# A Two-level algorithm for global radiation transfer of large 3D vegetation canopies at pixel scale

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**Abstract:** Accurate simulation of the radiation transfer within and above the land surface, especially vegetation canopies at pixel scale, is important in understanding the formation of satellite remote sensing signals and helpful in vegetation surface structure inversion. We had developed a realistic structure model for large-scale forest radiance simulation (**Huang et al., 2009, 30(2), International Journal of Remote Sensing**), which is good for forest canopies, but still not enough for complicated land cover due to local assumption.

In this paper, a two-level radiosity algorithm is developed here for the computation of global radiation transfer at very complex land cover called *HRAD*, which rapidly simulates the surface leaving radiances in three dimensional landscapes. The algorithm is a short integration of a ray casting module and an adapted hierarchical radiosity method with heterogeneous volume clusters. The algorithm can be described as the following procedures:

1) Scene subdivision from one big scene to some sub-scenes with same size; each sub-scene is also seen as a cuboid volume with around 5,000 polygons;
2) Estimation of the form factors between the cuboid volumes, which are defined by an accelerated graphics-based projection method; at the same time, the direct and diffuse fractions are calculated.
3) The irradiances from other volumes are set to be zero;
4) Local radiosity solution for each sub-scene is done by modified Radiosity-Graphics Model (RGM), which considers the irradiance from other volumes; the albedo and radiances of the four faces of each volume are

calculated;

5) Iteration solution of the energy exchange between volume clusters using radiosity; then the irradiance over each volume is derived.
6) Repeat step (4) and (5) until the changes of radiosity of all volumes and polygons between two iterations are less than a certain small value (10e-6).
7) The final solution is the global radiation transfer results.

Currently, the number of the polygons of a complex scene can be as large as 800 million. For large scenes, the calculation efficiency is highly improved than the original RGM. For example, the total time from subdividing scene to BRF calculation is four minutes, while it cost RGM ten minutes to simulate the same 30, 000 scenes. The time cost of our new algorithm is nearly linear to the polygon number. The maximum simulation scene for our model is 500*500 $m^2$.

The validity of the algorithm is done by model comparisons and theoretical assessment. The algorithm is first validated by comparing the simulated radiances with that of RGM at small scenes. The single scattering results are well matched with RGM model ($R^2$>0.99 and RMSE<0.005). The multiple scattering results are also perfect for visible bands ($R^2$>0.99 and RMSE<0.01), and acceptable for NIR ($R^2$>0.98 and RMSE=0.015). By using the Gauss scene in RAMI-III website, we also validate our algorithm.

Now, we are using *HRAD* to participate the RAMI-IV. We are still improving the stability and accuracy of our algorithms. Limited by the 32bit operational system and compiling system, the memory requirement and efficiency are also limited. Thus, the next step is to use the 64bit compiling system.

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