High performance spectral light transport model for agricultural applications

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Introduction

We present a spectral Monte-Carlo **light tracer** as part of **GroIMP**, an open source modelling platform in Java. GroIMP is 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.

The light tracer utilizes available computing resources through **OpenCL**. During simulation, each object keeps track of the amount of light it absorbs. Per object, it either computes a fully discretized absorption spectrum or several integrated weighted spectra, which are subsequently used in a photosynthesis model.

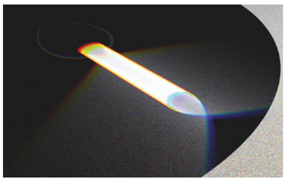


Figure 1.
GroIMP supports full spectral rendering.

Conversion to Photosynthetic Products

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.

Measurements

- Each object (typically a leaf or sensor) measures absorbed power.
- Power is accumulated asynchronously using atomics.
- To prevent excessive linearization, large objects use multiple measurements, proportional to the SA-Heuristic.

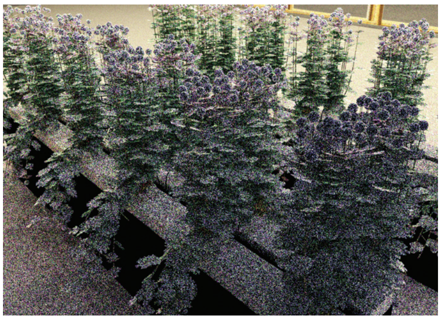
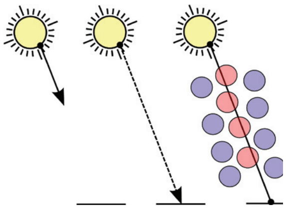


Figure 2.
Splatted visualization of the light tracer after a few seconds on an NVIDIA GeForce GTX 480.
The rendered image shows a cut-rose production system with upright and bent shoots, with a total of 48696 objects: leaves, internodes, flowers, plus inanimate objects (slabs, benches).

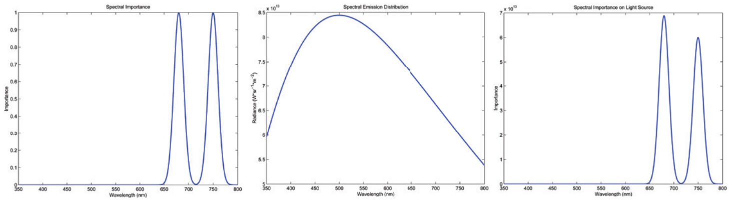


Sensor Clouds

Dense sensor clouds lead to large variations in path depths. This significantly reduces SIMD efficiency on the GPU. To improve performance, sensors and geometry are handled using separate acceleration structures: Each ray is first intersected with the geometry, afterwhich the corresponding ray segment is traced against the sensors.

Spectral Importance Sampling

To focus computing power, spectral wavelengths are sampled **proportional** to a user specified **spectral importance function** and the **spectral emission distribution** of each light source.



Platform Independence

The combination of Java and OpenCL results in **near**-platform independence with high performance on heterogeneous systems.

Some disadvantages:

- Little room for platform specific low level optimizations.
- Platform specific bugs.
- OpenCL + Java complicates debugging.
- OpenCL kernel compilation is slow for large kernels.

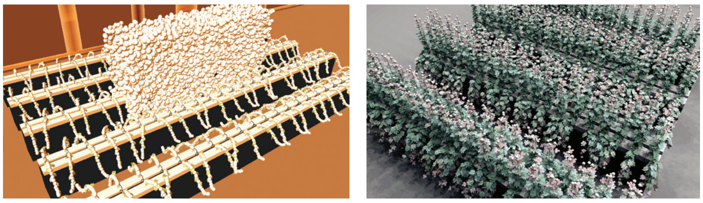


Figure 3.
Sensor cloud in virtual rose-production system.

References

Buck-Sorlin, G., P.H.B de Visser , M. Henke , V. Sarlikioti , G.W.A.M. van der Heijden , L.F.M. Marcelis , J. Vos. (in press) Towards a Functional-structural Plant Model of Cut-rose - simulation of Light Environment, Light Absorption, Photosynthesis and Interferences with the Plant Structure. Annals of Botany.

GroIMP is open source software and publicly available at:
sourceforge.net/projects/groimp/

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