Poster Submission: Platform Independent, High Performance Spectral Light Transport Simulation for Agricultural Applications

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Abstract

This poster describes our ongoing work on high performance spectral light transport simulation for agricultural research. The presented software is integrated with GroIMP, an open source modelling platform in Java, designed for modelling plant growth and development using growth grammars. Our work focuses on:

- Spectral light transport simulation
- Conversion of absorbed light spectrum in photosynthetic metabolites at individual leaf level
- High performance
- Platform independence

Spectral Light Transport Simulation In agricultural simulations of plant growth, researchers often require an accurate estimation of absorbed spectral power within the simulated canopy in order to simulate biological processes. For example, the ratio between absorbed red and far-red light influences the efficiency of photosynthesis within plants. Our work simulates light transport through Monte Carlo light tracing. During the simulation, each object keeps track of the amount of light it absorbs. Per object, the simulation either computes a fully discretized absorption spectrum or several integrated weighted spectra, depending on the particular application. Apart from light absorption per object, the light model also computes sensed irradiance within virtual sensor clouds, used to study the light distribution within the environment, such as a greenhouse.

Conversion of Absorbed Light Spectrum in Photosynthetic Metabolites at Individual Leaf Level Plants convert the absorbed light in metabolites (e.g. sugars), in a complex non-linear photosynthesis process, depending on factors as CO_2-concentration, temperature, and relative humidity. This is modelled using the Farquhar equation. The photosynthetic produce of a plant is cumulated per day and this determines the growth and development of the plant for the next day. In this way, the influence of the position and spectral distribution of light sources on plant growth can be simulated in detail. The developed system will be used in scenario studies, to optimize the efficiency of biosolar products.

High Performance The accurate estimation of absorbed light within a large canopy over the course of several days can be computationally expensive. Our system utilizes heterogeneous computing resources through OpenCL. Light paths are constructed in parallel to exploit the compute power of modern GPUs. Measurements are recorded using atomics. To prevent excessive linearization, multiple measurements are dedicated to large objects, proportional to the Surface Area Heuristic. On wide SIMD architectures, large variation in light path depth due to dense sensor clouds can significantly reduce efficiency. Therefore, geometry and sensors use separate acceleration structures: Each ray is first intersected against the geometry to determine its endpoint, after which the segment is traced through the sensor cloud to record the sensed irradiance. Our system applies importance sampling to wavelength selection. In practical applications, the importance of the accurate simulation of light may vary over the spectrum. Therefore, the user can provide a spectral importance function which is multiplied with the spectral emission of each light source to determine the spectral importance function for each light source.

Platform Independence OpenCL was used to utilize heterogeneous computing resources. The number of platform specific low level optimizations was kept to a minimum. Nevertheless, modern GPUs still perform significantly better than CPUs. Although OpenCL provides near-platform independence, subtle differences and bugs in the various OpenCL implementations require extensive testing on different platforms. The combination of OpenCL and Java resulted in a reasonably platform independent implementation, but significantly complicated OpenCL development. Furthermore, slow compilation of large OpenCL kernels on some platforms hinders development.

GroIMP is open source software and publicly available at Sourceforge.