

**Title:**

A Fast Interactive Graphical Modeling Toolkit for 3D Plants with Detailed Features

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Introduction:

Plants are essential to nature and human life, which play one important role in computer aided design packages and graphical applications such as architectural design, urban planning, computer games and video products. However, modeling plants with detailed features is challenging work. The main reason is that plants not only have unusually complex shapes, but the resulting shapes and structures should be in accordance with the plants' physiological mechanisms. Although lots of research work including L-system [1], the GreenLab model [2] is done on the interaction design on 3D modeling of plants, these methods mainly focused only on the overall structure of plants and the achieved models are generally without detailed features to reflect the plants' variety and seasonal diversity. For example, deciduous plants in spring grow flower buds and leaf buds instead of only leaves, and most tree branches often have irregular bulges or depressions. With the rapid development of interactive technologies such as touch screens and paintbrushes, sketch-based interactive design was increasingly used in plant design in recent years [3, 6]. Researchers have combined sketch-based design with physical simulation to generate plant morphological structural models, which are closer to plant physiological properties or to specific natural conditions [4, 7]. However, the three-dimensional (3D) plant models generated by the current methods still lack sufficient detailed features.

The purpose of this paper is to propose a 3D plant interaction design process and provide a graphical modeling toolkit for 3D plants, which can reflect the characteristics of plant variety. In the applications such as the botany teaching and scientific research, high-level details include flower buds, leaf buds, etc. on the tree branches should be fully modeled and displayed; the developed graphical toolkit in the paper supports the flexible design and instant display of plants with detailed features.

Main Idea:

Modeling 3D plant shapes includes four steps: 1) first sketch the 2D plant skeleton; 2) design the 3D plant skeleton; 3) generate the branch mesh model automatically; 4) place organs on the branches. In this section, each step will be introduced concisely.

Sketch the 2D Plant Skeleton

The skeletal design of the plant is carried out by sketch, which determines the general shape of the plant. In order to facilitate users to design the plant skeleton structure, one can design the 2D skeleton through a few simple strokes (Fig. 1). The type of branches is defined by strokes with different colors and sizes and each stroke stands for one branch.

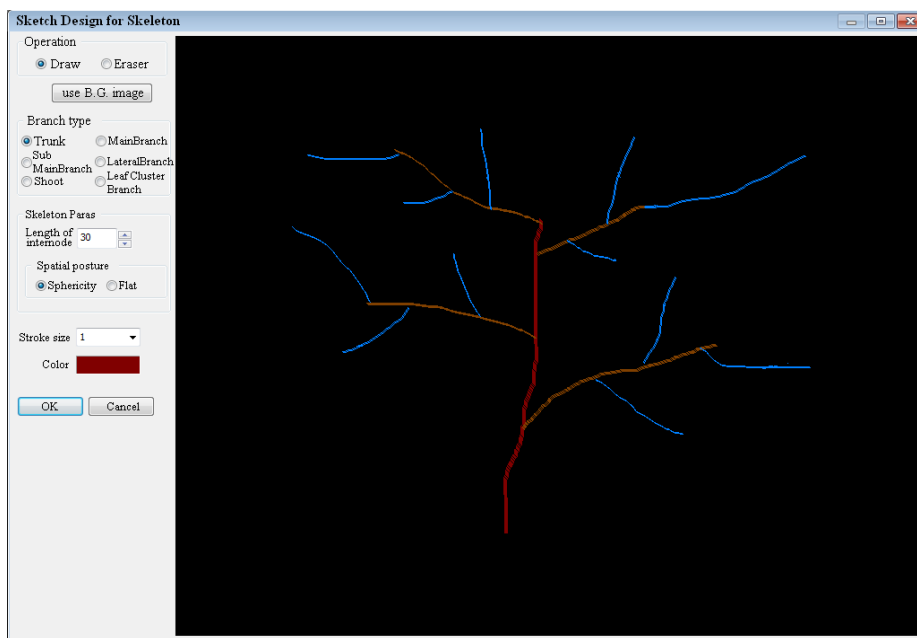


Fig. 1: Sketch design interface for the 2D skeleton of a plant.

3D Design on the Plant Skeleton

After obtaining the 2D skeleton, an algorithm is devised to generate a flat 3D skeleton. The algorithm divides each 2D skeleton line by a parameter "*length of internode*" into multiple line-segments. In Fig. 2(a), the branches are flattened on both sides of the trunk and the distribution of the branches is very different from that of the natural plants, so one more step is needed to make them be more reasonably close to the reality. Considering that the plant branches have the largest occupancy rate in space to get the maximum sunlight. Based on this knowledge, the branch skeleton line of Fig. 2(a) is automatically adjusted to generate a spherical shape as shown in Fig. 2(b), which is a 3D skeleton. The 3Dskeleton could be designed interactively in the provided interface. Users could pick an anchor point at each branch skeleton and drag it to any position by mouse as Fig.3(a) shows. Edit operation including copy,

move and delete can be performed on each branch. Meanwhile, another more efficient edit mode, i.e., sub-branch edit mode, is also provided to easy and speed up the design of branch, in which mode all sub-branches can be selected synchronously when their parent skeleton was picked and all edit operations can be done on them (see Fig.3(b)).

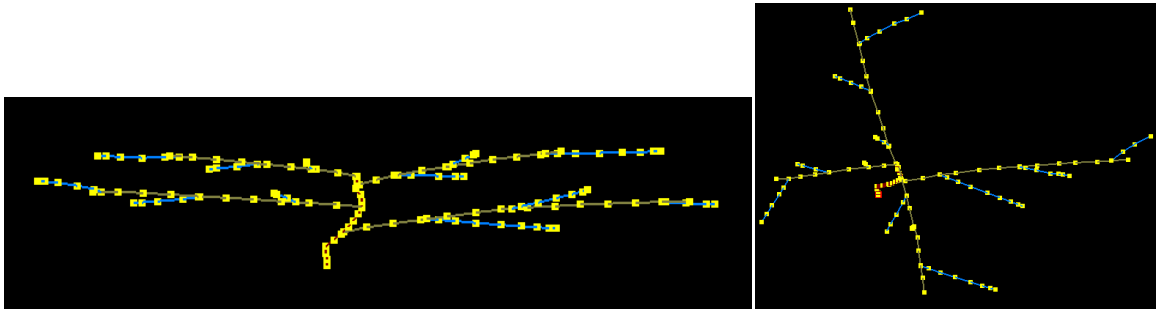


Fig. 2: The automatically generated 3D skeleton: (a) a flat skeleton, (b) a spherical skeleton.

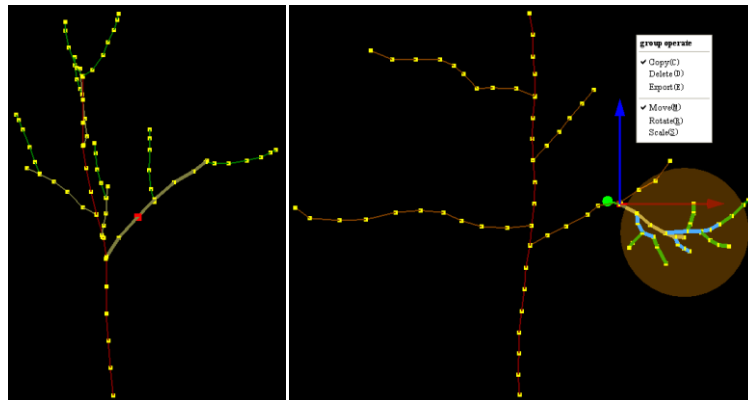


Fig. 3: Interactive design of branches: (a) design one branch through dragging anchor points, (b) design sub-branches at one time by selecting their parent branch.

Generation of the Branch Mesh Model

Once the 3D skeleton of the plant is obtained, its corresponding 3D mesh model can be generated automatically after simply inputting some feature parameters such as inter-node length, inter-node protrusion height, curvature, etc. (refer to Fig.4), which are used to quickly and easily control the detail level of the branch mesh model.

Organs Placement

The final step is to place the organs such as leaves, flowers and fruits on the plant's branch mesh model to form a complete three-dimensional plant model. In this step, internode division is first done.

The internode is a basic unit of plant structure. A branch consists of several internodes and organs such as leaves, flowers, and fruits grow on the internodes. In order to know where to place the organs in the branches, the branches are first divided into segments by setting the parameter "*internode length*"

in Fig. 4 (a). A reasonable random number will be input in this division process such that the length of the internodes on the same branch will not be fixed, making it be more consistent with nature.



Fig. 4: Design three-dimensional skeleton by setting different edit parameters: (a) parameters input interface, (b) bulge effect example, (c) bent shape example, (d) straight shape example.

After defining the length of internodes, the next step is to place the attached organs on the internodes of the branches. (All organs are provided in the form of a three-dimensional template file.) At this point, a series of simple parameters are provided to easily control the size and orientation of these organs. For example, one can set the length of the leaves on the branches through the interactive interface shown in Fig.5(a); the direction of the leaves is automatically calculated by the maximum space visibility algorithm of the leaves (Fig.5(b)). In this way, a more natural plant organ placement posture can be obtained.

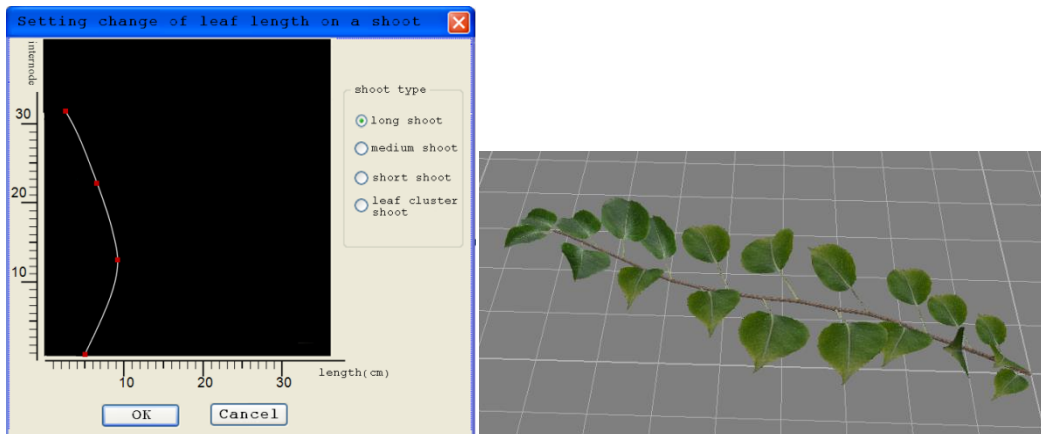


Fig. 5: Design the size and orientation of leaves: (a) the interface for parameter input, (b) determining one shoot with leaves.

Result Examples:

The toolkit presented in this paper has been used to generate plant morphological structures in different seasons. Fig. 6 shows the results of designing a three-dimensional model of an apple tree in the early spring germination stage. During this period, flower buds, leaf buds and auxiliary buds sprout on the tree branches. Fig. 7 is the resulting model of a flowering apple tree.



Fig. 6: Designing an apple tree in early spring: (a) a photo of the tree, (b) the corresponding model, (c) the details including flower buds, auxiliary buds and leaf buds.

Conclusions and Future Work:

This paper presents a graphical toolkit for the interactive design of the 3Dplants with detailed features, ranging from organs to plants to sub-branch groups. Our future work will be done in simulating the growth of plants under different seasons, i.e., a dynamic scene instead of static one now.

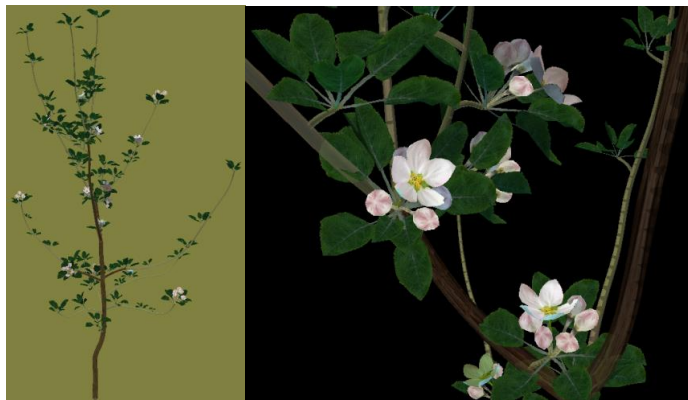


Fig. 7: An apple tree model with leaves and flowers.

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