Elementary image analysis techniques for calibrating and testing canopy light interception models

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The ECOPHYS model is a process-based simulation growth model based on juvenile poplar clones growing under conditions measured at the (FACTS-II) Aspen Free-air CO2 and O3 Enrichment (FACE) Project (USDA Forest Service, North Central Research Station, Rhinelander, Wisconsin, USA.) This model, like other Functional-Structural Plant Models (FSPM), relies on a computational sub-model that estimates at various times the intensity of photosynthetically active radiation (PAR) at each leaf in the tree canopy. The light sub-model distinguishes between portions of leaves directly sunlit and shaded leaf areas. Astronomical equations for sun location and individual leaf area orientations are used to compute mutual shading. Diffuse lighting and light reflected up from the soil surface are also computed, although by a Beer's Law-based approach.

Leaf-specific direct sunlight interception is estimated by applying a standard computer graphics "scan conversion" algorithm to discretized projections of leaf shadows ([1], [2]). In the absence of measured light interception data, we have developed a computer-graphics / image processing technique for the validation and calibration of this sunlight interception sub-model. The method extends [3], where it was demonstrated that computer graphics libraries in combination with off-the-shelf graphics boards provide an interesting alternative to current light interception models.

Specifically, ECOPHYS-estimated light interception data is compared to that measured by rendering (with the POVRAY imaging program) a color-coded image of the canopy. The image is generated using an orthographic projection, with camera and light source set at the "sun's view." The image is stored using a file format that maintains fully accurate information regarding image pixel colors. A set of simple Linux/Unix shell scripts are then used to apply public domain color histogram utilities to the image file for the full canopy, as well as image files rendering individual leaves. The obtained data is then used to obtain a highly accurate measure of leaf sunlit areas. The results provide a comparison benchmark by which the ECOPHYS scan-conversion method have been tested and calibrated.

The developed approach is not dependent on leaf shape or canopy architecture, hence is potentially useful to other FSPMs. Furthermore, modifications of the approach can be applied to diffuse lighting and (ground) reflective lighting models, as well.

References

[1] Isebrands, J. G., G. E. Host, and K. E. Lenz. 1999. Individual-based models of tree plantations using hierarchical and parallel approaches. In: (A. Amaro and M. Tome Eds.) Empirical and Process Models for Forest Tree and Stand Growth Simulation. Edicos Salamandra pp. 537-51.

[2] Isebrands, J. G., G. E. Host, K.E. Lenz, G. Wu, H. W. Stech. 2000. Hierarchical, parallel computing strategies using Component Object Model for process modeling responses of forest plantations to interacting multiple stresses. In: (R.J.M. Cuelemans, F. Veroustraete, V. Gond, and J.B.H.F. Van Rensbergen eds.) Forest Ecosystem Modeling, Upscaling, and Remote Sensing, SPB Academic Publishing, The Hague, The Netherlands. pp 123-135.

[3] Tordsen, L. 2003. Computational Advances in the Prediction of Light Interception in Deciduous Trees, Masters Thesis, Program in Applied and Computational Mathematics, University of Minnesota.