# IMPRESSIONISTIC TECHNIQUES FOR RENDERING WOODLAND SCENES

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The authors have been working on the simulation of trees and in particular their representation in the landscape when massed as woodland or forest. The purpose of this work is to provide a representation of trees en masse that is more visually convincing when used in architectural and environmental computer aided design applications - architectural models, landscape design and evaluation, and historical reconstructions. Although our research was directed initially at producing a better compromise between realism and the economical use of polygons, we found that we were developing an impressionistic approach to modelling elements in the landscape which, if applied in other contexts, challenged the conventional approach of creating simulations from a literal translation of the geometry of the subject. The paper explains the process by which the software was developed, describes the interaction by which the user produces the scenes, and ends by proposing tools which would allow the user greater determination of those factors which create a more visually convincing simulation.

**Categories and Subject Descriptors:** I.3.5 [Computer Graphics] Computational Geometry and Object Modeling; I.3.7 [Computer Graphics] Three-Dimensional Graphics and Realism.
**Additional Keywords:** Impressionistic techniques, Landscapes, Woodland.

## THE RESEARCH CONTEXT

### Drawbacks of conventional techniques

Trees form a important visual element of our landscape. Whether singly forming a landscaped setting for a new building, as part of mixed woodland within a local development plan, or an extensive coniferous plantation as a backdrop to a new motorway, trees provide a major element in the formation of a visual judgement of the quality of the environment.

The aim of the architect, designer or environmental planner in using modelled simulations is to communicate the appearance of the design proposition. Increasingly these visualisations include 'fly-throughs' which conventionally demand that as much data as possible is three-dimensional and can be shaded in real-time.

The modelling of man made entities such as buildings, roads or bridges is commonplace and can be achieved with all commercial CAD systems. It is now standard practice that the geometry creation for simulation is achieved by a literal process of geometry conversion in which the geometry of the real or proposed object is directly converted into a data based replica.

### The problems of the literal translation of geometry

However the creation of three-dimensional models of elements that exist within the natural landscape is far more problematic. To model individually every leaf and branch of hundreds of bushes and trees, would not be practical. For a start, the description of the geometry is forced into man made geometric analogues and is unsuited to natural elements. Irregularity and complexity are fundamental characteristics of a landscape and, in order to be faithful to nature, every element must be different since the eye is able to recognise pattern very quickly. Some specialist systems automate this process of literal translation but the extremely high polygon count generated by such a process is a severe handicap when motion through the scene is required.

Abstracting the forms by using simple geometric shapes such as spheres or cones to represent trees is more efficient, but the results appear unnatural and unconvincing. Texture mapping using 2D images is probably the most frequently used technique and has the advantage of keeping the geometric detail low. Inserting images of real trees into a landscape simulation in the form of "billboards" can be very effective. However, there are inherent difficulties integrating 2D representations into the 3D scene, the most significant being that these tree images will not accurately reflect changes in lighting conditions and view positions.

### The starting point for the research

The need for our research was generated by the inability of currently available architectural and environmental CAD systems to provide a means of producing visually convincing representations of woodland scenes. There was a mis-match between the ease with which visually convincing representations of built forms could be achieved using relatively modest architectural CAD systems and the very real difficulty of achieving similarly convincing representations of the natural landscape.

Figure 1. Lansdown Hill near Bath.

We considered the means by which artists, using a wide range of graphic techniques, have been able to create simulations of reality for thousands of years, albeit in two dimensions. "It looks so realistic" is not a comment about an image that depends on an accurate geometry description but on the quality of the representation employed and its ability to convince the viewer that it is a representation of the subject.

In constructing this realistic representation the artist does not attempt to paint or draw every single element of detail on a tree, but uses his skill as a visual interpreter to apply enough detail of form and colour to give us the impression of the natural object. Similarly, the traditional architectural modelmaker will produce a model of a building in which the trees may be made of wire and sponge and the lake from glass, yet still the effect is credible. Thus it should be with the representations and models used in virtual environments. The aim should be to create a visually convincing impression of the subject of the simulation.

**The development of an impressionistic approach**

Taking the general notion of three dimensional impressionist models as a possible avenue of exploration we started to consider how this could be achieved in practice. It soon became clear that, in the majority of instances, viewing of the woodland elements would take place at a distance from the viewer, in terms of model space, and that the geometry of the leaf itself was going to be sub-pixel in size and its precise geometry was therefore relatively unimportant. Here our approach diverged from the conventional approach.

With 'literal' geometry models the shading algorithm determines the visual representation to achieve a better, more visually convincing, simulation. The user must vary parameters such as texture maps, colour or lighting parameters to improve the effect. The alteration of the geometry itself in pursuit of a better visualisation is not usually an option.

Little consideration is given to the fact that the modeller may have a clear idea of how the simulation should appear to the viewer. Shading algorithms can have the unhelpful property of translating the geometry data into artificial looking simulations rather than simulations that look convincing. In order to counteract unrealistic looking shaded effects, one of the authors has considerable experience of using 'unreal' parameters -

such as underground light sources - to achieve a more 'realistic' visualisation.

So in this project we set out to achieve the opposite to the normal approach. We set out to provide the user with a tool that can be used to derive and optimise geometry entities that will produce visually convincing woodland scenes. If, in achieving this aim, this meant the leaves are square so be it.

An example of the output created by the program that has been developed is shown in Figure 1.

## THE DESIGN OF THE TREE SIMULATION SOFTWARE

### Research Aims

CAD systems using three dimensional modelling offer a means of representing or assessing the visual impact of environmental entities upon the landscape to a range of users from architects to environmentalists. The aim of our research was to develop software which can efficiently simulate wooded landscapes that are visually convincing in such applications.

### Research Brief

The following requirements formed the brief for the development of the software.

- The software will model the terrain and trees in three-dimensions.
- The shaded image generated will provide a representation that is as visually convincing as possible.
- The scene will be able to be viewed in real time from any arbitary point specified by the user.
- The user will not need to view scenes in which trees are in the immediate foreground.
- The method will be economic in the use of geometry in order not to restrict real time viewing.
- The topography will be described explicitly.
- The geometry of the trees will be determined through stochastic and procedural methods.
- The user will input the type of tree required in a given area, the density of planting, age and season. From this the tree position, shape, size and colour will be computed.

### Tree Architecture

The appearance of a tree is a direct consequence of its structure. Although accurate modelling of the structure has never been our objective, it has been helpful to refer to some papers on the architecture of trees. Our initial assumption for the underlying description of the tree was an ellipsoid and this was supported by McPherson and Rowntree[1] who found that if tree crowns were represented by ellipsoids, the differences between the ellipsoid and actual crown profile areas were not significant. Hutchinson et al[2] studied the distribution of leaf-inclination angles on deciduous trees in a forest. They discovered that the mean, area-weighted, leaf-inclination angle for the whole canopy was 33 degrees to the horizontal. They also discovered that the greatest leaf-area density was in the over-storey and the mean individual leaf area was maximum in the mid-canopy. This information has been useful when determining the polygon normals.

### Representation of leaves

The simplest polygon, the triangle, is used to represent not a single leaf but a group of leaves. All the polygons have the same width to length ratio, although their size may vary. When using the term polygon in the following description, we are referring to this single geometric entity that is used to represent the appearance of a group of leaves.

### Polygon placement

The position of a polygon is determined by using a 3D texture function[3] to displace a random point on a partial ellipsoid surface which forms one of the vertices of the polygon. Increasing the maximum displacement factor (roughness) will make the crown shape appear more irregular as demonstrated in Figures 5 and 6.

### Polygon orientation

We know that on real deciduous trees most leaves are inclined at angles about midway between the vertical and horizontal. Remembering that our tree model is only a simplification of the leaf canopy, we make the following assumptions:-

- The mean polygon inclination angle is 40 degrees.
- The actual inclination angle of a polygon is determined randomly from a +/- 8 degree range about the mean value.
- The polygon normal always points away from the centre axis of the tree with some random variation.
- The normal azimuth angle has a random variation of +/- 20 degrees.

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1 McPherson E G, Rowntree R A, 'Geometric Solids for Simulation of Tree Crowns' Landscape and Urban Planning, 15 (1988), pp79-83

2 Hutchinson B A, Mott D R, McMillen R T, Gross LJ, Tajchman S J, Norman J M, 'The Architecture of a Deciduous Forest canopy in Eastern Tennessee', Journal of Ecology (1986), 74, 635-646

3 Perlin K, "An Image Synthesiser", Proceedings of SIGGRAPH 85 in Computer Graphics 19(3), July 1985, pp287-296.

## Colour

Silicon Graphics' GL rendering routines are utilised to flat shade the polygons. To simulate daylight the scene is illuminated from a white light source at infinity. The GL reflection model requires specifying the diffuse, specular and ambient colour properties of the illuminated material. Each colour property is defined using a RGB colour triplet. The RGB colour model is not very intuitive when it comes to finding a particular colour, therefore the hue-saturation-value (HSV) colour model was used. HSV values are then converted into RGB.

## Simulated shadows

Shadows are an important visual characteristic of trees. Any simulation of foliage must include the brightly illuminated outer leaves and the darkened interior in order to be convincing. This effect was achieved by implementing an approximate shading technique, similar to that described by Reeves[4]. The sharp, accurate shadows which are produced at considerable computational cost by ray tracing techniques are not necessary. Our method simply assumes that polygons on the outer ellipsoid surface will be brightest and those displaced furthest by the 3D texture function towards the centre of the ellipsoid will be darkest. The variation in colour is achieved by altering the diffuse properties of each polygon.

## Polygon size

An undesirable consequence of using a parametric description of the ellipsoidal tree crown is that the density of the polygons will be greater at the top of the tree. This is an unnatural effect which can be overcome in two alternative ways.

One way would be to adjust the random selection of points on the surface so that there would be fewer polygons at the top. The other and much easier way has been chosen in which the size of polygons is varied so that they appear to be less densely packed at the top of the crown. This is not too dissimilar to what happens on real deciduous trees. Recall that Hutchinson et al[2] had found that leaves were smaller but occured in greater numbers at the top of the tree canopy. The polygon size is determined by linearly interpolating between a minimum value at the top of the crown and a maximum at the point of maximum crown diameter.

[4] Reeves W T, Approximate and Probablistic Algorithms for Shading and Rendering Structured Particle Systems' Proc SIGGRAPH '85 in Computer Graphics, v19, n3, July 1985, pp312-322

## Gaps

The underlying branching structure of a tree causes leaves to cluster into groups, leaving gaps in the foliage. To model this effect, the 3D texture function was used to remove groups of polygons. As explained earlier, a 3D texture value is associated with each polygon. The distance the polygon is displaced from the outer ellipsoid surface is calculated from this value. By introducing a threshold variable it is possible to select a proportion of polygons to be left undrawn. A polygon is drawn if the 3D texture value is less than the threshold value. As the threshold value is increased the gaps grow larger.

## Data structure

Three separate sets of data are used in the program:
**tree attributes:** The set of parameters which alter the shape and appearance of the tree foliage. The user can save any discrete set of parameters as a file.
**crown data:** The polygonal data-base generated from the attributes. It holds the coordinates of the three vertices of every leaf, and the 3D texture value from which the colour is computed. The data is stored to memory, not disk, to minimize access times. Dynamic memory allocation is used to allow flexibility in the number of leaves.
**tree data:** The position of the tree in world coordinates, and the angle through which the tree is rotated about its own vertical y-axis.

## Appraisal of the polygon-based model

In summary, the solution has the following main features:

- It is a representation designed to be efficient. The polygons representing the leaves are much simpler, larger and fewer than an accurate biologically based model would require. However when viewed, the individual polygons, which are no more than simple triangles, very successfully capture the appearance of tree foliage. Only the outer tree foliage is modelled. Although the internal branch structure is ignored, the back faces of the polygons serve the purpose of conveying the impression of this internal structure.
- The model is fully three-dimensional. The tree geometry is described using polygons in 3D space. The polygon database therefore can be exported to other modelling systems.
- Variable 'appearance' parameters are provided to control the attributes of the tree model. The general shape of the tree, the colour and density of the leaf canopy and the bumpiness or roughness of the tree crown can be altered. This provides considerable scope for varying the appearance of trees to match a range of different situations.
- Detail can be reduced with respect to distance. Efficiency is increased by reducing the number of

graphical elements as viewing distance increases. The general tree shape is not dependent on the size and number of polygons.

### Conclusion

A flexible program has been developed which allows for the easy introduction and testing of several new attributes to the tree model. By trying out different values for these attributes it is possible to assess visually what effects they have on the appearance of the tree model. The initial aim was not to produce especially realistic images of trees, but rather to discover the usefulness of each attribute. Note also that the appearance of the model could still be enhanced further by improving the techniques described below or by developing the model further. However a wide range of visually convincing effects can be achieved using these attributes.

## THE CREATION PROCESS

### Creation of a New Tree Model

The user goes through the following process:

- Select the type of tree required with the SHAPE|TYPE command. There is a choice of NORMAL, WINTER or CONIFER styles as depicted in Figures 2, 3 and 4.
- Enter the dimensions of the tree crown using the HEIGHT, DIAMETER and CROWN SIZE commands on the SHAPE menu.
- Use the NUMBER OF POLYGONS and POLYGON SIZE commands on the SURFACE menu to define the level of detail in the model.
- The tree model will now be displayed in the Viewing Window. Viewing the model can be performed from different angles and distances in order to assess subjectively the effect of the foregoing geometry parameters.
- Set the colour and material properties of the model, with the PROPERTIES|COLOUR command. The material properties are defined by entering HSV colour values. The shading in the interior of the crown can be altered by adjusting the minimum and maximum diffuse values.
- The shape of the crown can be refined further with the TIP POINT and CURVE commands on the SHAPE menu.
- The ROUGHNESS and GAPS commands can be used to introduce more irregularity to the crown's surface. The effectiveness of these functions is controlled by the DISTORTION attribute. Enter a value for this attribute with the DISTORTION command. The effect of these functions is depicted in Figures 5 and 6.
- All these attribute values can be adjusted until the appearance of the tree model displayed in the Viewing Window is satisfactory.

**Figure 2. Normal**

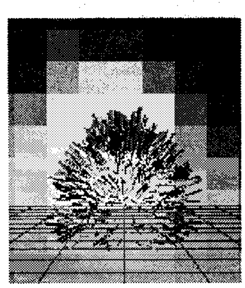

**Figure 3. Winter**

**Figure 4. Conifer**

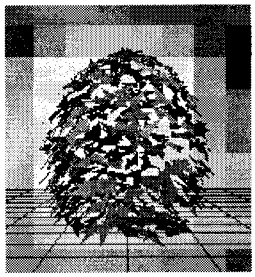

**Figure 5. R = 0.0**

**Figure 6. R = 0.3**