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Comparison of two different light models using a virtual tomato crop

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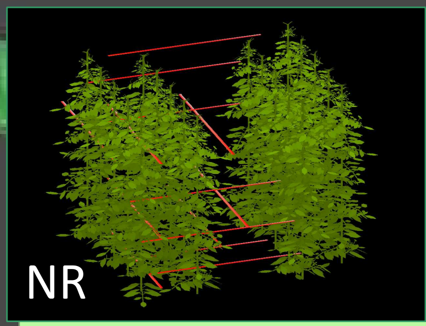
Aim: Compare two different radiation models implementing a path tracing (MCPT) and a nested radiosity (NR) approach in terms of suitability and computation time efficiency.

Methods

- Measurements of plant architecture and light were conducted on 5 plants of a tomato crop (cv. '*Komeett*') grown on slabs (2 plants per slab) in double-rows (spacing 50 cm, path width 1.10 m) in hydroponic culture at the Improvement Centre (Bleiswijk, The Netherlands). Crop height at the time of the measurements was 1.75 m, slab height was 1.50 m above ground and LAI was 3.66 m^2 m^{-2}. Each plant consisted of a single main stem with a total of 27 phytomers (with either leaves or fruiting trusses).
- Virtual plants were reconstructed using L-system rules in cpfg (L-Studio) or XL (GroIMP)
  - The cpfg model was coupled to the NR model using Caribu interface
  - In GroIMP, a MC light model based on a path tracer was used
- Both models reconstruct the measured 3D structure in 27 steps (= number of phytomers)
- Virtual light sensors were distributed as stacks of horizontal rods at different heights at various spots in the simulated scene (within plant rows, within path, …)
- Diffuse light conditions were simulated using 72 directional lights
- Light interception measurements were used for validation



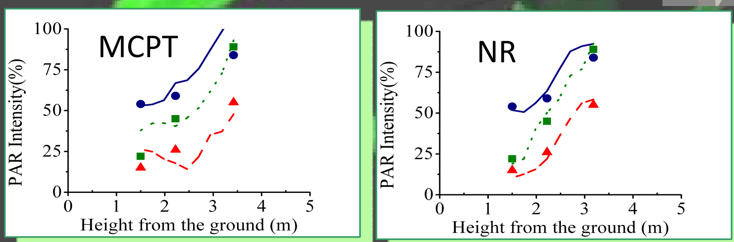


Figure 1: Vertical PAR gradient simulated using the MC raytracer of GroIMP and the nested radiosity model of L-systems. —, - -, - - -: simulated data; ●■▲: measured values. ■: perpendicular to the crop, ●: in path, parallel to the crop, ▲: parallel between the rows.

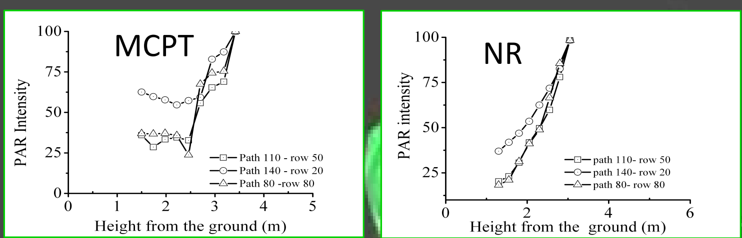
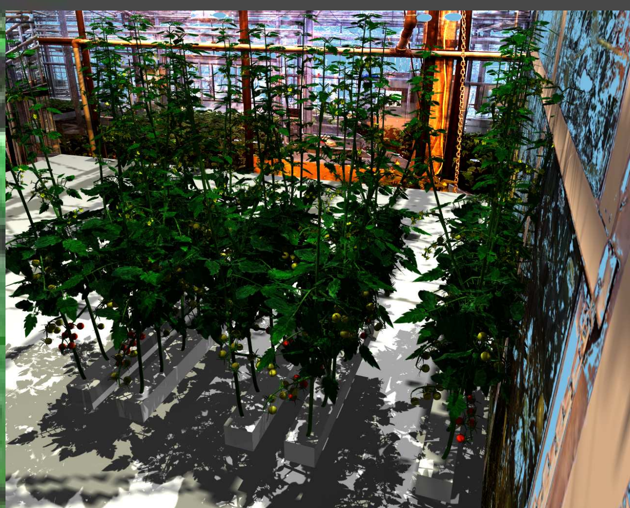


Figure 2. Simulations of three different canopy structure scenarios, varying path width and distance between parallel slabs in a double-row [cm].

Results and Discussion

- NR: The nested radiosity model provided an accurate prediction of measured values (Fig. 1). Computational time was 6 hours on a Lenovo laptop with Intel® Dual Core 2 Duo CPU (1.79 Ghz, 1.96 GB RAM), processing a scene of 7069 objects in total.
- MCPT: Using one billion rays and ten reflections at each run, the GroIMP radiation model took 74 minutes computation time on a ASUS laptop with Intel® Pentium® Dual CPU (2.17 GHz, 3 GB RAM), thereby processing a scene consisting of 356550 geometric objects (mainly plant canopy) and 1.7 Million graph nodes in total.
- The simulated light extinction pattern was the same for both approaches. In the nested radiosity approach though we observed lower light intensities in the lower canopy. Also, light intensity constantly decreased with increasing canopy depth whereas a plateau was observed in the lower parts of the canopy when the GroIMP path tracer was used.
- Patterns of simulated light levels for different canopy structures (changing the distance between plant rows) were comparable in the two approaches. However, the gradient predicted by the GroIMP model was flatter and its slope consisted of two parts: a part in the lower and middle canopy where light levels are rather constant and a part in the upper canopy where light levels are increasing very quickly from 30/50% to 100% within a canopy depth of one metre.
- Predicted light level in lower canopy about 10 % higher in GroIMP model (probably due to light penetrating from the border of the crop → too few border rows.)
- Infinite canopy similar to Caribu could be approached by using more buffer rows. Rigourously diminishing light levels from the sides by darkened side walls resulted in a light level similar to Caribu (results not shown). In analogy, when the Nested Radiosity option in Caribu was switched off, the curve resembled that obtained with the GroIMP raytracer.



Conclusions:

- Both NR and MCPT gave an accurate correlation between measured and simulated values
- MCPT was more efficient than NR in terms of computation time (74 mins vs. 6 hours)
- NR gave a better estimate for the lower part of the canopy

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