Accurate Colour in a Path Tracer

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Abstract

The goal of this project is to improve the colour of images in a path tracer. First, the path tracer will be extended to support a larger number of basis functions, stratified across the visible spectrum. Secondly, the output of the path tracer will be tone mapped and glare effects added to provide a physically plausible image assuming a human viewer.

1 Introduction

The traditional RGB or XYZ basis functions are insufficient for representing the interaction between realistic light sources and materials. As well, most path tracers provide an accurate view of the incoming radiance to the eye, it does not model how the eye perceives this light. This project will attempt to address each of these issues to produce a more visually realistic scene.

2 Design

2.1 Path Tracer Improvements

For faster convergence, the path tracer will first be extended to a bidirectional path tracer. This will hopefully speed up the path tracer slightly and produce less noisy images, and is something the author has been anxious to do. The reference will, of course, be Veach's PHD thesis [8].

To gain a more accurate view of the spectrum, the path tracer will then be extended to use a spectral based interpretation of colour. This will involve using many basis functions stratified across the spectrum (which, if I understand it correctly, may be called 'Stratified Wavelength Clustering - SWC') [2]. The spectrum will be represented by at least 10 non-overlapping box basis functions.

In order to demonstrate accuracy of this implementation, the path tracer will be updated to support reflectance and emission data which is a function of wavelength, for example, the reflectance data given for the Cornell Box, and Cornell's data for emission spectrums from standard indoor light sources.

To prove an obvious benefit of a spectral renderer, some colour filter primitives will be added to the path tracer, such that a yellow filter under green light will actually appear black.

Further depiction of accurate colour representation will be demonstrated by throwing in support for arbitrary BRDFs, again using the reflection data provided by Cornell [5] for those gorgeous automotive paints and spray paints.

2.2 Colour and the Eye

The first goal in this area will be to implement a tone mapping algorithm which can more effectively deal with high dynamic range scenes. The method used will be taken from Pattanaik 1998 [6], also from Chiu et al [1], and from the work done for the RADIANCE application. This project will not implement the Chromatic Adaptation methods discussed in Pattanaik's paper, but will rather focus on interpreting the image in terms of short, medium, long and rod sensitivities in the eye, and how we can process the image in this space to better understand the eye's view of the scene.

Equally important when dealing with areas of high brightness in a scene is a simulation of glare effects. To solve this problem, we will employ the ideas from Spencer et al's paper on the topic [7], which discusses a model suitable for use on rendered images. We will investigate at what stage of the tone mapping process this filter is appropriately applied.

One interesting issue in tone mapping is the handling of "night-vision" effects of scotopic and mesopic vision, where the rod sensitivities produce a "blue" effect in images. A modelling of this effect is discussed in the recent SIGGRAPH paper on the topic of the night sky [3]. Correctly factoring this effect into the model will be a goal of this project.

Since it is unlikely that the result of any of the processes above will produce in-gamut colours, an advanced gamut mapping algorithm will be used. This technique will be based on one of the methods described in Jan Morovic's PHD thesis [4], likely based on the $L*a*b*$ model of colour.

3 Goals

This project will involve the following goals (out of 10 marks):

1. Bidirectional path tracing for faster convergence (2 marks)
2. Handling of multiple basis functions stratified across the spectrum for more accurate wavelength-dependent colour (1 mark)
3. Support for reflectance and emission data which is a function of wavelength (1 mark)
4. Support for tinted transmissive objects (colour filters) to demonstrate colour interaction (1 mark)
5. Support for arbitrary BRDF reflection data for modelling more physically accurate objects where data is available (1 mark)
6. Implementation of a tone mapping function for plausible rendering of high dynamic range scenes (1 mark)

7. Visual-response based hue and tone mapping for accurate rendering of scotopic and mesopic vision (night vision) (1 mark)
8. A realistic simulation of glare effects (1 mark)
9. Use of an advanced gamut mapping function (1 mark)

4 Conclusions

This project presents solutions to a few key areas where the colour of synthetic images can be greatly improved. The key result of this project will be an investigation into the chain of colour representations in a raytracer, and how this can be efficiently managed: spectral data, to LMSR or XYZV representation for cones and rods, to Lab space for final gamut mapping.

References

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