Real-Time Rendering of Atmospheric Glories

Ari Rapkin Blenkhorn*
University of Maryland, Baltimore County

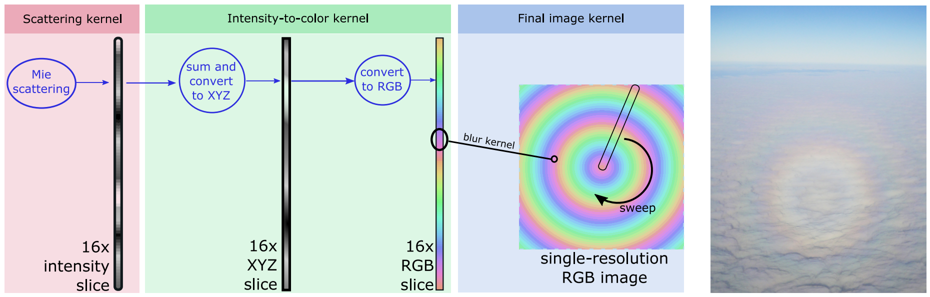

Figure 1: *left: GPU processing stages; right: actual glory on clouds, fainter due to haze and cloud background. (Glory photo by Sandstein [CC BY 3.0] via Wikimedia Commons)*

1 Introduction and Motivation

The *glory* is a colorful atmospheric phenomenon which resembles a small circular rainbow on the front surface of a cloudbank. It is most frequently seen from aircraft when the observer is directly between the sun and the clouds. Glories are also sometimes seen by skydivers looking down through thin cloud layers. They are always centered around the shadow of the observer's head (or camera).

Adding glories to digital cloud environments will provide increased realism and interest. Furthermore, the glory is a topic of active research for optical and atmospheric physicists, and they are eager to obtain faster simulation software.

Mie theory provides a mathematical description of the color banding, though it does not fully explain the underlying physical interaction. Mie theory computes scattering intensity for a single wavelength and angle. It must be repeated for hundreds of wavelengths per pixel for a stable simulation of the glory. Previous simulation methods do this sequentially on the CPU. Each (λ, pixel) scattering result can be calculated separately using the same method, I recast the problem as a highly-parallel GPGPU computation.

2 Technical Approach and Implementation

The resulting algorithm computes proceeds in four steps:

- Compute Mie scattering for one radial slice of the glory at 16x resolution
- Convert per-wavelength intensities to color values using CIE XYZ perceptual color-matching functions
- Construct full single-resolution image from the 16x color slice by sweeping full circle and applying Gaussian blending
- Render image to screen with optional "haze" effect for increased realism

The Mie scattering and color calculations are performed on the GPU by OpenCL kernels. The final image is rendered using OpenGL. OpenGL/OpenCL interoperability allows data to remain on the GPU, avoiding GPU-CPU data transfer costs. I further reduce the number of wavelengths required by a factor of ten over the uniform dense sampling used by the physics community by using importance sampling, which pseudo-randomly selects a small set of wavelengths per pixel, emphasizing those wavelengths which are strongest in sunlight. The radial symmetry of the glory permits significant additional optimization.

3 Results and Future Work

Current performance is 12ms per scattering wavelength for a 512x512 image on a NVIDIA GeForce GT 750M GPU. While not yet real-time this is already dramatically faster than previous CPU-based methods, which take seconds to minutes to complete. I am investigating additional importance sampling extensions which are expected to further reduce the number of wavelengths required.

Planned work includes development of both numerical and perceptually-based image quality metrics, of interest to optical physicists and interactive application developers, respectively, in order to guide users in selecting algorithm parameters.

References

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*e-mail:ari@acm.org

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