Interactive flower modeling with 3Gmap L-systems

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Abstract

Flowers have quite an intricate structure consisting of numerous components which, in turn, have an enormous variety of shapes. Therefore, it is not an easy task for computer graphics to simulate such kind of natural phenomena. We propose in this paper an application of the 3Gmap L-systems to flower modeling by growth simulation. Our approach combines L-systems grammar writing with interactive control of parameter settings. The L-systems are used for creating the entire model, with stems,stamens, petals, leaves, etc., by simply operating with 3Gmap volumes. The presented contributions will make the task of a user more obvious and intuitive enabling her/him to create more accurate models. Moreover the way the model is built allows us to take into account its internal structure. As the flower tissue is non-homogeneous, the possibility of obtaining its internal composition could be quite useful for rendering, allowing for instance to render more accurate subsurface scattering.

Keywords: *Geometric volume modeling, L-Systems, Natural phenomena, Flower modeling.*

1. INTRODUCTION

Men's habitat is a green carpet of plants covering our earth. And the most impressive among them are flowers. But besides its enchanted beauty they have quite intricate structure consisting of numerous components which, in its turn, have an enormous variety of shapes. Therefore, it is not an easy task for computer graphics to simulate such kind of natural phenomena.

We can distinguish two different approaches to flower simulation. The first one is aiming at getting a plausible model while the botanical correctness is usually disregarded. Here the task of modeling is undertaken mainly by the user describing a plant structure and its components and defining the required parameters. The degree of realism depends on the users skills. This approach is quite intuitive for a common user, but has the inconvenience of creating each sample from scratch in case of generating a variation of slightly different flowers [10], [11].

The other approach could be referred to as procedural modeling, which tries to provide biologically faithful and visually realistic models [22], [5], [15]. Most of these approaches are based on L-systems, which can generate complicated multicellular structures from a small number of rules [22], [5]. They are able to get a lot of flower samples based on a single grammar by simply changing the parameter values. Although these methods can provide impressive results, the underlying algorithms are not so intuitive for common users.

An analysis of previous work points to look for some kind of symbiosis between these two groups of approaches in order to simplify the task of the user and at the same time to retain the realism of the models. Pursuing this goal we propose in this paper an application of the 3Gmap L-systems: flower modeling by growth simulation. Our approach combines L-systems grammar writing with interactive control of parameter settings. Here the L-systems, in contrast with previously proposed models, are used for creating the entire model, with all its components by simply operating with subdivision of volumes, namely 3Gmaps [12]. The user can control the final result by interactively setting the parameters of the grammar. The used L-systems grammars have a nested structure allowing to combine several grammars which represent the different flower organs. These contributions make the task of a user more obvious and intuitive which in turn enables to create more accurate models. In addition, the way the model is built allows us to take into account its internal structure. As the flower tissue is non-homogeneous, this can be quite useful to render more accurate subsurface scattering.

2. PREVIOUS WORK

Flower modeling methods are not numerous and belong to a bigger research field such as plant modeling, which origins are traced back to L-systems introduced in 1968 by Aristid Lindenmayer. He proposed a formal description of plant development as a string rewriting mechanism which has a recursive nature and leads to a self-similarity in plants. Later on L-systems were extended to several geometric interpretations which were used by computer graphics as a diversified tool for plant modeling [22], [5], [15].

Plant modeling tools such as AMAP [23] and LIGNUM [16] provide a wide range of models and take into account knowledge about plant architecture. Lintermann and Deussen [3] proposed a modelling method that allows easy generation of many types of objects that have branching structures. In this approach, components encapsulate data and algorithms to generate plant elements. Although the L-systems are not explicitly used, still the architectural models described above follow the basic principles of plant development.

In [22], [19], [21] different types of L-systems were elucidated at length and accompanied with the modeling software L-studio [19] and the Virtual Laboratory [5]. These tools enabled to model a wide range of structures and developmental processes in plants by operating with the L-system-based languages (cpfg and lpfg). Yet the shapes of plant organs, represented mostly as predefined surfaces or generalized cylinders [9], are specified by the user and then are incorporated into a plant model. In [7], [8] flowers were described as configurations of modules in space. In [22], [6] such examples as sun flower head, zinnias, water lily and roses were performed using phyllotaxis. Peiyu [15] proposed a flower model using L-systems which represented the topologic information of plant flower and Bezier surfaces for depicting its geometric information. String L-systems are applied to model a wide variety of plants [20], [21]. However they are of one-topological dimension, even if 3D geometrical features are incorporated into a model. Many shapes in nature can only be described by two or three topological dimensions. Thus, Prusinkiewicz and Lindenmayer described in [22] map L-systems and cellwork L-systems which were mainly used for mod-

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eling of cellular layers. These methods provide quite realistic results. However, it is quite difficult to specify L-system grammars and there is not enough control over the generated topologies. In [17], [24] 2Gmap and 3Gmap L-systems address some of the limitations of the previously described methods. These approaches are applied to model realistic leaves and wood. 2Gmap and 3Gmap L-systems are based on two and three-dimensional generalized maps [12], which could be controlled by the operations associated with production rules. The direct use of high level operations on surfaces and volumes simplifies model specification and the use of adjacency relations between volumes allows context-dependent behaviors.

Other methods have also found its niche in the plant modeling area, since the L-systems specification is not so intuitive for the common user. Sketch-based modeling techniques allow a user to easily create a rough model from several strokes. The work of Igiri [10], [11] is an interactive modelling system for flower composition. Here the task of the user is quite easier and takes less time, but still we cannot reckon on creating the models of complicated structures with botanical correctness, neither cannot consider the obtained model as a sample for creating the huge diversity of individuals.

Taking into account the benefits of the previous approaches some methods were proposed, such as [14], [18], [13]. Here the L-systems are mixed with interactive methods, such as Sketch-based or 3D gesture modeling or simply interactive control of parameter values performing bending and pruning branches and arranging and clipping leaves and flowers. Anastacio and Prusinkiewicz [1] propose a combination between sketch-based modeling and L-system, where construction lines are employed to parameterize global features of L-system models.

3. BIOLOGICAL ASPECTS OF FLOWERS

From the biological point of view, a flower can be pictured as a short stem (the receptacle) which holds the components in sequence. At the very tip of this stem are the female organs (carpels), which are surrounded by the male organs (stamens). The outside part of the flower is enveloped by petals and sepals. If we go further into analysis of flower, we can find that the internal structure of its organs is not homogeneous, which plays an important role in the way they absorb and reflect light. Leaves and petals tissues consist of different layers of cells, which have their own properties defining the variety of surfaces and colorations (Figure 1b, 1c). As we can see

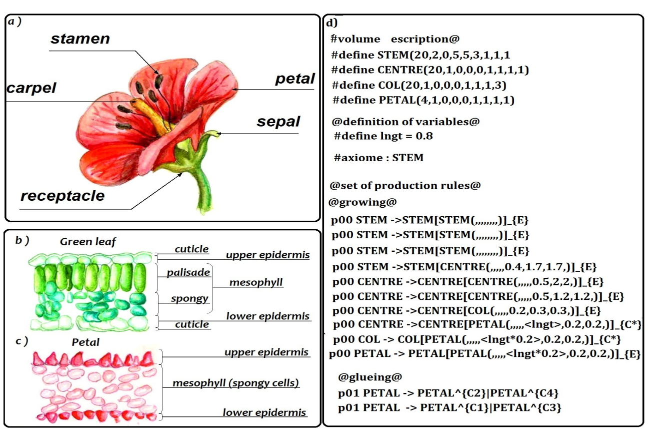

Figure 1: a) Description of flower structure. b) Internal structure of green leaf. c) Internal structure of petal. d) Grammar of a simple flower.

from the flower structure in Figure 1, the shapes of flower components are not only flat but also volumetric, so we have to use a 3 topological dimension structure to represent them. In this paper we propose a flower modeling based on 3Gmap L-systems, which allows to construct a topology of any three-dimensional subdivision. In our method we use a formal L-system grammar to describe a flower structure. The grammar is provided with different tools which make the creation process easier and allows to generate a various flowers with the same grammar. The obtained model then can be interactively adjusted by the user to get more accurate results.

4. GENERATION OF FLOWERS WITH 3GMAP L-SYSTEMS

We propose a flower modeling based on 3Gmap L-systems, a model based on three-dimensional generalized maps, which could be controlled by the operations associated with production rules. 3Gmap is an ordered topological model that allows to represent the topology of subdivisions of orientable or non-orientable 3D spaces, with or without boundary. It is close to facet-edge data structure [2] or cell_tuple [4].

A subdivision of a topological space is a partition of this space into cells with dimensions 0, 1, 2, 3, i.e. into vertices, edges, faces, volumes. This model is based on the use of an unique basic element on which four operators act. These operators are used to represent adjacency relations between edges, faces and volumes. A combination of these basic elements allows to represent the topology of an object, which corresponds to an unlimited number of embeddings of this structure in the three-dimensional space.

3Gmap L-systems are operated with volumes, which are mostly regular prisms. In order to distinguish each volume we use a label, associated to it, which is the word in capital letters. A prism V of order n is denoted as V(n). Each face of a volume also has a label which is defined as V_O, V_E and $V_{C1}, V_{C2}, \ldots, V_{Cn}$ for the base, the end and the side faces of the prism V respectively. A flower

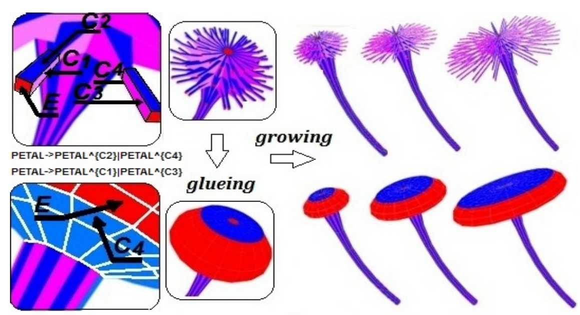

Figure 2: Generated model of grammar in Figure 1d, where growing and glueing operations are used. The model is generated with steps 1, 3 and 6.

shape is created by building volumes using a formal L-systems grammar which consists of a volume description, a variable definition, an axiom and a set of production rules (volume growing, splitting and joining) (Figure 1d, 2). Using 3Gmap L-systems, we can create different flower shapes (Figure 2). By writing a grammar we are operating recursively with different volumes and thus forming an appropriate shape. Once written a grammar we can change its parameter values and get a diversity of flowers.

5. 3GMAP L-SYSTEM ENHANCEMENTS

3Gmap L-systems allow getting quite complex models, however the more complicated the model is the more difficult it is to handle the grammar and the less intuitive it becomes for the user. In order to facilitate the task we propose to add new functionalities such as materials, interactive change of parameter values and modules.

5.1 Materials

Flower structures consist of various organs, which have distinct shapes as well as distinct materials. Different groups of volumes of the grammar represent different components of the flower, such as petals, leaves, stamens etc, which are characterized by diverse colors and illumination properties. Thereby we decided to add a new parameter in a volume definition of grammar. It represents a material of a flower organ and is denoted as integer, which is a number of materials listed in *material.mtl* file, containing definition of its various properties. This function is also useful for the models having an internal structure. Flower tissue is not homogeneous and consists of several layers: upper epidermis, lower epidermis, veins, mesophyll. If we create a model of a petal with all these layers, we assign to each one of them its proper material. Using this contribution the rendered results look much more realistic, as each component of a flower has its own color, illumination properties, etc.

5.2 Interactivity

3Gmap L-system is a parametric model, which allows us to adjust the shape of the flower, by interactively changing parameter values of the grammar. We do not have to recreate the model, but, reusing its topology, reload the embedding of the model (Figure 3a). This constitutes a great advantage because separate management from the topology and from its embedding simplifies the algorithms allowing us to easily create lots of model variations.

After the first loading of a grammar, the model may have a lot of imperfections because the parameter values of the volumes might have not been fitted properly. In order to fix it we should have to come back to the grammar again, change the values of parameters and load a model from the very beginning. This work occupies enough time to make the process of the model creation quite cumbersome. We added a new functionality which makes it possible for a user to change parameter values interactively. This way of changing parameter values is quite faster as it only takes into account the embedding part, leaving the topology part of the program untouched. In Figure 3b we can see how different components of the flower are changing. A user just selects an appropriate volume and, by clicking on a box of parameter values, changes a model shape on the fly, observing the results at the same time. Groups of different volumes can represent flower organs. In order to control them we used variables, which represent different flower component measures. The variable values can also be interactively changed, thus making the flower shape managing even more intuitive and faster. We can also change the topology of volumes interactively which simplifies the creation of models with different number of petals, leaves, etc. In this case the order of the prism is changed and we have to rerun the grammar from the very beginning which is a much slower process than the previous one. Nevertheless, this makes the process of modeling more intuitive for the user.

5.3 Grammar modules

The more complicated the flower is the more intricate and cumbersome the grammar could be. As the flower consists of different organs we decided to introduce modules which can substitute them. Modules are files containing grammars which can represent flower components. They are included into initial grammar, representing the whole model. The module itself can include another module, therefore the grammar has a folded structure, which simplifies its construction and allows creating quite intricate models. In order to construct a grammar with modules which can substitute the flower component, or a flower itself, we just add a needed module like a usual volume, with the only difference that its name must have an ”&” in front of it.

In order to facilitate a task of grammar creation we added a Flower Database (Figure 5a) with different flower organs, where the user can have a look at already existing modules.

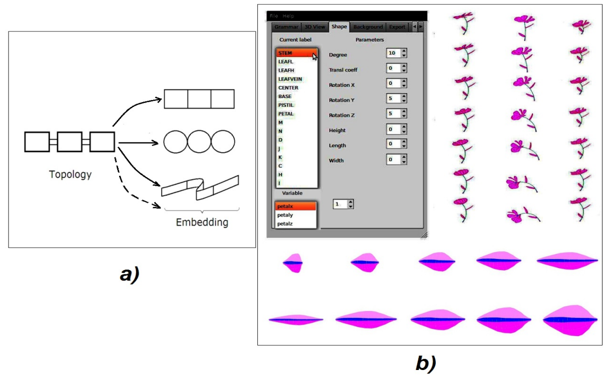

Figure 3: a) Principle of separate management. b) Interactive changing of parameter and variable values in order to modify rotation angle and shape of flower petals and stems.

6. RESULTS

Our method allows to get a mesh of huge variety of flowers, as well as flower compositions and terrains. The software was developed under Linux Ubuntu 9, in c++ using cross platform library Qt, version 4.2. The output is exported to obj format file with the information of material assigned to each volume composing a flower geometry. The geometric models are rendered using Blender version 2.49. In Figure 4 several species of flowers are presented. Figure 5b shows a model of a petal which consists of three layers, each one of which has its proper material. Using subsurface scattering these layers will improve the realistic effect of the rendering results. All the models were created using modules and adjusted interactively.

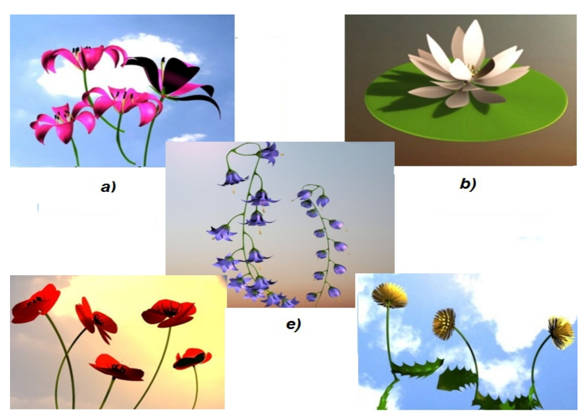

Figure 4: Models of : a) lilies; b) lotus; c) poppies; d) dandelions; e) bluebells.

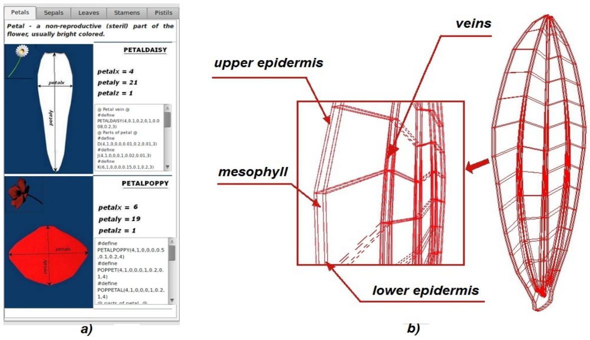

Figure 5: a) Flower database; b) Petal consisting of three layers, each one of it has its own material.

Moreover, our method allows to create realistic terrains of flowers

Figure 6: Flower terrains with models of a) wildflowers; b) daisies.

just using one grammar. We construct a terrain containing volumes and add modules which represent different flower species. In Figure 6 we can see several terrains of flowers, where each flower is different due to passing random parameter values of the modules. The time of generation of models, represented in Figures 6a and 6b is 42.4 s and 27.5 s respectively.

7. CONCLUSION

We introduced a method of flower generation based on 3Gmap L-system, allowing to create a grammar in order to construct flower models. Once written one grammar we can get a great variety of flowers by simply changing the values of its parameters. In that way we have a possibility to obtain complicated scenes with a large number of different flowers with a minimum amount of work on the grammar. We also took into account the needs of the user to have an intuitive modeling tool. Thus the shape of the flower can be modified interactively and the grammar has an intuitive structure allowing to use the modules. Due to volumetric model we can construct the internal structure of flower tissue, which consists of several layers. Assigning a material with special properties to each layer, we would be able to get more realistic results while rendering. Using subsurface scattering for rendering by taking into account the internal structure of the tissue is a future task yet to be implemented. Another improvement to be attained is texture generation according to the flower organs.

8. REFERENCES

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