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Coniferous Canopy BRF Simulation Based on 3-D Realistic Scene

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Abstract It is difficulties for the computer simulation method to study radiation regime at large-scale. Simplified coniferous model was investigated in the present study. It makes the computer simulation methods such as L-systems and radiosity-graphics combined method (RGM) more powerful in remote sensing of heterogeneous coniferous forests over a large-scale region. L-systems is applied to render 3-D coniferous forest scenarios, and RGM model was used to calculate BRF (bidirectional reflectance factor) in visible and near-infrared regions. Results in this study show that in most cases both agreed well. Meanwhile at a tree and forest level, the results are also good.

Keywords BRF; RGM model; L-systems

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Introduction

Vegetation canopy structure plays an important role in energy exchange between vegetation and its surrounding environment[1-3]. The vegetation canopy scatters solar radiation anisotropically. The physically based model for vegetation is potentially more effective to simulate the radiation regime between vegetation and solar radiation. Directional canopy reflectance models are undoubtedly an interesting tool for retrieving and monitoring the change of biophysical parameters such as leaf area index (LAI) and forest crown closure (CC) from remote sensing images. The studies indicated that canopy bidirectional reflectance factor (BRF) has a profound, influence on the biophysical properties of vegetation canopy. Some physically based reflectance models have been developed and validated the radiation regime for homogeneous vegetation canopies.

Because of the vertical complexity of forest canopy structure and spatial heterogeneity, a large number of assumptions and simplifications are usually needed when rendering the canopy in different applications. A method that branches with needles can be replaced by effective "green" branches has been studied[4-6]. The research is very valuable in rendering a matured conifer tree with RGM model[7-9] and for computer graphics based methods such as the L-systems approach, more than millions of polygons are needed. Therefore, it is critical to find a simple "substitute" structure with less details of the finest structural elements (such as needle) but physically "equivalent" to the realistic scene (i. e., having the same LAI and BRF magnitude and shape).

In this paper, we described an experiment being conducted to find a simple branch (or tree) structure but physically equivalent to the complicated, realistic ones. Two kinds of conifer branches were simulated and compared primarily for analyzing the effects of different spatial distributions of leaf clumping on canopy's BRF distributions: (1) small coniferous branch with realistic needles; (2) coniferous branches

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with needles replaced by partial "green" branches without needles.

1 Rendering 3-D scenes

L-systems method is a popular one which is used to render the three dimension forest scenes. L-systems[10, 11], a computer graphics iterative technique, is applied to generate different 3-D architectural scenarios. Part of the solid "green" cylindrical branch is applied to replace real coniferous branches with many small needle-leaves. The degree of "greenness" of the needle-leaves branches depends on green needle's reflectance and fraction of needle's area in the total area (needle plus branch). The cylindrical, partially "green" branch vs. realistic coniferous branch and the single conifer trees consisting of both kinds of branches are depicted in Fig. 1. Here, needles (646 in total) are small four-sided facets and all have the same size with needle-to-twig angle of 60°. Mean needle length is 4 mm and diameter is 0.9 mm. The branch length is 39 cm, and diameter is 4 mm. The background size is 0.4 m×0.4 m. Each branch or soil element is characterized by a number of four-sided polygons with given optical properties (reflectance and transmittance). The detail information on canopy geometry and physical properties of all polygons is stored in a file as input to RGM.

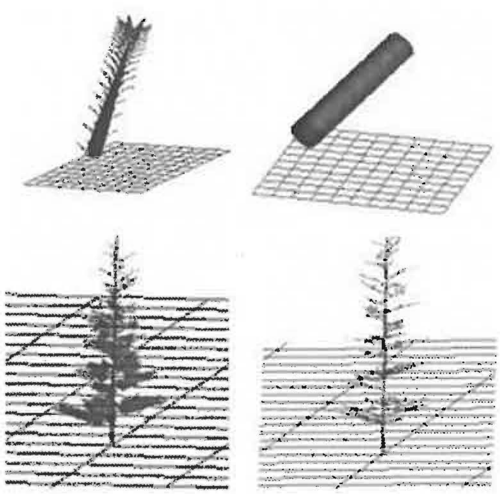

Fig. 1 A single tree with and without needle

A new approach to handling needle clumping within shoots in canopy reflectance models was developed and validated by Smolander and Stenberg[5]. The radius of the equivalent branch R was calculated by the following formula

$$4\,\overline{\mathrm{STAR}} \times \mathrm{TNA} = 2\pi R^2 + 2\pi RL \tag{1}$$

where TNA is the total (all sides) needle area of the shoot, $\overline{\mathrm{STAR}}$ denotes the ratio of the spherically averaged shoot silhouette to total silhouette, mathematically defined as

$$\overline{\mathrm{STAR}} = \frac{1}{\mathrm{TNA}}\frac{1}{4\pi}\int_{4\pi}\mathrm{SSA}(\Omega)\,\mathrm{d}\Omega \tag{2}$$

where SSA(Ω) is the shoot silhouette area in direction Ω. Here $\overline{\mathrm{STAR}}$ has the value of 0.067, so R is 8 mm calculated from equation (1). The optical parameters of different canopy components and soil background, which were measured with an analytical spectral devices (ASD) FieldSpec Pro FR Spectroradiometer in Changbai Mountain Nature Reserve area in summer of 2007.

2 Coniferous branch and tree simulation

The scene radiation regime is calculated with the RGM and results of the two schemes (branches with and without needles) are compared in the visible and near infrared regions. The reflectance and transmittance of "Green" branch is partially replaced by those of needles. The comparison of two types of branches is depicted in Fig. 2—Fig. 4. The solar zenith angle is 25°and azimuth angle is 68°. Three setups of the coniferous branch are studied with zenith and azimuth orientation angles of [40°, 90°], [40°, 0°], and [30°, 180°], respectively. Also, three background sizes (for both single branch and single tree) are considered: 0.4 m×0.4 m, 0.5 m ×0.5 m, 0.4 m×0.4 m and 5 m×5 m, respectively. Field of view (FOV) is 10°. BRF distributions on view planes are

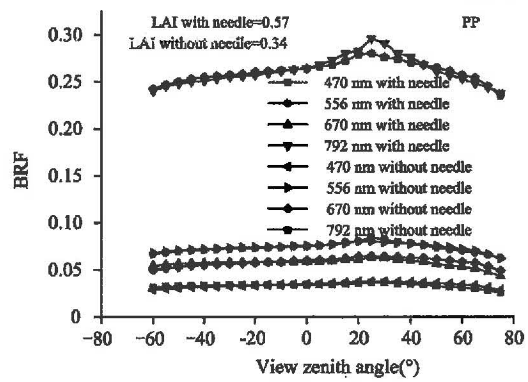

Fig. 2 Zenith and azimuth angle is [40°, 90°]

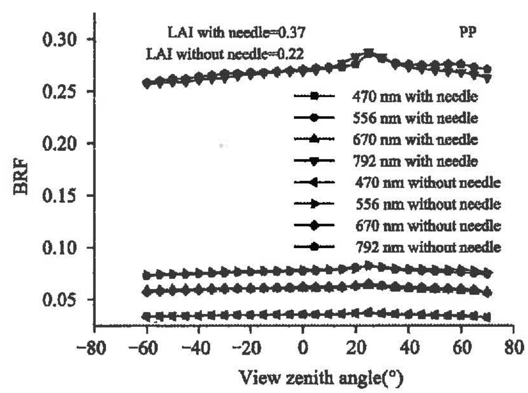

Fig. 3 Zenith and azimuth angle is [40°, 0°]

shown here: the principal plane (PP, relative azimuths of 0° and 180°). Generally speaking, the agreement for single branch is good except at high view zenith angles in case 3 (Fig. 4). While at a tree level, the agreement is very good (Fig. 5).

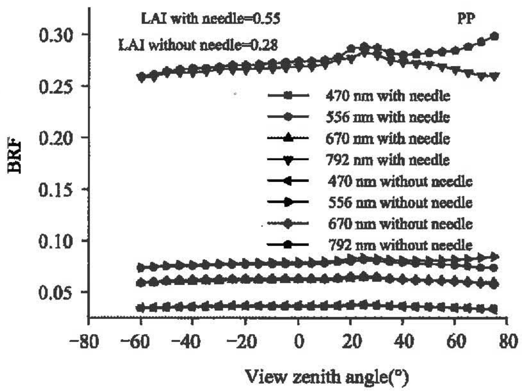

Fig. 4　Zenith and azimuth angle is [30°, 180°]

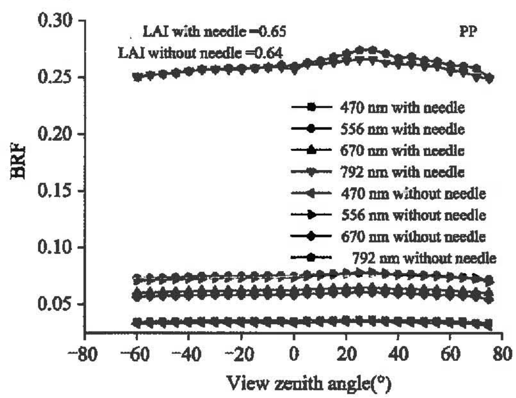

Fig. 5　BRF distribution of the conifer tree

3　Coniferous forest simulation

The L-systems is applied to render the coniferous forest scene. Its size is 30 m×30 m. The average height is 20 m. The average DBH (diameter at breast height) is 40 cm. The average width of the tree crown is 10 m. The number of coniferous tree is 50. Figure 6 shows the scene of the coniferous forest that is rendered with L-systems. The solar zenith and azimuth angles are 39° and 143°, respectively. Field of view (FOV) is 0°. The view zenith angle is from −75° to 75° (recorded at 5-year intervals). The BRF distribution in the principal plane (PP, relative azimuths of 0° and 180°) at visible and near infrared four spectral bands is plotted in Fig. 7.

Results in Fig. 7 show that the BRF curves have a very apparent hotspot at visible and near infrared bands. The hotspot locates at the solar zenith angle. Reflectance increases from visible to near infrared band. Reflectance of red band is rather lower than green band because the leaves absorb much more red light than green light.

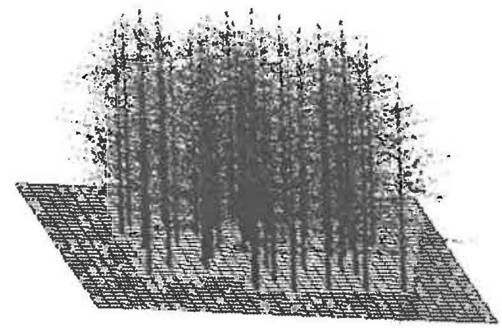

Fig. 6　Coniferous forest scene

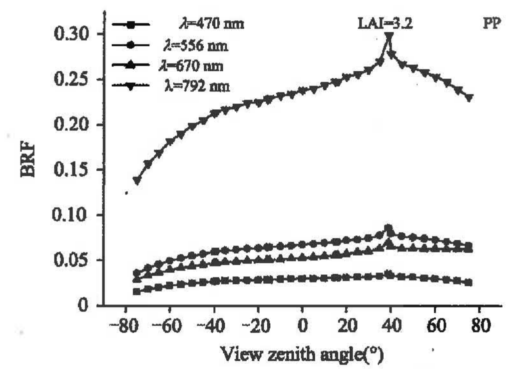

Fig. 7　BRF distribution of coniferous forest

4　Conclusion

Using the radiosity method to simulate the radiation regime of coniferous canopies with and without needles, the simulation results are compared at two levels-branch and tree. The study concludes that (1) both types of branches (i. e., realistic branch *vs.* "green" branch without needles) and trees (consisting of these two kinds of branches) basically have the same BRF distribution on the solar principal plane and they are agreed well. (2) It is feasible to use a part of "green" branch to replace the real conifer branch with green needles. It makes the radiosity method combined with L-systems more powerful in simulating the coniferous forests over a large-scale region.

Based on the method of a simplified 3-D structure of coniferous tree canopy, RGM model is employed to calculate the BRF distribution. Results in the study show it much practical to use radiosity method such as L-systems to generate a large number of conifer trees, which is required in simulation of large-scale areafor quantitative remote sensing study. This included, but was not limited to, retrieval of coniferous forest canopy structural and biophysical parameters from multiangle remotely sensing imagery.

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