Dynamic Generation of Plants in Graphics Simulations

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Abstract: In this paper we present methods for the visualisation of plant life for computer games and other graphics simulations in real time. Current systems generally use a very limited number of models of plants that are created in advance and loaded into the system at execution time. Real-time generation saves disk space and allows for a great variety of plants to be used in a simulation. The methods described here will allow the creation of interesting and varied plant life and thus produce a far richer, more appealing and engrossing environment for users.

Keywords: Graphics, Simulation, Games Programming, Real-Time

1 Introduction

In flight simulators, games or visualization it is desirable to be able to display landscapes with a large variety of plant life. This poses a problem for computer systems as models of trees and other plants take up a large amount of memory. To avoid this problem developers normally keep the variety of plants to a minimum and use techniques such as textures to represent plants. Further, these representations of plants are produced in advance and loaded into the application at runtime.

Currently there are two main approaches to producing plant life. The first is the *billboard* approach and the second is the use of polygon meshes. With the billboard approach a picture of the plant is applied to either one or two polygons [1]. This gives a very realistic view of the plant, but only when the plant is viewed from the front. A different type of billboard approach is to use *directional billboards*. Here the view of the plant switches between one of several possible texture maps depending on the viewing direction. This gives good results, but only if the plant is not viewed close up, from above or from below. Another alternative with billboards is the use of *slices*. With this method a number of billboards are used for the same plant. The tree is produced as a series of slices that provide parallax. Again this works only if the plant is not viewed close up, from above or from below. The other main approach is the use of polygon meshes. With polygon meshes the aim is to attain a somewhat realistic looking plant with the least number of polygons. Regardless of which method is used the plant life used in a simulation is created prior to the execution of the application. The plant life is stored to hard disk and loaded when the application starts. Storing the plant life to disk limits the amount of plant life due to the amount of disk space required for the game. For this reason many games are limited to twenty or so individual plants which appear repeatedly throughout the game.

In our work we are investigating methods for creating plant life in real-time. Real-time generation will save disk space and allow for a far greater variety of plants to be used in the game. Our methods were developed to meet the following objectives:

- Quick execution
- Production of results faithful to the visual appearance of plant life
- Production of a wide variety of species
- Production of visible variation in different plants of the same species

2 Plant Modelling

The methods presented in this work are focused on replicating what plant structures look like, that is, plant appearance, rather than modelling biologically correct plant structure. This difference is subtle, but is used to accelerate the modelling of plants, because it is easier in many cases to utilise the rules of plant appearance, rather than the rules of plant growth. A good discussion of mathematical modelling of plants is found in Lindenmayer [2].

To produce results faithful to the visual appearance of plant life, data used to formulate individual plant models is derived partly from field research, and partly from on-line botanical databases. The main on-line database used was Plants Database [3].

Because of the focus on plant life appearance, a view of plant topology will be defined for use in this work. It is stressed that this view is biologically based but is not necessarily true to the correct biological topology of plants. This proposed topology is derived from our research into visual aspects of plant topology combined with existing research on biological topology. The adaptation of the biological topology of plant life for plant life generation is well presented by Reffye et al [4].

The most common model of plant topology is a recursive model as shown in Figure 1. Central to plant life topology is branch order. The order of a branch determines the behaviour of the branch. The highest order branches are leaves. The lowest order branch is the trunk of the tree.

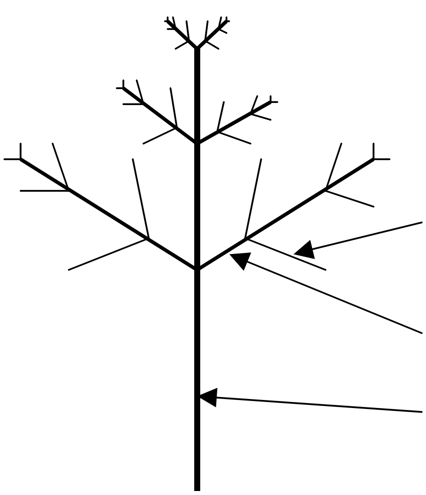


Figure 1. Plant topology showing branch order

A plant generally follows these rules.

- A branch is a length of wood containing nodes
- Nodes are spaced at similar intervals along a branch
- A node may spawn one or more branches of equal or higher order.
- A node may spawn a leaf

Each species of plant life has a maximum branch order. For example, one species may have a branch order of 3 while another may have a branch order of 4. The various attribute of plants that determine their appearance are set for each branch order. These attributes (which hereforth we will refer to as parameters) are presented in the next section.

3 Parameters For Plant Generation

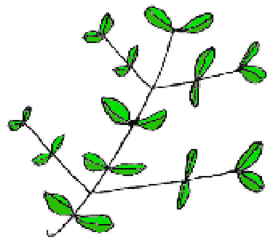
The various features of plant appearance are represented in the form of parameters. Lindenmayer [5] discusses a range of different attributes of plants. The parameters chosen for this work and described below are those that are considered to have the greatest influence on plant appearance. The intent is to be able to produce the greatest amount of feature variation with the least number of parameters. Each of these parameters has a number of variables that control how the parameter is to be applied to the plant. Most of the parameters and their variables have associated probability values. These probability values dictate whether or not the parameter or one of its variables will be invoked at a particular time. For example, the chance of a particular variable being invoked at some time may be one in three.

The following parameters have been incorporated: Ramification, Length Reduction, Fertile Area, Bifurcation, Continued Bifurcation, Gnarl, Phyllotaxy, Multiple Branch nodes. These parameters will now be discussed with reference to how they create realistic plant life representations and how they meet the objectives of detail and variation in plant life.

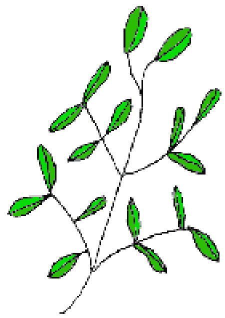
3.1 Ramification

According to basic plant topology branches can have sub-branches that are of higher or equal order. Ramification is defined as a branch being given a higher order than its parent, i.e. the sub-branch is of a different order to its parent.

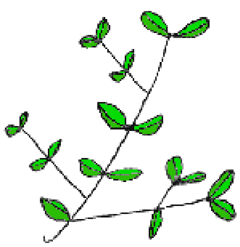
There are three types of ramification: Rhythmic, Continuous, Diffuse. These are shown in Figure 2.



Rhythmic



Continuous



Diffuse

Figure 2: Branch order ramification

The variables that can be set for ramification are ramification type, branch order and node survival rate. Node survival rate determines whether the branch will survive or not. For example in Figure 2 leaves or branches are growing from the main branch.

3.2 Length Reduction

Length reduction refers to the phenomenon by which new sub-branches are generally smaller than their parent. This phenomenon is caused by the sub-branches being younger than their parents and not having as much time to grow. Sub-branches being smaller than their parent is not always the case, alterations to this rule are commonly observed when there has been damage to a plant.

3.3 Fertile Area

A sub-branch produced by a parent branch is usually produced at the top of the parent branch. As the branch grows the first sub-branch created remains towards the base of the branch. i.e. the closer a branch is to the base of its parent the older it is. Most forms of plant life have branches with infertile regions that contain no sub-branches. This phenomenon for the purposes of this work is categorised into two forms - Constant Fertile Area and Percentage Fertile Area. With constant fertile area a set length at the top end of a branch is the fertile part. With percentage fertile area a certain percentage of the branch is fertile.

3.4 Bifurcation

Bifurcation was first examined for it's mathematical basis by Leonardo Da Vinci. Bifurcation is the phenomenon where a branch splits into two; the Frangipani in Figure 3 is an excellent example of this phenomenon.

Figure 3: A Frangipani plant

Bifurcated branches are all of the same order. The branches formed from bifurcation are not sub-branches (from a biological perspective) and can be considered as being the same branch. Bifurcation is similar to identical human twins in that two branches are formed instead of one.

The bifurcation variables include balance and bifurcation angle. Balance determines whether one branch dominates.

3.5 Continued Bifurcation

Often branches on a plant will appear to divide into 3 or more parts as shown in Figure 4.

Figure 4 : Continued bifurcation

Sometimes what appears to be a three way split is often a bifurcation of one branch followed by a bifurcation of one of the other branches. Many plants will develop a secondary bifurcation one node after the original bifurcation, similar to how human triplets are produced.

3.6 Gnarl

A gnarl is the twist of a branch, either because of traumatic conditions or because of the nature of the plant. One of the gnarl variables is the gnarl angle.

3.7 Phyllotaxy

Phyllotaxy is the position of the buds that create leaves with respect to each other. The most common form is spiralled phyllotaxy, which is the type modelled in this work. An angle can be set between each node on a branch. See Figure 5.

3.8 Multiple Branch nodes

It is possible for one node to create more than one sub-branch as shown in Figure 6. Typically there are one, two or four sub-branches per node. This can vary though as, for example, clover has 3 leaves at its nodes.

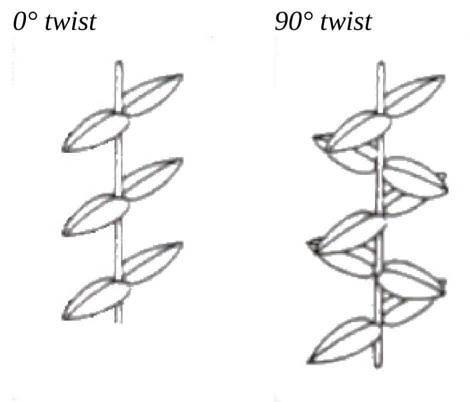


Figure 5: Examples of phyllotaxy.

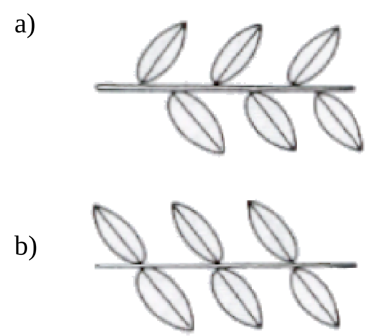


Figure 6: Branch with (a) one sub-branch per node and (b) two sub-branches per node

4 Plant detail

Through the methods outlined above detailed polygon meshes for the plants are produced. To produce a realistic appearance texture maps for bark and leaves are added to the meshes.

Various different species of plants are achieved by two means. Firstly the values of various parameters and their associated variables are set for each species. Secondly, different texture maps are placed on the generated meshes appropriate for the particular species.

Each species has a specified maximum number of orders (i.e. the level of branching) and also a specified average height. The height specification ensures that the relative size of plants is appropriate.

The variation of different plants of the same species is achieved by the random placement of branches that follow the rules for the species. Plant meshes can be structured differently but still be in adherence with the statistics of their plant species. This results in plants that appear very different but are still noticeably the same species. Figure 7 shows three different plants created with our method, using a low quality setting and low leafage, that all appear to be the same species but exhibit variation.

Figure 7: Variation among plants of the same species

Much of the optimisation in this work is based on a simple observation of plant life - plants have more leaves than branches. A plant with only ten branches is likely to have a hundred or more leaves. This results in the recursive algorithms used to generate plants spending most of their time creating leaves. (The leaves are the highest order branches for a particular species). It is because of the relatively large amount of time spent creating leaf nodes that the leaf creation functions are made as simple as possible, thus minimising CPU time used. Conversely the branch algorithms are the ones least called and as they contribute most to the shape and appearance of the plant they are more detailed and demand relatively more CPU time.

5 Conclusion

Our methods for the creation of plants in real-time allow for a large variety of plants to be placed in a game or other graphics simulation. We have identified the parameters required to produce realistic looking plants. Whereas current games typically use a small number of different plants, our methods allow a great variety of plants in a scene thus producing a more realistic environment.

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