Inelastic Scattering in Participating Media Using Curved Photon Mapping

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1 Introduction

True global illumination algorithms in participating media are very costly, owed to the multiple interactions between light and the medium that need to be evaluated in order to achieve a correct result. Some common simplifications include considering only homogeneous media and single, isotropic scattering.

We present Lucifer, a global illumination environment capable of handling inhomogeneous, participating media while taking into account multiple inelastic scattering. Additionally, light is bent through the media according to Fermat's Principle. To the authors' knowledge, it is the first time that all these conditions and effects are considered in a single algorithm. Several limitations and mechanisms of the Human Visual System (HVS) are also computed before mapping the image to the output device.

2 State of the art

Most spectral algorithms just sample the visible spectrum of light into a set of fixed wavelengths and produce results for each sampled wavelength that are independent from one another. The very few existing exceptions are Glassner [1995], Wilkie et al. [2001] and Cerezo and Seron [2003]. But in these works light travels following straight paths instead of being curved as it happens in reality, owed to the index of refraction not being constant.

3 Lucifer

Lucifer provides a full global illumination solution for inhomogeneous, participating media, taking into account energy transfers between wavelengths, thus computing multiple inelastic scattering. It uses what we call the *curved volume photon mapping* algorithm, which curves both photons and eye rays as they travel through the medium, according to Fermat's Principle. By storing in the photon map even the direct contribution of the light sources we avoid casting shadow rays, one of the main problems of previous curved raytracing works (Berger and Trout [1990]; Musgrave [1990]; Stam and Languenou [1996]; Gröeller [1995]).

To fully account for both elastic and inelastic scattering, the Full Radiative Transfer Equation (FRTE) must be solved. But this equation is very costly to evaluate; so the Radiative Transfer Equation, a simplification of the FRTE that does not consider inelastic scattering, is usually considered instead in the existing literature.

Lucifer does not assume any simplification and solves the full equation; it starts by sampling the visible spectrum, tracing photons into the scene at each sampled wavelength. The probability of a photon being definitely absorbed by the medium or re-emitted through inelastic scattering is given by the *quantum efficiency* $\Gamma(\lambda_i)$, defined as the total number of photons emitted in all wavelengths divided by the number of photons absorbed at excitation wavelength λ_i. We find the distance that a photon travels between scattering or absorption interactions in the participating medium. At each interaction, Russian Roulette is used to decide whether the photon is absorbed or scattered, with the probability given by the scattering albedo. Whenever an absorption event is detected, a second Russian Roulette will determine, based on the quantum efficiency $\Gamma(\lambda_i)$, whether or not inelastic scattering takes place. If it does, a new photon with a greater wavelength will be traced from that point. This way we can account for all energy transfers between wavelengths, therefore simulating multiple inelastic scattering.

4 Atmospheric effects

The atmosphere is a participating, inhomogeneous media, and most of its effects we see in nature are caused by a gradient in its index of refraction, as well as by scattering phenomena. We have therefore chosen to mimic several of these effects (such as the inferior and superior mirages, split, flattened or double suns or the green flash) to test our global illumination environment.

Starting from the USA Standard Atmosphere, we have coded an Atmosphere Profile Manager (APM) which is based on Fermi distribution. This APM lets us interactively create the temperature and pressure conditions needed to easily simulate the above mentioned atmospheric effects.

What is remarkable about the green flash effect is the fact that, apart from being generated by wavelength dependant dispersion in the atmosphere with Rayleigh scattering, it is enhanced by bleaching of the photoreceptors in the eye, which turns the flash even greener to our eyes. A model of this bleaching affect has been designed and implemented in S·E·K·E·R, our HVS simulator

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