INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team GreenLab

Plant Growth Modeling and Visualization

Liama - Beijing - Chine

THEME BIO

Activity Report

2008

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GreenLab is an research project located in LIAMA of Institute of Automation, Chinese Academy of Sciences. It is associated with INRIA DigiPlante Project.

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2. Overall Objectives

2.1. Overall Objectives

The EcoInfo - Greenlab team focus on: 1)development of the Greenlab methodology on plant growth and modeling, 2)visualization of plants. GreenLab represents a methodology on plant growth modeling and visualization. GreenLab model, being a plant functional-structure one, is shared by all research partners who contributes to its development. The long term goals for GreenLab are set on two levels. The first, or scientific, level is to advance the knowledge of plant growth and its related techniques on modeling and visualization. The second, or application, level is to facilitate the technique transfer into the areas of agriculture, forestry, and land uses. GreenLab, as a virtual circumstance for scientific research, has its definition extended to include the research in eco-informatic models, machine learning, graphic models, and realistic rendering. In addition, it is also our expectation that GreenLab will provide a good platform for international cooperations on studying and solving global problems, like food shortages and land uses. The detailed objectives are given below:

- Formalism and the parametric studies of the model for plant development, and its integration with the functional both in the deterministic and the stochastic cases;
- Interaction between organogenesis and photosynthesis through the biomass supply and demand, with link to the plant-environment interactions (eg. effects of light, temperature, water);
- Parameter optimization of the model to improve yield under constraints, and its connection with genetics;
- Development of softwares around the simulation GreenLab model (GreenScilab and other package in C++);

- Shape information processing and recognition of complex geometric models. Reconstruction of plant morphological and functional information from sensor data;
- Fast and realistic rendering of objects with polygon based, images based and point/line based approaches. Application of these techniques to forest landscape visualization;
- Compression of complex graphic models. Simplification of plant architecture and plant topology.

3. Scientific Foundations

3.1. Plant modeling and Computer graphics

3.1.1. Plant modeling

Keywords: *Functional structural plant model (FSPM)*, *model calibration*, *optimization*.

Participants: Baogang Hu, mengzhen Kang, Rui Qi, Yuntao Ma, Jing Hua.

Functional-structural plant model (FSPM), aiming at simulating both plant development (organogenesis) and plant growth, strongly relies on multiple-disciplinary knowledge from applied mathematics, computer science, botany, agronomy and forestry. The plant structural models come from the domain of computer science, the most influential studies being L-system and AMAP. While L-systems are very powerful and flexible for modeling any type of dynamic processes, AMAP presented a modeling approach specific for plant objects. The plant functional or ecophysiological model is a traditional subject concerned by agronomists. The pioneer work includes the research group leaded by de Wit in Wageningen University in Netherlands since 1970's. Basically, these studies missed the studies on plant structural parts. The combination of both two kinds of model gives FSPM, which is becoming increasingly important . Several functional-structural models have appeared since end of last century, eg. LIGNUM. Basic issues remain on the background of plant growth modeling, model selection, parameter estimation, optimization, and more recently, link with genetics. Although these issues have been well addressed in control engineering, or adopted in many other fields, applications of these theoretical fundamentals in plant growth studies are neither straightforward nor simple due to their high degree of complexity in plant growth and development.

3.1.2. Computer graphics and virtual reality

Keywords: *geometric models*, *interactive*, *navigation*, *plant reconstruction*, *rendering*, *sensor data*, *shape analysis*, *simplification*.

Participants: Xiaopeng Zhang, Yikuan Zhang, Wujun Che, Adelin Barbacci, Qingqiong Deng, Zhanglin Cheng, Xing Mei, Chao Zhu, Jia Liu, Mingrui Dai, Ning Wang, Hongjun Li, Bo Xiang.

Vegetation is a necessitate element in virtual scenes, and it is an important object in modern computer graphics and virtual reality . Fast and realistic plant rendering becomes a common request for numerous applications concerning computer animation, flight simulation, urban visualization, visual environment, entertainment, and agri-forestry research. Geometric modeling of plant shapes and realistic rendering of a single plant and plant community have become a hot topic in this area since the early days of computer graphics.

With the assistance of modern sensors, digitalization of real objects and geometry data processing / analysis become a new challenge in computer graphics, computer vision, pattern recognition, signal processing, and geometric modeling. These are widely cared about in virtual reality and agro-forestry research. The advanced techniques in computer graphics in recent development focus on precise shape modeling and high performance visualization . The new trends related to vegetation include data compression, highly realistic rendering on light refraction across plant crowns, and rendering with points, lines, polygons, volumes and images. Plant modeling from image series , from scathes, and from LIDAR data is widely referred also. These interests show the technical value in itself, but application to plant/eco system inventories and forest landscape as well.

4. Application Domains

4.1. Applications in agriculture

Keywords: *agriculture*, *energy saving*, *model calibration*, *yield optimization*.

Traditionally, crop studies in agriculture are based on empirical knowledge from filed experiments. This is quite time consuming and expensive. Up to now, there is an increasing need for agronomists to resort to modeling approaches in agriculture applications. While plant growth models can help us to understand the mechanisms of plant development and growth in related to the environmental factors, they do provide a very important tool for realizing optimal yields of crops with an efficient means. The typical example of utilizing models is the optimization crop yield for a given amount of nutrition supply, or for a minimum of energy cost in greenhouse applications.

4.2. Applications in forestry and ecosystem

Keywords: *ecosystem*, *forestry*, *land use*, *model calibration*.

Plantation plays an important role in applications of forestry, land use, and ecosystems managements. Acquisition of plant architecture and functional information through modern electronic techniques become important in these applications. The experiments on different pruning or thinning schemes on a given plantation are very expensive or even impossible for a long-term evaluation of management effects. Visualization of plant in different scales and that of ecosystem become critical for resource inventory and decision-making.

Rendering of the development of a single plant or plant scenes is an assistant tool to check plant growth modeling simulation result. Processing and analysis of LiDAR data and Photogrammetry data became widely cared for forest assessment and inventory. Visualization of a large-scale plant landscape realistically and interactively becomes a new need for forest management.

4.3. Applications in educations

Keywords: *GreenScilab software*, *education*, *plant modeling and visualization*.

In China, more than thirty universities entitled "Agricultural" or "Forestry" names. For example, "Chinese Agriculture University", "Beijing Forestry University", "Nanjing Agriculture University", "Northwest Agriculture and Forestry University", etc. However, at present, studies on modeling and visualization are not common in these universities. Most teaching courses are still given within the traditional subjects. Integration of information technique and applied mathematics into those traditional subjects will be a challenge for advancing the related educations. Free distribution of the open-source toolbox for plant modeling and visualization, named "GreenScilab", can promote this subjects in education domains.

5. Software

5.1. GreenScilab-Crop

Keywords: *GreenLab*, *Scilab*, *crop*, *model calibration*, *plant growth simulation*, *plant visualization*, *tree*.

Participants: Mengzhen KANG [correspondant], Rui QI [project GreenLab&DigiPlante], Philippe de Reffye [project DigiPlante], Veronique Letort [project DigiPlante].

The prototype of the plant toolbox that runs the GreenLab model built in Scilab, GreenScilab (www.greenscilab.org), is still under development this year. A new version for simulating inflorescence (see Section 6.1.2) has been designed. Special versions for tomato, chrysanthemum, wheat have been developed for application. This year it was used again for teaching GreenLab model in AgroParis.

5.2. PlantVis - View-dependent plant visualization

Plants usually have a complex topological form and rich geometric details, which makes real-time rendering of plant scenes a challenge. Software system PLANTVIS (view-dependent **Plant Vis**ualization, abbreviated as PLANTVIS) is designed for a fast rendering of tree branches and leaves. This software can be to conduct real-time rendering of trees and forests while maintaining more realistic details. The main feature of the system PLANTVIS is that an optimization of time and space is performed while maintaining certain realism of plant rendering. This leads to real-time rendering of large-scale forest scenes at last and meets a variety of requirements on roaming the speed. It is easy to operate.

Level-Of-Detail (LOD) techniques are adopted to establish the multi-resolution model of plant crowns. When plant scene modeling is connected to plant model simplification algorithms, navigation can be eventually achieved with satisfactory speed and quality through the forest of tens of thousands of trees. More free navigation ways are supported, such as head-up, looking up, and looking down. The communication of GPU with CPU is well considered through a special data structure, so that hardware acceleration can be supported. Figure 1 shows the interface of the software when a holly tree is simplified.

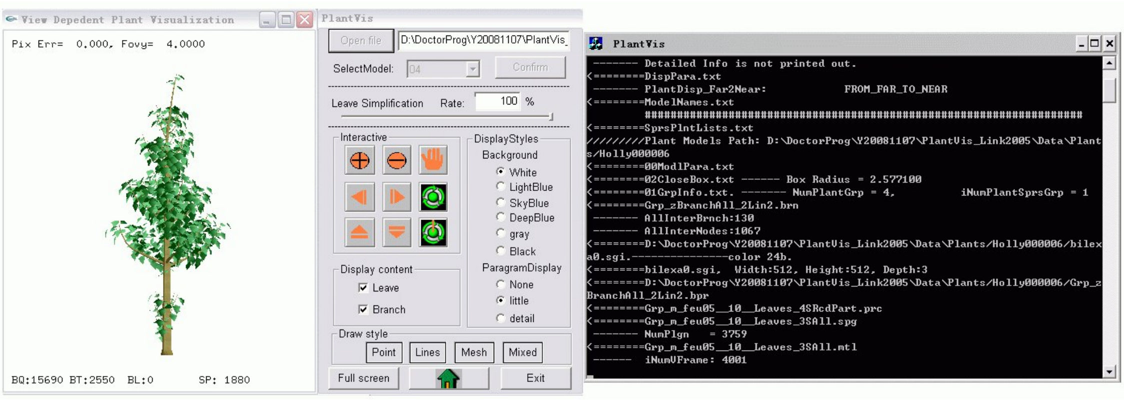

Figure 1. Interface and View-dependent rendering of a single holly tree.

6. New Results

6.1. Applied mathematics

6.1.1. Structural identifiability of model parameters

Participants: Shuanghong Yang [project GreenLab], Baogang Hu [project GreenLab], Paul-Henry Cournède [project DigiPlante].

For modeling complex livings, like plants, many sub-models may be integrated as a complete model. For example, we developed a so called "Generalized Constraint Neural Network Models" which integrated one knowledge based sub-model, and one neural network sub-model. When two models are combined, the parameters from two sub-models may not be identifiable. Structural identifiability seems still an open problem in modeling. One paper entitled "Structural Identifiability of Generalized Constraint Neural Network Models for Nonlinear Regression" was published by NeuroComputing, in which we derived analytical theorems for structural identifiability on MISO models. Further investigation is made on the first-order difference equation proposed by GreenLab. In its originally form, this equation has five free parameters, and we found the independent parameters are two, and they both present locally structural identifiable properties.

6.1.2. Modeling growth of inflorescence

Participants: Mengzhen Kang [project GreenLab], Philippe de Reffye [project DigiPlante].

An inflorescence is a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches. Inflorescences are a particular case where the expansion time of a phytomer is not simply related to the creation time as it is the case for trees. Flowering sequence of inflorescence has been simulated by Lindenmayer and Prusienkiwiez using signal to mimic hormone transportation. Although the visual effect was quite nice, the size of flowers are predefined instead resulting of biomass computation, i.e., the growth of flowers were not modelled. We propose a method of modeling growth of inflorescences in GreenLab. GreenLab model has already been used for inflorescences on Chrysanthemum and Arabidopsis, but it was limited to case of first branching order. To simulate growth of inflorescence, each phytomer has two features: a creation time for development and an expansion time for growth. We can introduce expansion time (or delay of expansion) of phytomers very easily, depending on the position of phytomers, and therefore their creation time, inside plant structure. This generally way facilitates simulation of flexible several flowering sequences in plant structure of any branching order. (Fig.2).

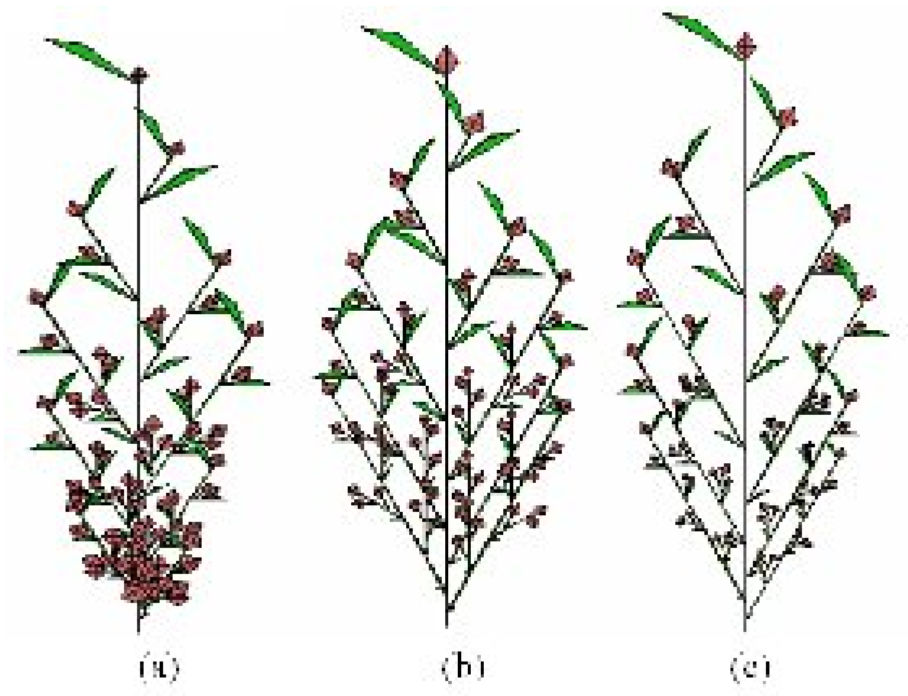

Figure 2. Simulation of inflorescence structure of order four with different growth sequence of flowering: (a) bottom-up (b) simultaneous (c) top-down.

6.1.3. Applications of optimization in agronomy and forestry

Participants: Rui Qi [project GreenLab&DigiPlante], Paul-Henry Cournède [project DigiPlante], Philippe de Reffye [project DigiPlante].

Cereals are life's necessities. As lack of resources and increasing population, it became an important topic to improve cereal yield through improving breeding strategies and cultivation modes. It has been widely accepted that plant growth models may provide efficient tools to study plant growth behavior, as they can complement field experiments. GreenLab model is one of the functional-structural plant growth models, which combining the description of organogenesis, photosynthesis and biomass partitioning. As it can be considered as a dynamic discrete system with mathematical formulations, it is possible to apply optimization methods to solve particular issues in agronomy and forestry, such as maximization of seed yield (maize cob, wheat), of wood yield , of leaf yield (salad, tea plant, tobacco), of stem yield (sugar cane), of fruit yield (tomato, apple), of root yield (sugar beet), of fiber yield (cotton). The optimized parameters are either related to plant genetics in order to design new breeding strategies, or related to cultivation modes.

6.2. Model Application

6.2.1. Applications in genetics

Participants: Mengzhen Kang [project GreenLab], Rui Qi [project GreenLab&DigiPlante], Jing Hua [project GreenLab], Philippe de Reffye [project DigiPlante].

An introgression line (IL) population originated from a cross between the green-fruited species Lycopersicon pennellii in the cultivated tomato (cv M82), each of the lines containing a single homozygous L. pennellii chromosome segment. Together the lines provide complete coverage of the genome and a set of lines nearly isogenic to M82. Although this plant material has been used to detect quantitative trait loci (QTL), the formation of plant yield, remains too complex to be attributed to the chromosome segments. GreenLab is a functional-structural plant model that simulates the dynamic plant development and growth. Using the plant architectural information (the biomass of individual organs) as the target, the growth parameters of GreenLab (sink & source functions) could be identified. These parameters allow analysis of the dynamic assimilate production and allocation inside the plant. GreenLab model is applied to the L. pennellii lines, aiming at discovering the difference of yield formation among ILs.

6.2.2. Simulation of fruit set in pepper plant with interactions of plant growth and development

Participants: Yuntao Ma [project GreenLab], Philippe de Reffye [project DigiPlante].

Cyclic fluctuations in fruit yield are an important problem in sweet pepper production. These fluctuations results from cyclic variations in fruit set. Therefore, the relationship between fruit set , plant sink and source strength should be investigated. Functional-structural plant model GreenLab can be used to simulate the interactions between plant growth and development. In order to calibrate the model on pepper, pepper plants of six cultivars were sown in trays with potting soil and planted in Rockwool cubes at uniform, Wageningen, The Netherlands (Fig.3) (Fig.4).

6.2.3. Simulation of tomato growth under different population density

Participants: Mengzhen Kang [project GreenLab], Lili Yang [Chinese Agriculture University].

Reaction of tomato grown in greenhouse to population densities is important to understand behavior of plants under different conditions. Experiments were conducted in solar greenhouse in Chinese Academy Sciences of Agriculture, and plants were detailed measured. GreenLab was used to analyze the behavior of plants by identifying model parameters. The model catch well the variations in sink-source parameters for each condition (Fig.5). The next work is to link the flower abortion to the internal relationship between biomass supply and demand for tomato of each population density.

6.3. Fast rendering of plant scenes

Fast rendering of plant scenes become a challenge due to the complex geometric information included. Different approaches have been developed in the level of detail (LOD) of tree models and their application to the rendering of plant scenes.

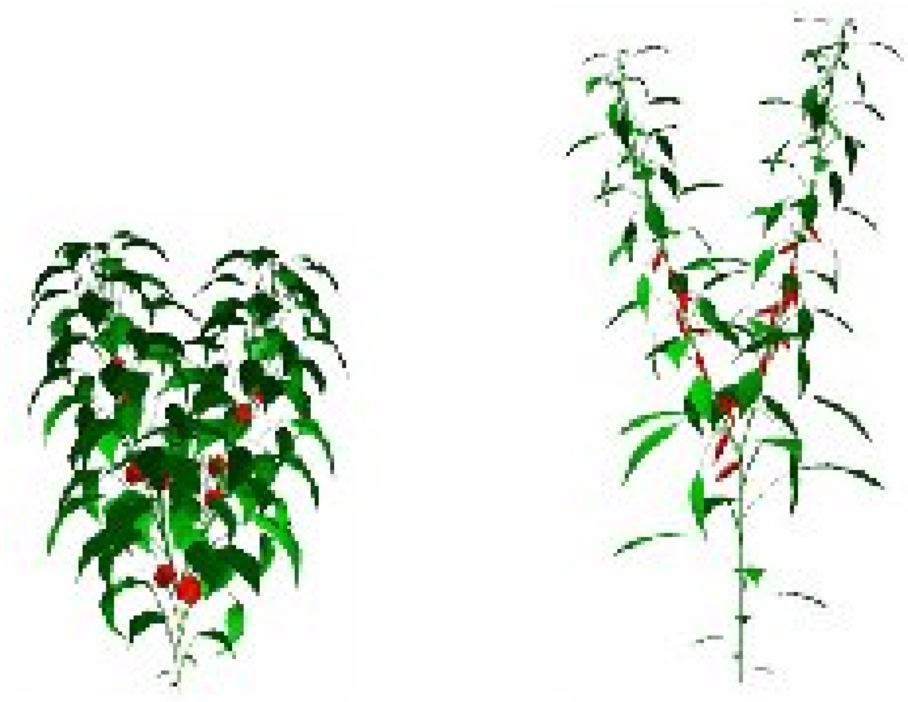

Figure 3. Three-dimensional simulation of sweet pepper and hot pepper.

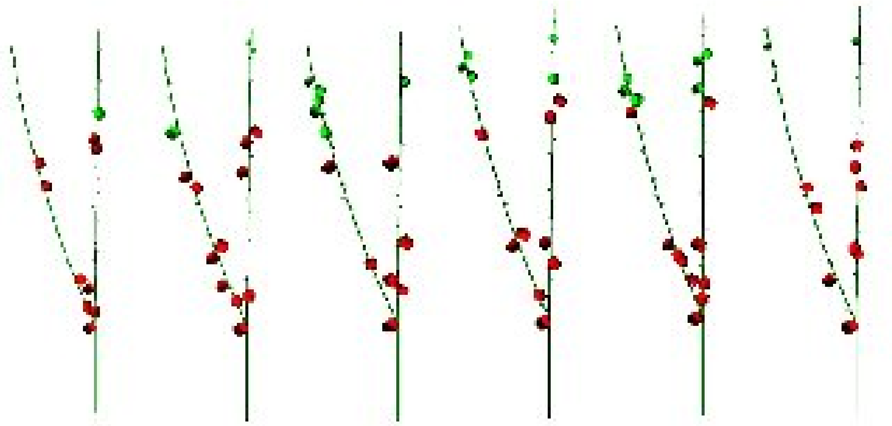

Figure 4. Monte Carlo simulations of fruit set in sweet pepper.

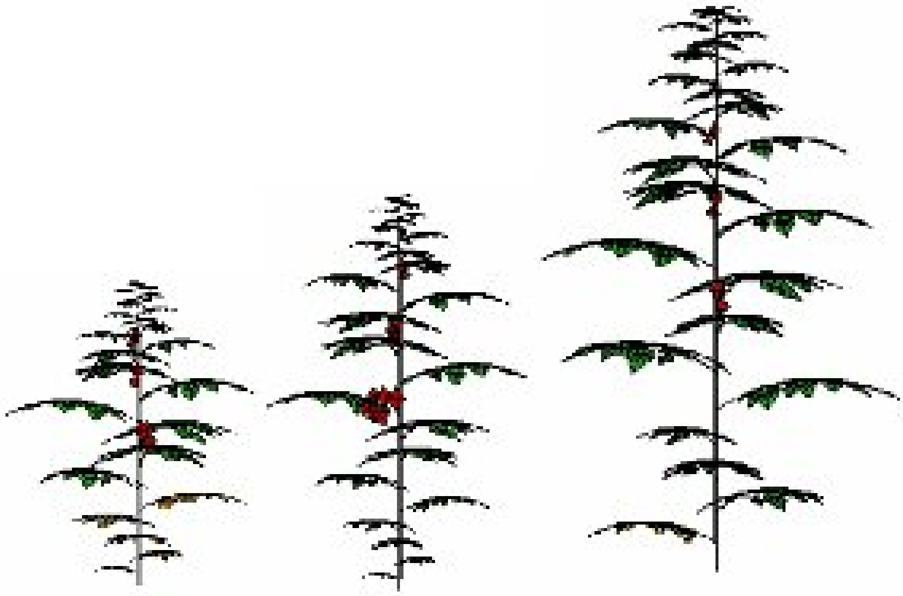

Figure 5. Simulation of tomato plants under different population densities using GreenScilab-tomato.

6.3.1. Grid-based view-dependent foliage simplification

This paper presents a new algorithm to efficiently construct level of detail plant foliage models based on a uniform subdivision of the crown volume. This algorithm includes two phases: preprocessing and rendering. In the preprocessing, the leaves of a tree are first clustered by a regular 3D grid structure, and then for the leaves in each cell of the grid, a recursive leaf union is performed hierarchically in two levels: phyllotaxy group and whole foliage. The simplification data of each cell will be stored in the hard disk as a binary tree structure in the end of preprocessing. In the rendering phase, the global level of detail of a tree is constructed according to its distance to the viewer. Then, the local level of detail model of each cell is extracted according to a simple heuristic rule: leaves on the rear or inside of the crown are statistically less visible than front ones, so they can be rendered with coarse models. The contributions of this approach are higher efficiency in level of detail construction in preprocessing and higher data compression for view-dependent rendering. (Fig.6).

6.3.2. Efficient extraction of multiresolution foliage with GPU support

We present a new foliage simplification framework. We propose several improvements of leaf fusion based techniques, both in the LOD model construction and the rendering data structure. We show first that the cost of the LOD series construction can be drastically dropped down by cluster subdivisions, built from an uneven subdivision of the tree crown volume. We introduce then a new concept, leaf density, allowing compression adaptation to local distribution of leaves, so that more visual sensitive details are kept at low densities, while compression is higher on dense parts, leading to a higher overall compression. We propose then a specific implementation of the classical LOD binary storage structure. The costly hierarchical traversal is replaced by a simple linear lookup array retrieval. Moreover, the design of this dedicated array structure is GPU-oriented, aiming to drop down communication cost between CPU and GPU at LOD level model load during rendering. According to foliage nature (broad leaves or needles), higher compression are finally reached using mixed polygon/line models. The proposed foliage simplification framework is implemented and tested on virtual scene with high detail simulated trees. Experiments show that this approach is efficient in data compression and allows fast rendering of forest scenes with rich geometric details. (Fig.7).

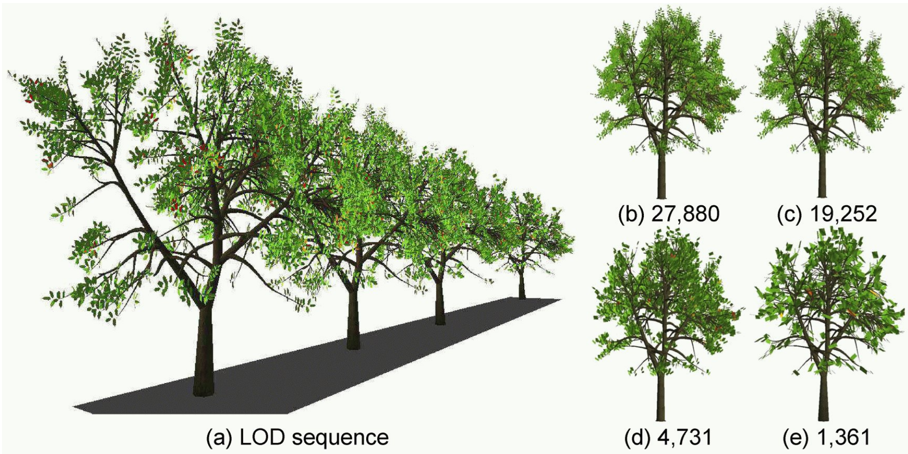

Figure 6. LOD models of a 25-year-old chestnut tree; (a) An application of the LOD models; (b)-(e) Model complexity of each LOD model in (a).

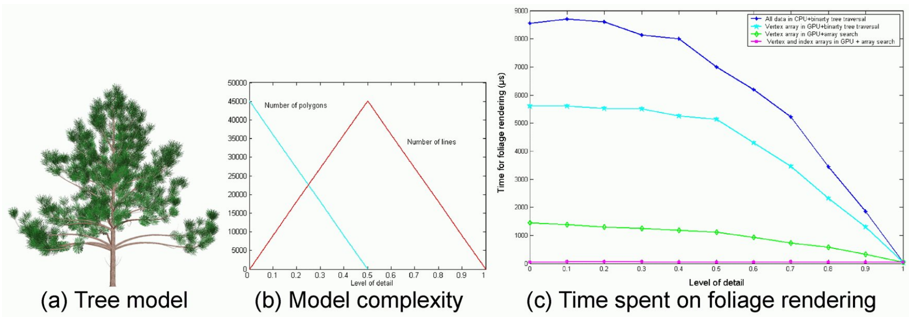

Figure 7. Comparison of four strategies on the time spent on foliage rendering of Scots pine. (a) Model view; (b) Model complexity for different LOD levels; (c) Curves of four strategies of time spent on foliage rendering with different detail degree.

6.3.3. Fast forest visualization on hierarchical images and visibility

Fast visualization of plant functional structural information in forest facilitates to understand the effects of natural disturbance. It is an important work in forest management on forest growth, species composition, structure and dynamic changes at different scales. We propose a new image-based rendering algorithm for interactive visualization of functional structural plant models foliage involving visibility analysis. In our approach, a pre-processing stage generates a hierarchical structure of billboards with respect to the plant topology. Moreover, this structure is constraint by plant production, i.e. the total leaf area is kept constant. In the rendering phase, foliage clusters (foliage hold by plant sub-structures) are represented by different level of image models according to distance and visibility, simply obtained by using the relationship between the current viewing direction and the average direction of each first-order branch, and the information of branch densities. Besides, The advantage of self-similarity of plants is applied in our approach to reduce the memory cost for textures (Fig.8).

Figure 8. Visualization of a larch-dominant mixed stand.

6.3.4. Real-time marker level set on GPU

Participants: Xing Mei [project GreenLab], Philippe Decaudin [project GreenLab], Baogang Hu [project GreenLab], Xiaopeng Zhang [project GreenLab].

Level set methods have been extensively used to track the dynamical interfaces between different materials for physically based simulation, geometry modeling, oceanic modeling and other scientific and engineering applications. Due to the inherent Eulerian characteristics, interface evolution based on level set usually suffers from numerical diffusion, sharp feature missing and mass loss. Although some effective methods such as Particle Level Set (PLS) and Marker Level Set (MLS) have been proposed to tackle these difficulties, the complicated correction process and the high computational cost pose severe limitations for real-time applications. In this paper we provide an efficient parallel implementation of the Marker Level Set method on latest graphics hardware. Each step of the MLS method is fully mapped on GPU with an innovative combination of different computation techniques. Relying on GPU's parallelism and flexible programmability, the method provides real-time performance for large size 2D examples and moderate 3D examples, which is significantly faster than previous CPU-based methods (Fig.9).

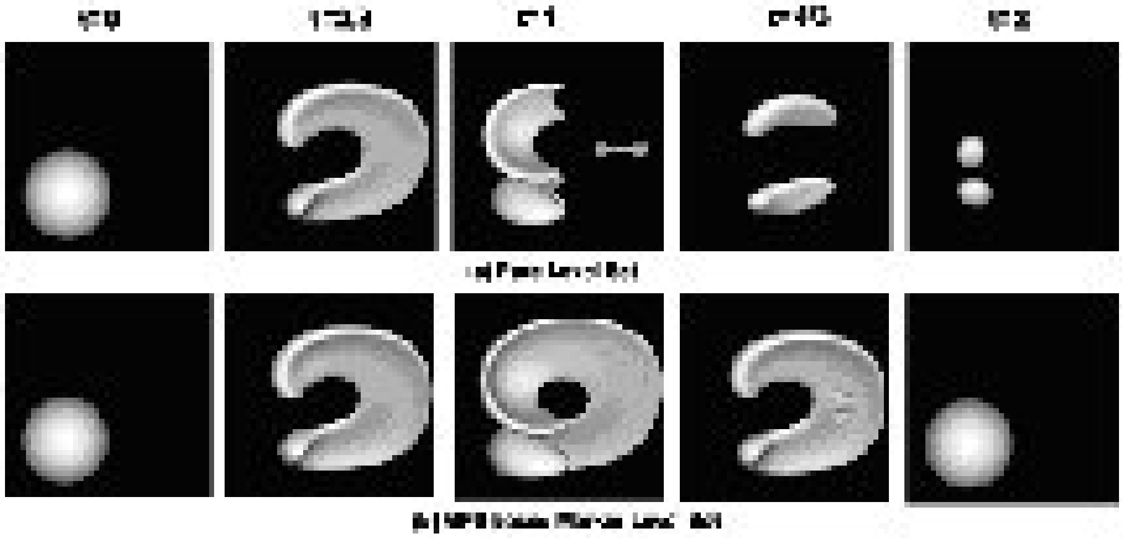

Figure 9. 3D Enright deformation test: (a) interface evolution with level-set (b) interface evolution with GPU-based MLS.

6.3.5. Simple empty space removal for interactive volume rendering

Participants: Vidal Vincent [project GreenLab], Xing Mei [project GreenLab], Philippe Decaudin [project GreenLab].

Interactive volume rendering methods such as texture-based slicing techniques and ray-casting have been well developed in recent years. The rendering performance is generally restricted by the volume size, the fill-rate and the texture fetch speed of the graphics hardware. For most 3D data sets, a fraction of the volume is empty, which will reduce the rendering performance without specific optimization. In this paper, we present a simple kd-tree based space partitioning scheme to efficiently remove the empty spaces from the volume data sets at the preprocessing stage. The splitting rule of the scheme is based on a simple yet effective cost function evaluated through a fast approximation of the bounding volume of the non-empty regions. The scheme culls a large number of empty voxels and encloses the remaining data with a small number of axis-aligned bounding boxes, which are then used for interactive rendering. The number of the boxes is controlled by halting criteria. In addition to its simplicity, our scheme requires little preprocessing time and improves the rendering performance significantly (Fig.10).

6.4. Shape Analysis and 3D Reconstruction of real plants

Laser scan becomes a popular way to acquire shape data of real objects. Reconstruction of real plants is one of difficult problems in digital geometry processing and analysis. Different approaches have been developed in the shape information processing and application to the reconstruction of real plants.

6.4.1. Curvature estimation of 3D point cloud surfaces

As the technical development of laser scanning and image based modeling, more and more point cloud data are obtained to represent 3D geometric shapes of natural objects. Calculation of differential properties of 3D discrete geometry becomes one fundamental work. Through the relation of discrete normal curvatures and principal curvatures, a new algorithm is presented on estimating the principal curvatures and principal directions 3D point cloud surface. Based on the local fitting of each normal section circle properties with the

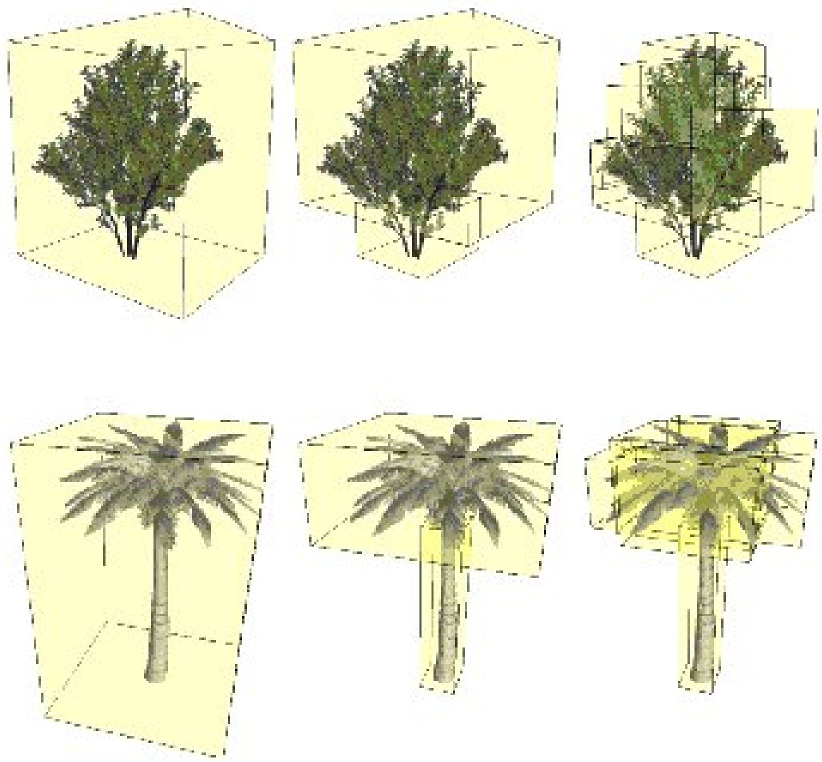

Figure 10. An illustration of our empty-space removing method. Empty voxels are progressively removed from the original volume with a kd-tree based spatial partitioning scheme.

position and the normal at a neighbor point, principal curvatures and principal directions are estimated from the contribution of these neighbor points. Optimization of this estimation is converted as a linear system by least squares fitting to all discrete normal curvatures corresponding to its neighbor points. A local feature curve, called as normal curvature index lines, is constructed to show the efficiency of this work. This curve is intuitive and equivalent to Dupin index line. Experiments are designed on Gaussian curvature, mean curvature and principal directions for an analytical surface and discrete surfaces of point cloud data. Experimental results show that this work is more advantageous than similar approaches, ad have applications to shape analysis and measurements (Fig.11).

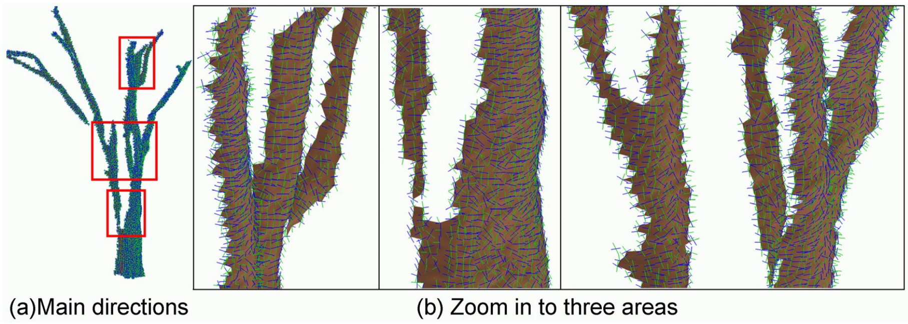

Figure 11. Curvature directions on a branch surface estimated by our approach.

6.4.2. Reconstruction of tree crown shape from scanned data

We proposed a novel approach to reconstruct in 3D the scanned tree crown, in order to constrain the definition of the branch structures, especially the thinner ones, and contribute to define local geometrical constraints for leaf area reconstruction. The novel approach for tree crown reconstruction is based on an improvement of alpha shape modeling, where the data are points unevenly distributed in a volume rather than on a surface only. The result is an extracted silhouette mesh model, a concave closure of the input data. The principle of this approach is based on the use of the alpha-shape on the range point data set, a generalization of the convex hull and subgraph of the Delaunay triangulation. In the Delaunay triangulation process, we choose the triangle candidates on the boundary according to the alpha value, and constrain the surface mesh to stay a manifold. Therefore, our constructed boundary mesh builds in fact the silhouette of the crown. This shape of the tree crown is much more convincing than the convex hull of the tree crown in keeping the concave features of the crown (Fig.12).

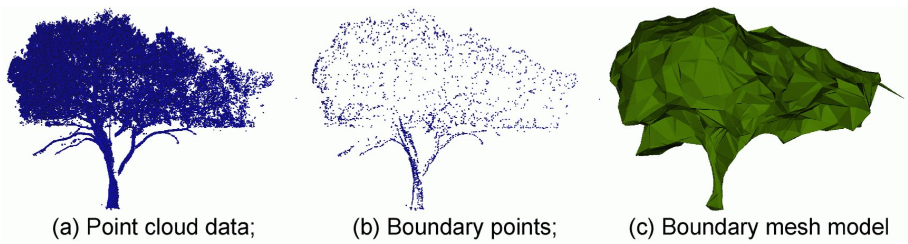

Figure 12. Extraction of the Crown shape of a Maple tree.

6.4.3. Modeling small plants with sensor data

Sensor data, typically being images and laser data, are essential to modeling real plants. However, due to the complex geometry of the plants, the measurement data are generally limited, thereby bringing great difficulties in classifying and constructing plant organs, comprising leaves and branches. The paper presents an approach to modeling plants with the sensor data by detecting reliable sharp features, i.e. the leaf apexes of the plants with leaves and the branch tips of the plants without leaves, on volumes recovered from the raw data. The extracted features provide good estimations of correct positions of the organs. Thereafter, the leaves are reconstructed separately by simply fitting and optimizing a generic leaf model. One advantage of the method is that it involves limited manual intervention. For plants without leaves, we develop an efficient strategy for decomposition-based skeletonization by using the tip features to reconstruct the 3D models from noisy laser data. Experiments show that the sharp feature detection algorithm is effective, and the proposed plant modeling approach is competent in constructing realistic models with sensor data (Fig.13).

Figure 13. Reconstruction of real plants (Nephthytis and Anthurium scherzerianum) from photo series.

6.4.4. Skeletonization of branched volume by shape decomposition

We present an algorithm to automatically extract skeletons for branched volumes by shape decomposition. First, a region growing strategy is adopted based on a distance transformation to decompose a volume into several meaningful components with simple topological structures. Then, the skeleton of each component is individually extracted. Finally, the skeletons of all the components are integrated and a structural skeleton of the volume data is obtained, where the structural skeleton is topologically equivalent to the volume. The contributions of the algorithm are: the elimination of the influence of different branches and the accurate skeleton extraction with topological structure of the model due to exact decomposition. Experiments show that this algorithm is applicable to shapes with complex topology (Fig.14) (Fig.15).

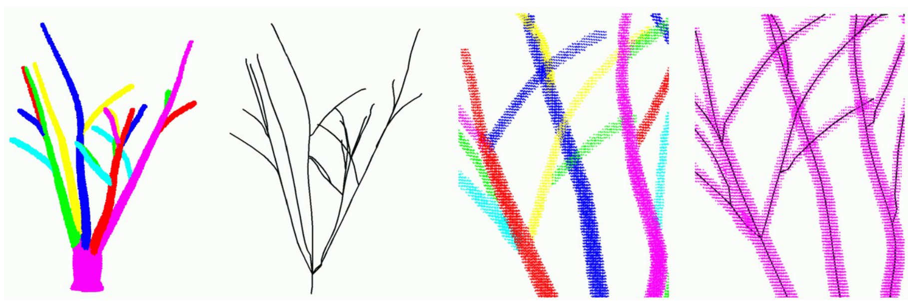

Figure 14. Branched Volume Decomposition and Skeletonization of a virtual willow tree.

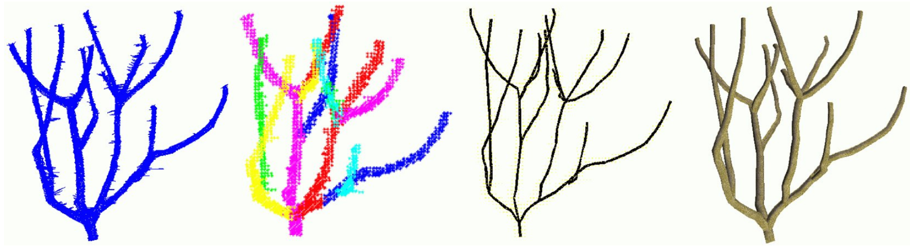

Figure 15. Modeling of a real Bonsai tree Murraya paniculata. From left to right are the raw data, the decomposition results, the extracted skeletons and the final reconstructed models.

6.4.5. Objective evaluation of 3D reconstructed plants and trees from 2D image data

Participants: Baogang Hu [project GreenLab], Xiaopeng Zhang [project GreenLab], Marc Jaeger [project DigiPlante].

A study of 3D plants reconstructed from 2D image data of the target plants has received increasing attentions in recent years. Although several approaches on image-based modeling of 3D plants/trees were successfully developed, they usually applied a subjective inspection to assess the quality of synthesized plants/trees based on their given image data. For this reason, we propose a preliminary study on objective approaches g the synthesized plants from the given image data. Two measures, in a general name of ce Index (RI)", are defined and investigated based on the normalized mutual information (RINI), ent-bit-counting criterion (RICBC), respectively. We propose a strategy of hierarchical evaluations attributes of objects. In this study, we apply the proposed approach in evaluations of 3D plants nsider the geometrical and crown distribution attributes. The numerical investigations confirm the be useful for a fast evaluation of 3D reconstructed plants/trees from image data. Discussions are the two measures based on the numerical examples.

this work is to provide a feedback loop on the image-based modeling from an objective evaluation ance mapping from a "real world" to a "virtual world"(Fig. 1). In future, two modulars in Fig.1 will d for refining representations of the "virtual world" to be more resemble to its "real world" from arances. To our knowledge, the approach proposed in this work is novel for the complex natural plants or trees. A paper of introducing this work was appeared in the CyberWorld 2008 (Fig.16).

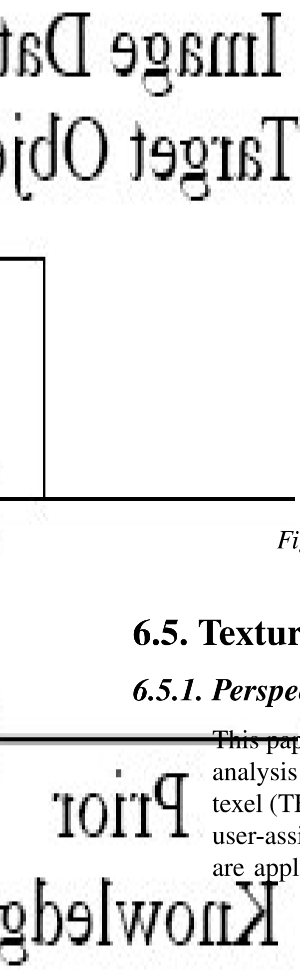

Figure 16. Schematic Diagram of Image-based Modeling and Evaluations on 3D Virtual Objects.

6.5. Texture analysis and synthesis

6.5.1. Perspective-aware texture analysis and synthesis

This paper presents a novel texture synthesis scheme for anisotropic 2D textures based on perspective feature analysis and energy optimization. Given an example texture, the synthesis process starts with analyzing the texel (TEXture ELement) scale variations to obtain the perspective map (scale map). Feature mask and simple user-assisted scale extraction operations including slant and tilt angles assignment and scale value editing are applied. The scale map represents the global variations of the texel scales in the sample texture. Then, we extend 2D texture optimization techniques to synthesize these kinds of perspectively featured textures. The non-parametric texture optimization approach is integrated with histogram matching, which forces the global statics of the texel scale variations of the synthesized texture to match those of the example. We also demonstrate that our method is well-suited for image completion of a perspectively featured texture region in a digital photo (Fig.17).

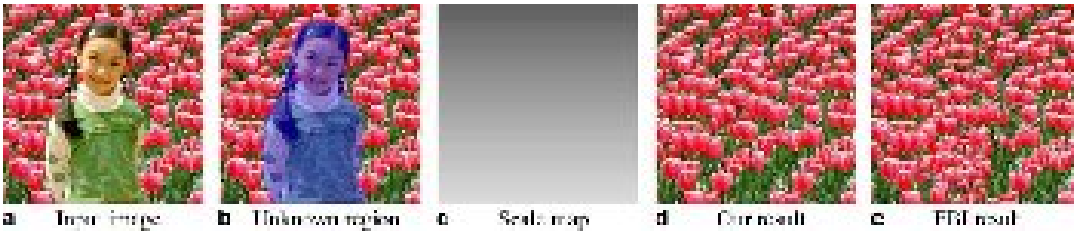

Figure 17. Image completion for textured region by perspective-aware synthesis.

6.5.2. Robust tile-based texture synthesis using artificial immune system

One significant problem in tile-based texture synthesis is the presence of conspicuous seams in the tiles. The reason is that sample patches employed as primary patterns of the tile set may not be well stitched if carelessly picked. In this paper, we introduce a robust approach that can stably generate an x-tile set of high quality and pattern diversity. First, an extendable rule is introduced to increase the number of sample patches to vary the patterns in an xtile set. Second, in contrast to other concurrent techniques that randomly choose sample patches for tile construction, ours uses artificial immune system (AIS) to select the feasible patches from the input example. This operation ensures the quality of the whole tile set. Experimental results verify the high quality and efficiency of the proposed algorithm.

6.5.3. Tile-based interactive texture design

In this paper, we present a novel interactive texture design scheme based on the tile optimization and image composition. Given a small example texture, the design process starts with applying an optimized sample patches selection operation to the example texture to obtain a set of sample patches. Then a set of ω-tiles are constructed from these patches. Local changes to those tiles are further made by composing their local regions with the texture elements or objects interactively selected from other textures or normal images. Such select-compose process is iterated many times until the desired ω-tiles are obtained. Finally the tiles are tiled together to form a large texture. Our experimental results demonstrate that the proposed technique can be used for designing a large variety of versatile textures from a single small example texture, increasing or decreasing the decreasing the density of texture elements, as well as for synthesizing textures from multiple sources

7. Other Grants and Activities

7.1. Actions in China

7.1.1. Plant growth modeling and visualization for agriculture and forestry

Participants: Baogang Hu, Xiaopeng Zhang, Mengzhen Kang, Zhanglin Cheng, Qingqiong Deng, Xing Mei, Chao Zhu, Jia Liu, Mingrui Dai, Hongjun Li, Guobo Bao.

National Natural Science Foundation of China projects No. 60073007,MOST International collaboration project No. 2007DFC10740

7.1.2. Fast modeling and realistic rendering of complex plant scenes

Participants: Xiaopeng Zhang, Baogang Hu, Zhanglin Cheng, Qingqiong Deng, Xing Mei, Chao Zhu, Jia Liu, Mingrui Dai.

National High-Tech Research and Development 863 Plan of China project No. 2006AA01Z301.

7.1.3. Study on the genetic basis of tomato yield components using a mathematical plant model and introgression lines

Participants: Mengzhen Kang, Rui Qi, Jing Hua, Véronoque Letort.

National Natural Science Foundation of China projects No. 60703043

7.1.4. Parametric design of plant 3D shape and plant animation generation

Participants: Mengzhen Kang, Baogang Hu, Ning Wang, Xing Mei, Qingqiong Deng, Zhanglin Cheng.

National High-Tech Research and Development 863 Plan of China project No. 2008AA10Z218.

7.2. Actions in France

7.2.1. NATSIM, Nature simulation: hybrid representation for modeling, simulation, visualisation and streaming of animated natural scenes.

Participants: Marc Jaeger, Xiaopeng Zhang, Qingqiong Deng, Bo Xiang, Jia Liu, Chao Zhu.

French National Research Agency project ANR-05-MMSA-45.

7.2.2. EMERGE - Compatible evaluations of volumes, biomass and mineral masses in forest: toward a countable and sustainable management of wood energy.

Participants: Marc Jaeger, Thierry Constant, Xiaopeng Zhang, Adelin Barbacci, Zhanglin Cheng, Mingrui Dai, Hongjun Li.

French National Research Agency project ANR-08-BIOENERGIES-0.

8. Dissemination

8.1. Activities in scientific communities

- Edutainment 2008(The 3rd International Conference of E-Learning and Games - Edutainment 2008), Xiaopeng Zhang, Program Chair, Nanjing, China, June 25-27, 2008
- Edutainment 2008(The 3rd International Conference of E-Learning and Games - Edutainment 2008). Yikuan Zhang, Xiaopeng Zhang, A Sufficient Condition for Uniform Convergence of Stationary p-subdivision Scheme, Oral presentation, Nanjing, China, June 25-27, 2008
- Edutainment 2008(The 3rd International Conference of E-Learning and Games - Edutainment 2008). Chao Zhu, Xiaopeng Zhang, Reconstruction of Tree Crown Shape from Scanned Data, Oral presentation, Nanjing, China, June 25-27, 2008
- Huazhong Agricultural University, Xiaopeng Zhang, Fast visualization of plant scenes, A hybrid Approach of Geometric Compression and Image-based Rendering, Wuhan, China, September 25, 2008
- Huazhong University of Science and Technology, Xiaopeng Zhang, Digital Geometry Processing and Fast Visualization of Plant Scenes, Wuhan, China, September 26, 2008
- CIRAD-AMAP, Chao Zhu, Reconstruction of Tree Crown Shape from Scanned Data, Montpellier, France, October 20, 2008

- CIRAD-AMAP, Jia Liu, Approximate and Fast Modeling of Plant Skeleton Based on Images, Montpellier, France, October 20, 2008
- CIRAD-AMAP, Bo Xiang, Skeletonization of Branched Volume by Shape Decomposition, Montpellier, France, October 20, 2008
- CIRAD-AMAP, Xiaopeng Zhang, Plant 3D Reconstruction and fast visualization, Montpellier, France, October 20, 2008
- CCPR 2008 (Chinese Conference on Pattern Recognition 2008), Bo Xiang, Xiaopeng Zhang, Wei Ma, Skeletonization of Branched Volume by Shape Decomposition, Beijing, October 22-24, 2008.
- Asia Graph 2008. Hongjun Li, Curvature Estimation of 3D Point Cloud Surfaces Through the Fitting of Normal Section Curvatures, Oral presentation, Tokyo, Japan, October 23-26, 2008
- INRA Forest Center, Xiaopeng Zhang, 3D Plant Reconstruction form LIDAR data, Nancy, France, November 4, 2008
- VRCAI 2008 (7th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry). Xiaopeng Zhang, Volume Decomposition and Hierarchical Skeletonization, Oral presentation, Singapore, December 8-9, 2008
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- ISCMDS 2008 (International Symposium on Crop Modeling and Decision Support). Mengzhen KANG. A Functional-Structural Plant Model–Theory and Applications in Agronomy. Oral presentation, NanJing, China, April 19-22, 2008
- ISCMDS 2008 (International Symposium on Crop Modeling and Decision Support). Rui QI. Oral presentation, NanJing, China, April 19-22, 2008

8.2. Teaching

- Baogang Hu, Intelligent Control, Graduate University, Chinese Academy of Sciences, 2008
- Xiaopeng Zhang, Computer Graphics and Application, Graduate University, Chinese Academy of Sciences, 2008
- Baogang Hu,Mengzhen Kang, ShiLi, Mathematical Modeling and Open Source Software Scilab. Ecole Centrale BeiJing, BeiHang university, 2008

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