Natural Lighting of Vegetation based on Polar Planes

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ABSTRACT

We present a lighting method for outdoor scenes with vegetation. The method is compatible with multi-resolution trees generated using random L-systems. We include a sky dome model that gets the luminance and chromaticity values at several sampling points for different time and location. The samples are used to compute the light arriving to the objects in the scene depending on the insolation conditions. The method proposed is based on the form factor and polar plane concepts. These concepts are used not only to illuminate leaves or ground, but to solve visibility problem too.

Keywords

Natural Scenes, Lighting simulation, Vegetation Rendering, Form factor

1. INTRODUCTION

In this paper, we present a new method for rendering vegetation scenes. It includes the sky modeled as a light source that allows the illumination of the different objects in the scene, like leaves or ground, for different insolation conditions.

Our illumination method is applied to trees modeled using a multi-resolution L-system [Lluch03] which we had also developed.

In 1996, Max [Max96] proposes to combine pre-computed images in order to get new images from different viewing positions. Leaves are rendered using textured polygons obtained from digitalized real leaves.

Later, several investigators have used radiosity methods for lighting scenes with vegetation [Max97] [Daub97] [Chel98] or ray-tracing techniques [Trax97].

In 2000, Jakulin [Jaku00] shows a new approach for trees interactive rendering that uses a ray-tracing software for visualizing textures.

Meyer, Neyret and Poulin [Meye01] have introduced a method based on a hierarchy of bidirectional textures (HBT). When rendering, an image for the current view and light directions is reconstructed, interpolating between the two closest pre-computed billboards.

Recently in 2003, Nakamae, Tadamura and Nagai [Qin03], have proposed a method for obtaining photo-realistic outdoor images of trees. They use a combination of 2D buffers for storing geometrical and shading information of tree surfaces.

Realistic rendering techniques for vegetation scenes have tried to solve the complexity problem and the incorporation of natural light sources. Because the particular characteristics of the sky as light source, several investigators have proposed specific modelling methods [Pere93] [Pree99].

Section 2 describes the sky model implemented. In Section 3 and 4, an illumination method based on the polar plane concept for the calculus of the form factor is proposed. We apply our method to the visualization of a scene in Section 5, and the main characteristics of our approach are underlined in Section 6.

2. SKY MODEL

The sky dome is modeled using a triangle mesh hemisphere approximation. The triangulation is done by levels. The high level triangle vertexes are the sampling points used to the radiance computing. A sky model is applied all these points to get the radiance.

Thus, we only apply the sky model in a preprocessing phase saving rendering time.

The light coming from the sky dome can be considered as a non uniform wide light source. The light angular intensity depends on insolation conditions. We apply a parameterized illumination function, based on the methods described in [Pere93] and [Pree99]. The parameters used in this function allow us the adaptation to the insolation conditions.

For each hour we store the color of all sampled points in a color-buffer.

3. SINGLE POLAR PLANE

The *form factor* of a surface *i* to a surface *j* (F_{ij}). It allows calculate the reflection among objects assuming luminous energy is conserved in a closed environment [Sill94]. Our interest relies in the fact that we can use it in our method for simulating the proportion of radiant flux coming from a surface (the sky) and arriving to another surface (leaves or ground).

The polar plane method can be included into the group of techniques that use an infinite plane parallel to the differential surface dA_i containing x point from which we wish to calculate the form factor.

The same simplifications used in the calculation of the form factor by discrete projective methods are adopted here, emphasizing the similarity of the polygon-polygon's form factor to the point-polygon's form factor [Sill89] [Cohe93].

In [Vice99][Vivo01] is demonstrated how given a form factor value it is possible to calculate the sequence of radius *Ri* that define successive circles centered on the pole. All rings defined by two adjacent circles have the same form factor.(figure 1).

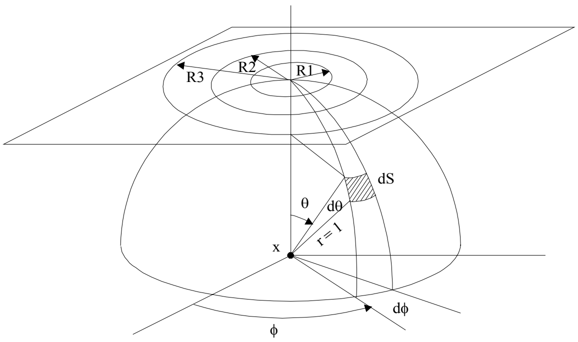

Figure 1. Circular rings with constant form factor.

Thus if *n* rings are sought, the form factor will be the same for all:

$$\Delta FF = 1/n$$

Considering all of this, we propose the arrangement of identical form-factor sectors in order to calculate a point to polygon form factor. Given a ring, it is uniformly subdivided into *m* sectors, so the form factor of each sector is:

$$\Delta ff = \frac{1}{n \cdot m}$$

4. POLAR PLANE LIGHTING

The luminous intensity that reaches any polygon is obtained taking advantage of the color computed for each sky dome sampling point. The polygon is supposed to be centered in the hemisphere representing the sky dome, since can be assumed that light coming from sky does not depend on the height over the ground.

The calculus of illumination for an arbitrary polygon is a very computationally expensive process. That is why the illumination for specific orientations is pre-computed and stored in a table using the polar plane technique.

The main idea consists in projecting onto its polar plane the visible sky portion for each orientation and time. We assign to each occupied sector the luminance corresponding to the sky patch projecting on it.

The maximum luminance for each time corresponding to a specific orientation is the addition of the occupied sectors luminance, assuming there is not occlusion problem (figura 2).

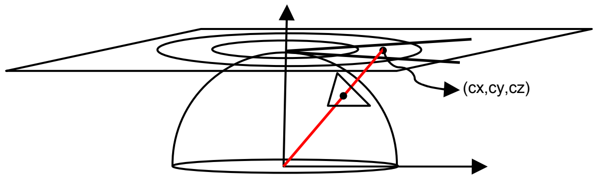

Figure 2. Projection of the sector central point.

Once known the triangle where the sector central point projects, the sector luminance is assigned interpolating among the triangle vertices.

The illumination process of each leave in a tree depends on its orientation and position. A leave is modelled with a single polygon whose orientation is known. So, the maximum luminance coming from the visible sky can be computed for each leave and time interpolating among the four closest pre-computed orientations.

Since leaves are not isolated part of light corresponding to the orientation of a leave is hidden by other surrounding objects.

The polar plane for an *i* leave is obtained interpolating among polar planes of its closest orientations. So, the addition of all the visible sectors values matches up the radiance value for that leave orientation at each specific time.

5. APPLICATION TO A TREE

In this section we apply our lighting method to the visualization of a tree.

The ground has been defined as a mesh of quadrangles, as an alternative to applying a texture. Therefore, the light reaching the ground is the light emitted by the sky at specific time. Random perturbations are applied to the vertices mesh, this lets the ground to adapt to the lighting conditions, i.e. not only its color, but also the shadows thrown by the trees.

5.1. Branch generation

The model of trees used here is based on multi-resolution L-Systems [Lluc03]. The L-Systems' derivation process generates a chain, whose interpretation generates a multi-resolution branch structure. It allows visualize the tree with different levels of detail. In order to apply the described lighting method it is necessary to have, additionally to the data structures which represent the sky and the leaves, data structures storing the hierarchy of the tree branches.

We randomly distribute the leaves inside the bounding box of those branches supporting leaves. Generally, only the branches in the last level will be considered to be leave generators although this will be eventually decided by the L-System in use.

5.2. Data structures

The sky is represented using a list of vertices and a list of triangles. For each vertex, its coordinates and the color obtained at every hour are stored. Additionally, the position of the sun at every hour is stored (figure 3).

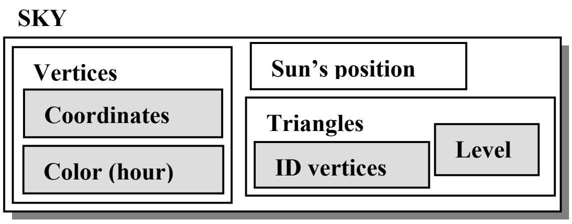

Figure 3. Data structure for the sky.

The data structure which is used for storing the information of every pre-computed orientation (fugure 4) includes the vector normal to the polar plane corresponding to that orientation, the maximum luminosity (color) for each hour and the corresponding polar plane. For each polar plane are stored de radius of every ring, the radius of the balance hemi-rings of equal form factor and the central point of every sector. Furthermore, for every sector, the luminosity which corresponds to that orientation for every hour is stored.

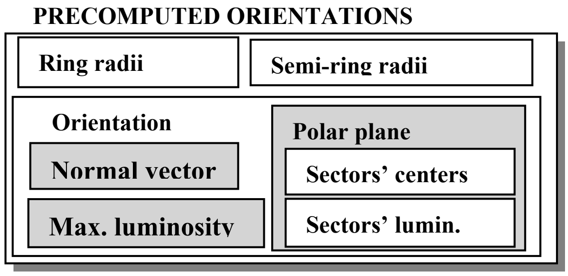

Figure 4. Pre-computed orientations.

Also, the information for each branch in a certain level of detail is stored.

For each leave the following information is stored: the normal vector, its location, vertices in local coordinate system and the luminosity for every hour. Finally, each leave randomly orientated maintain a data structure to keep its polar plane information.

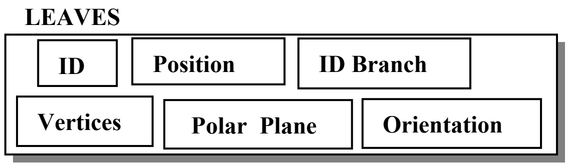

Figure 5. Data structure for leaves.

5.3. Results

In this section we show the results we have obtained applying our method.

The values of luminosity and chromaticity of the sky have been computed for 14 different hours corresponding to our time zone, in the interval from 6:00 a.m. to 7:00 p.m. The position on earth chosen has been the city of Valencia, which corresponds to 0.26917° longitude west and 39.28583° latitude north. The images have been rendered for the 175th Julian day.

In figure 6 we show a hemi-sphere with pre-computed orientations at 2:00 p.m. Figure 7 shows a tree we whose leaves have been distributed accordingly to the multi-resolution L-system structure.

Figure 6. Pre-computed orientations. 14:00h.

Figure 7. Left: 7:00h; middle: 12:00h; right: 18:00h.

6. CONCLUSIONS

A natural lighting method has been presented here, which includes modeling of the sky, the ground and the vegetation. We have achieved the goal of computing easily the amount of sky light that arrives to each object in outdoor scenes. The method has been fundamentally applied to the illumination of the random oriented leaves. The leaves belong to a synthetic tree which was generated with a multi-resolution L-System.. Our main contribution is to pre-compute the radiance in a set of polar planes to speed up the rendering process.

Another fundamental part of the method is the visibility function. Taking advantage of the polar plane structure we can approximate the amount of light arriving to a leave by simple interpolation. In addition, the same structure acts a visibility buffer saving memory and giving coherence to all the process.

REFERENCES

[Chel98] M. Chelle, B. Andrieu, K, Bouatouch, Nested radiosity for plant canopies, The Visual Computer, Springer Verlag , pg.109-125, 1998

[Cohe93] Cohen, M.F., Wallace, J.R. Radiosity and realistic image synthesis. Academic Press, 1993.

[Daub97] K.Daubert, H.Schirmacher, F.X.Sillion and G.Drettakis, “Hierarchical Lighting Simulation for Outdoor Scenes”. Springer Computer Science, Rendering Techniques’97, pag. 229-238, 1997.

[Jaku00] A. Jakulin. Interactive Vegetation Rendering with Slicing and Blending EUROGRAPHICS 2000

[Lluc03] J. Lluch, E. Camahort, R.Vivó, “Procedural Multirresolution for Plant and Tree Rendering”, 2nd International Conference on Virtual Reality, ComputerGraphics, Visualization and Interaction in Africa. AFRIGRAPH 2003. ACM SIGGRAPH, pp 31-38, 2003.

[Max96] N. Max “Hierarchical Rendering of Trees from Precomputed Multi-Layer Z-Buffers.” In Rendering Techniques'96, Springer Computer Science, pages 165--174. SpringerVerlag Wien New York, 1996.

[Max97] N. Max, C. Mobley, B. Keating, W. En-Hua, “Plane-Parallel Radiance Transport for Global Illumination in Vegetation”, Rendering Techniques’97, Springer Computer Science 1997, pg.239-250

[Pere93] R. Perez, R. Seals, J. Michalski, “All-Weather model for sky luminace distribution- Preliminary configuration and validation”, Solar Energy Vol. 50 nº3, pg.235-245, Pergamon Press , 1993

[Pree99] J, Preetham, P. Shirley, B. Smits, “A Practical Analytic Model for Daylight”, Computer Graphics Proceedings, 1999, pg.91-100, SIGGRAPH 99

[Qin03] X. Qin, E. Nakamae, K. Tadamura, Y. Nagai, “Fast Photo-Realistic Rendering of Trees in Daylight”, Computer Graphics forum, vol.22,3, pg.243-252, 2003

[Sill89] François Sillion and Claude Puech. A General Two-Pass Method Integrating Specular and Diffuse Reflection. Computer Graphics, 23(3):335-344, Julio 1989.

[Sill94] F.Sillion, C. Puech, “Radiosity & Global Illumination”. Morgan Kaufmann Publishers, inc. San Francisco, California. 1994.

[Trax97] C. Traxler, M. Gervautz, “Efficient ray tracing of complex natural scenes”. Proceedings of Fractal 97. 4th International Multidisciplinary Conference 1997.

[Vice99] M.J.Vicent, J.Lluch, R.Vivó, Un método para el cálculo del factor de forma alternativo a hemi-cubo. Congreso Español de Informática Gráfica, CEIG’99, I.S.B.N. : 84-89869-81-2, pp. 303-316. Jaén 1999, Spain.

[Vivo01], R.Vivó, M.J.Vicent, J.Lluch, R. Molla, P.Jorquera. Study of the form factor calculation by single polar plane. IASTED. International Conference on visualitation imaging and image processing. ISBN: 0-88986-309-1.Marbella 2001, Spain.