Mathematical Methods of Modelling Morphology of Spruce Trees

Růžena Janoutová[1,2], Marek Pivovarník[1]
[1] Czechglobe Global Change Research Centre AS CR, [2] janoutova.r@czechglobe.cz

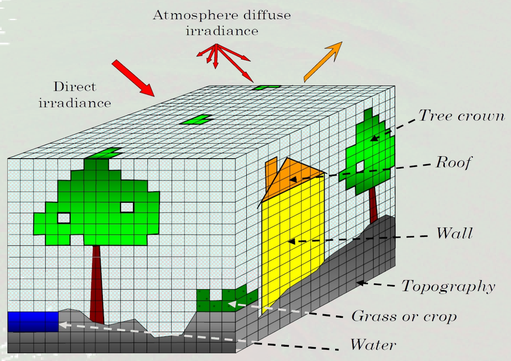

Figure 2 - DART cell matrix of the Earth system (CESBIO : Centre d'Etudes Spatiales de la BIOsphère)

Introduction

The aim of the study is description of implementation of L-system theory in building 3-D spruce tree models (Fig. 1). The tree models and their optical and thermal parameters are the key inputs in radiative transfer (RT) models. Physicaly basedl RT models enable simulation of forest biochemical and properties of forest stands. The study is focused on mountain Norway spruce forest ecosystem and we apply the tree models in the DART (Discrete Anisotropic Radiative Transfer) model (Fig. 2).

Figure 1 - Example of trees generated by L-system algorithm

Data acquisition

Laser scanning data for the model were acquired with terrestrial laser scanner OPTECH Ilris-36D (Fig. 3) at the Černá hora locality in Šumava Mts. on October 8th, 2009. Fifteen trees were scanned, each from two sides - the front and the back positions lying in a line. The first and the last reflection were recorded for each laser shot with point cloud density 2 centimetres.

Figure 3 - Terrestrial laser scanner OPTECH Ilris-36D

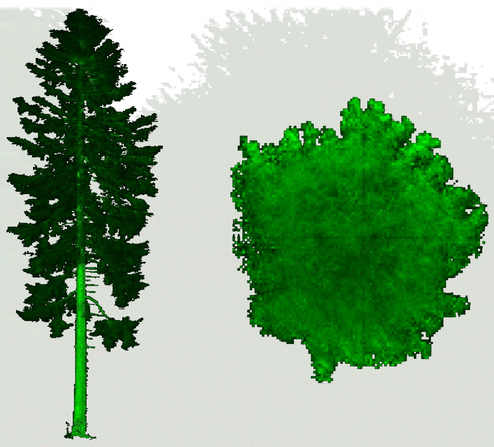

Figure 5 - Example of tree from LiDAR

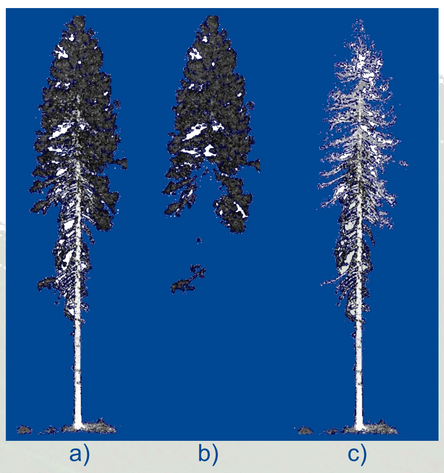

Figure 6 - Selection from reflection intensity - a) whole tree, b) foliage, c) woody elements

Theory of L-systems

The main idea of L-systems is that a starting symbol is overwritten with a string following specific rewriting rules (Fig. 4). That is recursively repeated for each character of a new string until the algorithm stops. A spruce tree model is formed with both parametric and nondeterministic L-systems. The parametric L-systems can assign parameters to some chars of the L-system string. Nondeterministic L-systems differ from the deterministic ones in the selection of rewriting rules where the specific symbol is rewritten to specific list of symbols. In nondeterministic L-systems the specific symbol can be rewritten to more than one list of symbols.

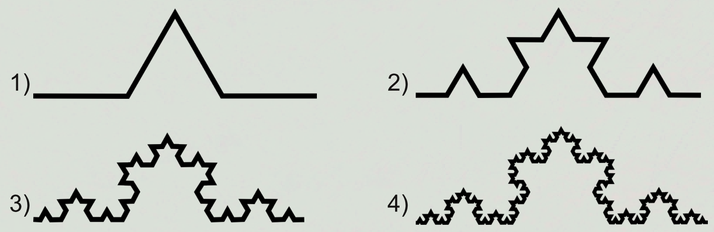

Figure 4 - Example of 1st to 4th iteration on Koch curve

Data analyses

All tree images were georeferenced and the two sides of a single tree were georectified using identical points (branches) (Fig. 5). Separation of the foliage from woody elements (Fig. 6) was based on reflection intensity (PolyWorks IMSurvey soft.).
Using combined visual interpretation of tree scans (tree foliage and branches distribution) and in situ observations we estimated following tree model parameters:

- height of the tree
- height of the living and dead tree crown
- normalized parameters of foliage distribution along the branches (α,β,γ,κ) (Fig. 5)
- semi-axes of ellipses representing crown horizontal (Fig. 6) and vertical (Fig. 7) projection of each tree
- number of all tree branches the number of branches per tier
- zenith deployment angle of the branch (Fig. 8)
- yearly increment of the branch and angle of the branching.

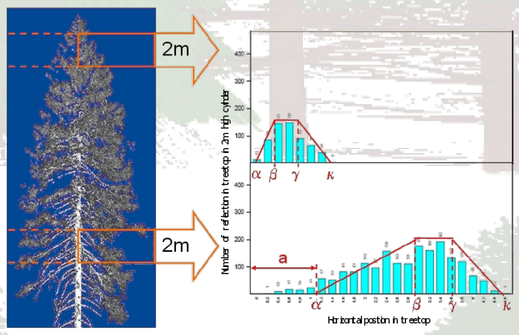

Figure 7 - Graph of foliage distribution on treetop

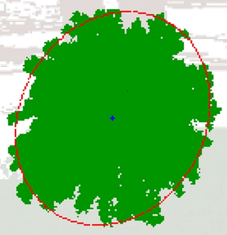

Figure 8 - Ellipse approximating the horizontal projection of the treetop

Figure 9 - Ellipse approximating the shape of the tree crown in vertical projection

Figure 10 - Zenith deployment angle of the branch

Algorithm

Above generated tree parameters are realized as a random selection from the predefined parameter intervals (e.g. height from interval 10-20 m). The branches parameters are generated before start of growth algorithm. The branches are derived on theory of L-systems. At the beginning of a branch growth simulation it is necessary to calculate parameters α,β,γ,and κ. The parameters were calculated on empirical equations.
Woody elements of the tree are represented by cones while foliage is mimicked by faces around cones (implemented in Python). Foliage in the model is classified to five groups by age. The graphical output of a tree model is generated in Blender script.

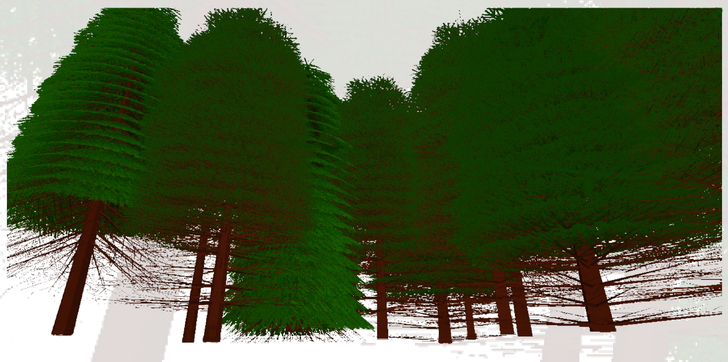

Figure 11 - Example of trees generated by L-system algorithm

Conclusion

Our experience shows that the spruce model can be build more realistically than we did so far. The following improvements are suggested:
1/ Gravitation effect can be implemented on the branches instead of a single plane predefined by zenith deployment angle of a branch;
2/ Foliage of the model is very dense (Fig. 11, 12). This can be improved by better determination of the growth of the new segment. Recently the algorithm generates branch segment in full growth at each end point of the branch. In real life the branches can be damaged by wind and other nature events.
3/ Leaf area index obtained from field measurements can refine foliage of tree model. This can be reached by an inversion technique applied to adjust the original morphological parameters of the tree model to fit the field LAI.

Figure 12 - Example of trees generated by algorithm

Acknowledgement

The study is supported from following projects: COST OC09001, MEYS of CR; CzechGlobe – Centre for Global Climate Change Impacts Studies, Reg. No. CZ.1.05/1.1.00/02.0073; CzeCOS infrastructure LM2010007.

CzechGlobe
Global Change Research Centre AS CR, v.v.i.