LIGHT SIMULATION INSIDE TOMATO CANOPY BASED ON A FUNCTIONAL-STRUCTURAL GROWTH MODEL

Qiaoxue Dong [1] , Weizhong Yang [1] , Yiming Wang [1,*]
[1] *College of Information and Electrical Engineering, China Agricultural University, Beijing, China, 100083;*
[*] *Corresponding author, Address: P. O. Box 63, China Agricultural University, 17 Tsinghua East Road, Beijing, 100083, P. R. China, Tel: 86-10-62737591 Email: ym_wang@263.net*

Abstract: This paper present how the light transfer and interception inside the canopy was computed by combining a tomato dynamic growth model. The tomato functional structural growth model was applied to produce the topology and geometry of individual plant, and through transformation, the canopy could be composed of multi-individual plants. In this simulation system, a radioactive transfer model named hierarchical instantiation for radiosity, was coupled effectively into this tomato growth model to compute the repartition of light energy throughout the canopy, so the key interface technology when integration were explained in the paper. Finally, the visualization results were presented for the light simulation inside canopy.

Keywords: Tomato, Light simulation, Functional structural growth model , Visualization

1. INTRODUCTION

Computation of the distribution of light energy in vegetation mainly depends on the illumination model and representation of vegetation. Up to now, in the field of agronomic research, most approaches consider the vegetation as a turbid medium (Ross 1981), and attenuation factors was used to estimate direct illumination in the plant without accounting for light scattering inside the vegetation. Recent researches on virtual plants(Goel et al., 1990) enable detailed three dimensional canopy structure to be computergenerated (Fournier,et al., 2003).This kind of representation makes it possible to properly simulate light transfer and distribution within virtual plant scenes. Furthermore, by combining illumination model (Soler et al,2003) with plant growth models, structural-functional mode(Yan et al,2004) of crop growth not only provide an accurate tool to compute light interception and photosynthesis, but also enable to investigate plant growth response to external light signal or to quantify mutual influence of plant morphogenesis and plant physiological functions(de Reffye et al,1997).

2. OVERVIEW OF SIMULATION

Figure 1 summarizes the architecture of this simulation system. The tomato growth simulator kernel on the left-hand side is in charge of three tasks: computing the plant topology, computing the volume of organs, and computing the geometry of the plant. The light simulation module depends on the solution of some key interface technology such as creation of instances, light sources and leaf optical property.

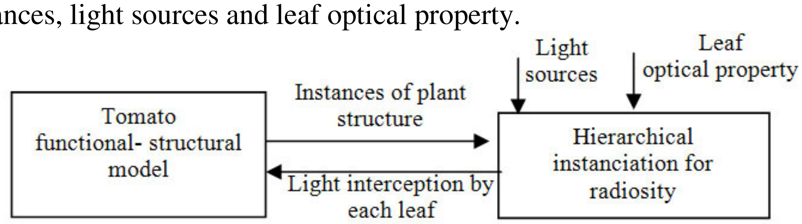


Figure 1: Architecture overview of tomato growth simulation system

2.1 Tomato functional-structural model

Tomato functional-structural model combines a process-based model (Heuvelink, 1999) with a three-dimensional description of plant in one modeling framework. The process-based model deals with the growth and development of individual organs, so in such model, the organs not only play a functional role, but provide reliable information about biomass production and allocation as well as construction of organ shape, which depends on the cumulated biomass inside it. So the model is driven to simulate the growth of tomato plant by their interaction among above modules (Dong et al, 2003).

2.2 Light simulator

Here, hierarchical instantiation for radiosity (Soler et al, 2000) was selected as radiation transfer model, where a new radiosity algorithm based on the concept of hierarchical instantiation was proposed. So one of the key interface technologies is how to identify similar geometry, thus insatiable structures in the plantation scene. The tomato structural model provides this possibility by producing topological and geometrical information. Plants are defined as hierarchies of botanical structures, each one attributed with a collection of botanical parameters, such as physiological age, the kind of axis, branching order, and so on. This useful information can be used as a criterion of similar structures (Fig.2).

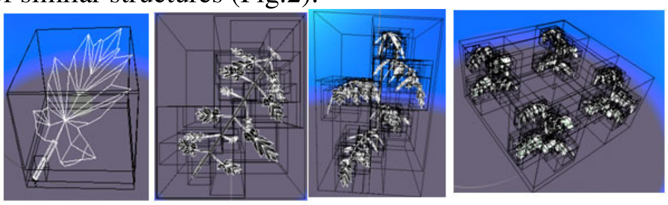
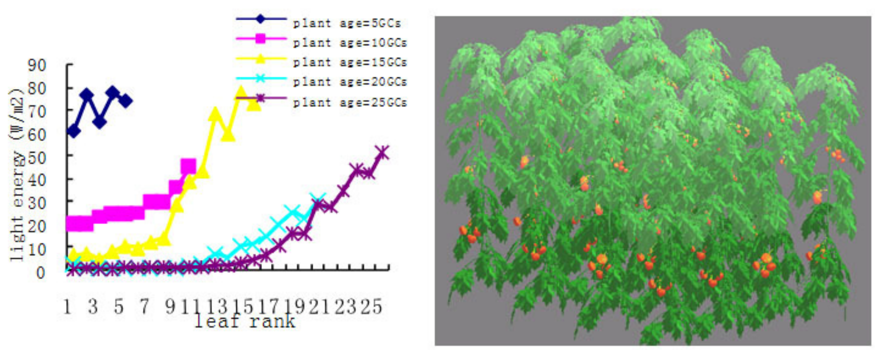


Fig.2: Hierarchical insatiable structures of tomato growth scene

When simulating light distribution inside canopy, the greenhouse light environment needs to be provided to hierarchical instantiation algorithm. An advanced technology named image-based lighting technique (Debevec, 1998) was used to capture real-world illumination inside greenhouse and then to generate directional light sources feed into light simulator.

3. RESULTS AND DISCUSSION

The parameters of tomato growth model were obtained by field measurement and optimization procedure (Dong et al, 2003). Based on these parameters, tomato growth engine can produce the geometrical vegetation for each growth stage, and then light simulator was applied to compute the light distribution at the organ level. (Fig.3 (a)). And a visualization result was also shown in Fig.3(b).



(a) Light interception by leaf (b) visualization

Fig.3 Light distribution inside plantation

It have showed that the tomato functional-structural model can output the geometrical and topological information dynamically, which enables an efficient combination with the radioactive transfer model to compute the light absorption by each individual organ. This will allow some tests of hypotheses by model experiments, concerning the question how the local radiation interception influences the control of shoot growth and plant architecture. But because canopy geometry are based on the very geometry of the plants, and radiosity techniques are often quite costly, how to improve the efficiency of this light simulation system will be included in further study.

ACKNOWLEDGEMENTS

This study was supported by the National Natural Science Foundation of China (#60073007), and the LIAMA laboratory in Beijing, China.

REFERENCES

de Reffye P., Houllier F.. Modeling plant growth and architecture: some recent advances and application to agronomy and forestry. Current Science, 73(11):984-992(1997).

Debevec P. 1998. Rendering synthetic objects into real scenes: bridging traditional and image-based graphics with global illumination and high dynamic range photography. In: Proc. Siggraph 98, Computer Graphics, ACM Press, New York,, pp. 189-198

Dong QX, Wang YM, Barczi JF et al.. 2003. Tomato growth modeling based on interaction of its structure-function.. In: Hu BG, Jaeger M (eds.). Proc. Plant Growth Modeling and Applications (PMA'03), Beijing, China. Tsinghua University Press and Springer, pp. 250-262

Fournier,C. .Andrieu B, Ljutovac S. and et al., 2003. ADEL-wheat: A 3D architectural model of wheat development. In: Hu BG, Jaeger M (eds.). Proc. Plant Growth Modeling and Applications (PMA'03), Beijing, China. Tsinghua University Press and Springer, pp. 55-63.

Goel, N.S, Knox L.B., and Norman M.N, 1990. From artificial life to real life:computer simulation of plant growth. Int.J.Gen.Syst., vol. 18, pp.291-319

Heuvelink E. Evaluation of a dynamic simulation model for tomato crop growth and development. Annals of Botany, 83: 413-422(1999).

ROSS, J. 1981. The radiation regime and architecture of plant stands. Junk Pub., The Hague.

Soler C ，Sillion F, Blaise F, and et al. 2003. An efficient instantiation algorithm for simulating radiant energy transfer in plant models. ACM Transactions on Graphics, 22(2): 204-233

Soler C.,Sillion F,2000.Hierarchical instantiation for radiosity. In： Rendering Techniques ’00, B. Peroche and H. Rushmeier (Eds). Springer Wien, New York, NY, pp. 173~184

Yan H.P, Kang, M.Z., de Reffye P., and et al. 2004. A dynamic, architectural plant model simulating resource-dependant growth. Ann. Bot, 93: 1-12