefore it can be seamlessly integrated into the existing rendering systems.

2. Digital Holography Essentials

At the beginning, there was a light wave, which can be described by the Equation 1. There are two terms in the equation, the spatial one: $\exp\left[-i\varphi\left(\vec{x}\right)\right]$ and the temporal one: $\exp\left(i\omega t\right)$. Only the spatial one is the important one for the synthesis. The temporal one can be omitted without consequences because the temporally coherent light is assumed.

$$\tilde{u}\left(\vec{x},t\right) = A\left(\vec{x}\right)\exp\left[-i\varphi\left(\vec{x}\right)\right]\exp\left(i\omega t\right) = \tilde{u}\left(r\right)\exp\left(i\omega t\right) \quad (1)$$

The spatial term together with an amplitude $A\left(\vec{x}\right)$ is called the complex amplitude. Each complex amplitude is, obviously, determined by the amplitude and phase and can be therefore written as a complex number, which is more convenient.

The whole holography stands on a phenomenon of interference. The interference occurs if two and more light waves are superposed. The complex amplitude of the resulting wave is obtained as a simple summation of complex amplitudes of the original waves. An optical intensity of the composed wave is computed using the Equation 2. Only the last two terms of the Equation 2 are computed in digital holography, see [Luc94].

$$I = \left|\tilde{u}_R + \tilde{u}_S\right|^2 = \left|\tilde{u}_R\right|^2 + \left|\tilde{u}_S\right|^2 + \tilde{u}_R\tilde{u}_S^* + \tilde{u}_R^*\tilde{u}_S \quad (2)$$

The complex amplitude of a wavefront emerging from a scene has to be computed at each sampled point at a hologram frame. Once the complex amplitude is known, the final hologram is obtained using the Equation 3 where $\tilde{u}_S$ is a scene's complex amplitude and $\tilde{u}_R^*$ is a reference beam's complex amplitude.

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