Extended Ambient Term

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Abstract

The ambient term in a renderer is a constant color added to all points which is a crude global approximation to indirect lighting. Because the ambient term ignores geometric occlusion conditions, it is computationally inexpensive. We present an extended ambient term that provides better results than the constant term but is still inexpensive because it also does not compute occlusion conditions. It is based on the idea of finding a six-sided axis aligned environment which is similar in color and area to the real scene, and deriving an approximation to indirect lighting by computing interreflections in the simplified scene.

1 The Classic Ambient Term

The ambient term was first used in computer graphics in the early shading models [Pho75]. A principled way to set the ambient term was introduced in the context of a sort of remainder term in radiosity solvers [CSWG88, NTE95]. In that work the ambient color is approximated by the amount of indirect light in a room with constant reflectance equal to the average reflectance of the real scene being rendered. While such an approximation is likely to be in the right general range of values, it is a constant term which lacks the visual richness of real indirect lighting.

2 The New Extended Ambient Term

From a basic idea suggested by Neumann et al. [NN95], we develop the *extended ambient term*, a new operator that incorporates some geometric considerations of the scene without including expensive occlusion operations. The polygons in the scene are classified into a small number C of classes according to their surface normal vectors. The distribution of the unshot power of the classes is then estimated rapidly by solving a system of small linear equations. In essence, this is a radiosity solution for a simple enclosure that is in some sense representative of the real scene. The unknowns in this system are the indirect lighting colors (ambient terms) for each class. To solve the system of equations, we first must estimate the form-factors between the classes.

The extended ambient term is an improvement over the classic ambient term in that it includes more information about the distribution of scene normals and reflectances. Instead of having only one average reflectance for the whole scene, we will work with one average reflectance for each class, and instead of considering a single unshot power for the whole scene, one for each class will be used.

To simplify both the estimation of the form-factors and the solving of the system, the number of classes has been fixed at six, with each class identified with the face of a cube. Thus, in analogy with the faces of a cube, we set the value of the form-factor between two different classes to 0.2 and between a class and itself to 0. Note however that a different number of classes C could be used.

2.1 Polygon Classification

A first naive approach could assign each polygon (patch) in the scene to just a single class. Instead of this, we use a more sophisticated approach in which each polygon i will have a weight μ_{ik} for each class k (the sum of the weights for each polygon being 1). This approach uses more geometric information with a very small increase in cost. A higher value of the weight will mean a higher contribution of the polygon to the class, and *vice versa*. Note that these weights can easily be computed by using the identification of each class with the face of a cube. In this case, the dot product between the normal vectors of the polygon and the face will give (if positive) the weight (if negative, the weight will be set to 0).

Once the weights are obtained, we compute for each class the quantities:

- $A_k^{cl} = \sum_i \mu_{ik} A_i$, the total area of class k.
- $\bar{\rho}_k^{cl} = \frac{\sum_i \mu_{ik} A_i \rho_i}{A_k^{cl}}$, the average reflectance of class k.
- $U_k^{cl} = \sum_i \mu_{ik} U_i$, the total unshot power of class k.

where A_i, ρ_i and U_i are the area, reflectance and unshot power, respectively, of patch i, and the sum runs over all patches.

2.2 The system of equations

We can establish, for every class k, the radiosity equation, where the unknown B_k^{cl} is the outgoing radiosity corresponding to class k and F_{kj} is the form-factor from class k to class j:

$$B_k^{cl} = \frac{U_k^{cl}}{A_k^{cl}} + \bar{\rho}_k^{cl} \sum_{j \epsilon 1..C} B_j^{cl} F_{kj} \tag{1}$$

This leads to a linear system of C equations where C is the number of classes. By solving this system we obtain for each class k the outgoing radiosity B_k^{cl}. The incoming ambient radiosity for the class k is then:

$$B_k^{cl(in)} = \frac{B_k^{cl} - \frac{U_k^{cl}}{A_k^{cl}}}{\bar{\rho}_k^{cl}} \tag{2}$$

Finally, we obtain the outgoing ambient radiosity corresponding to each patch by computing the weighted average of the ambient radiosity of every class and multiplying by the reflectance of the patch:

$$B_i^{AMB(out)} = \rho_i B_i^{AMB(in)} = \rho_i \sum_{k \epsilon 1..C} \mu_{ik} B_k^{cl(in)} \tag{3}$$

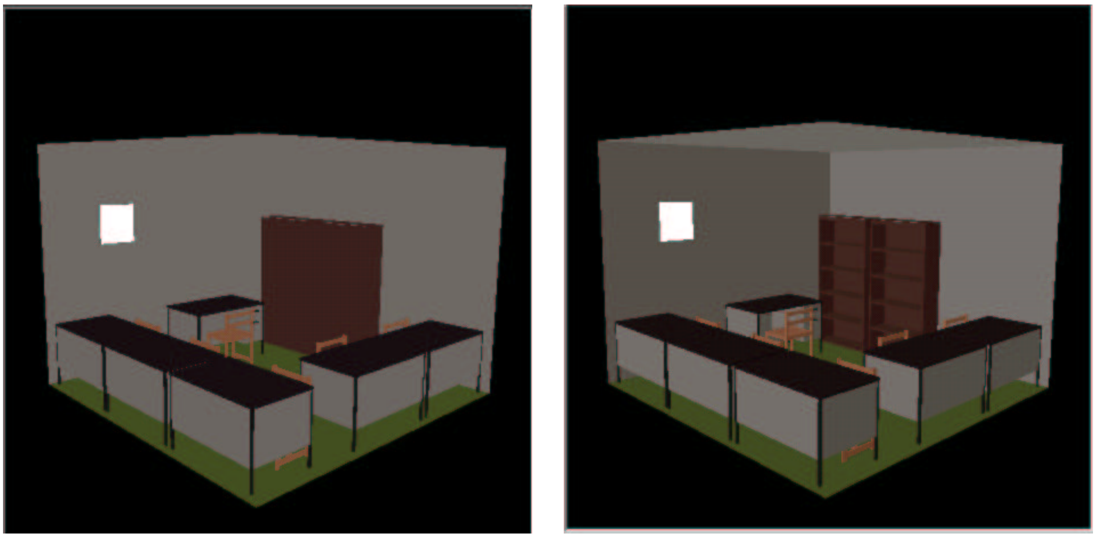
3 Results

The application of the extended ambient term makes the ambient illumination much better than the classic ambient term. The use of C ambient values, C being the number of classes (6 in our case), instead of a single term, gives greater expressivity to the obtained images, which can be seen in Figure 1. The image obtained with the extended ambient term (on the right) offers more information than the other image, due to the contribution from each class. Note that in this example no direct illumination was computed, so the radiosity for every patch is only due to the ambient term and, in the case of light sources, to emittance. The increase in execution time with the extended ambient term is very small, from 0.24 to 0.29 seconds. All images in this section were computed on a Pentium II at 350 Mhz.

Some color bleeding effects can be observed in Figure 2. The scene represented consists of a grey cubic room with a red wall and a green wall opposite each other. There is a white sphere in the center, and a square lamp stuck on the ceiling. The image on the right was computed using the extended ambient term. Observe the color bleeding in the sphere; the zones in front of the red wall look reddish, and the ones in front of the green wall look greenish. These color bleeding effects are due to the zero contribution of a class to itself in the system of equations (remember that the form-factor $F_{kk} = 0$). Thus in this Figure the reddish patches have a large weight for the class to which the green wall belongs, and this class is influenced by the other five classes, but not by itself. Then, the reddish patches have received a very small influence from the green wall, which explains its reddish color (the same occurs for the greenish patches).

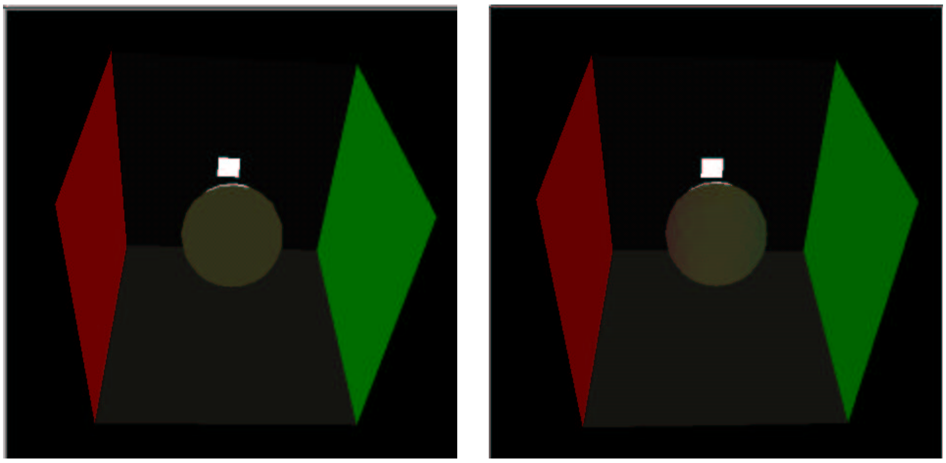
Note that the color bleeding effects are related to the reflectances of the classes established in the scene. For instance, in the scene of Figure 2, where the contribution of each wall to the reflectance of the classes is very important, changing the color of the walls could cause the color bleeding to disappear or even be inverted.

Another important effect that we can observe in Figure 2 is the color shifting between adjacent patches on a curved surface. This smooth transition is due to the use of the weights to express the relation between patches and classes. Without this fuzzy classification, we would have an unpleasant non-continuous transition instead of color shifting.



(a) (b)

Figure 1: *(a) Classic ambient term. Execution time: 0.24 sec. (b) Extended ambient term. Execution time: 0.29 sec.*



(a) (b)

Figure 2: *(a) Classic ambient term. Execution time: 0.27 seconds (b) Extended ambient term. Color bleeding and smooth transition are noticeable. Execution time: 0.31 seconds.*

The extended ambient term has some limitations. Large environments divided into several rooms could produce undesired effects. For instance, if we consider a scene with some light rooms and some dark rooms, the results will not be acceptable, because the ambient term will be added to both dark and light rooms. Essentially, this drawback is due to the fact that occlusion conditions are not taken into account by the extended ambient term. Note however that the same drawback exists for the classic ambient term.

4 Conclusions and future work

We have introduced here the extended ambient term, an improvement on the classic idea of the ambient term. It is a new and simple method to view the unshot (or residual) power in the solution. The main point of this new technique consists in the replacement of the constant operator that involves the classic ambient term with a more complex operator that takes into account geometric considerations. These considerations lead us to the use of a small number of classes in which the polygons in the scene are classified in a non-disjointed way according to their normal orientation, being assigned a weight for each class. A radiosity system of equations solves the balance of power between the classes. Note that occlusion conditions are not considered, just self-emission, reflectances and normal vectors of the surfaces.

Using six classes seems suitable because it makes the classification of the polygons easier while reducing additional storage to a minimum. Although a higher number of classes could be used, the increase in cost makes this unattractive. The extended ambient term produces some nice effects that significantly improve the visual quality of images by simulating many of the large-scale effects of a much more computationally expensive radiosity solution.

Because the extended ambient term is an improvement on the classic ambient term, it has the same applications. It can be applied to radiosity methods that compute the expansion solution for the rendering equation in an explicit way as in progressive radiosity [CSWG88], and in an implicit way as in the multi-path method [SPNP96]. The improvements in the obtained images can have repercussions in several fields such as design, animation production, or interior decoration. Note that the extended ambient term can be used both to rapidly obtain an image without any initial distribution of power, and as a final stage of the global illumination process to smooth the result by distributing the unshot power.

Although in this paper we have only taken care of radiosity, the idea of the extended ambient term could be used in global illumination methods that deal with non-diffuse environments, like ray-tracing, z-buffer, etc. The execution for non-diffuse cases would use the average albedo instead of the reflectance ([NN95]) and patches would be replaced with pixels. Note that non-diffuse surfaces would show color change (also for planar polygons) according to the incident angle of view direction. So, it is important to note the generality of this extended ambient term in global illumination. Practically, it can complete every rendering software (z-buffer, classic ray-tracing, radiosity, etc.), adding all the nice features previously mentioned, at negligible computational cost.

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References

[CSWG88] M.F. Cohen, E.C. Shenchang, J.R. Wallace, and D.P. Greenberg. A progressive refinement approach to fast radiosity image generation. *Computer Graphics, 22(4)*, pages 75–84, 1988.

[NN95] L. Neumann and A. Neumann. Radiosity and hybrid methods. *ACM Transactions on Graphics. Vol. 14, No. 3*, pages 233–265, 1995.

[NTE95] L. Neumann, R.F. Tobler, and P Elias. The constant radiosity step. *Rendering Technics*, pages 336–344, 1995.

[Pho75] B.T. Phong. Illumination for computer generated pictures. *Communications of the ACM, 18(6)*, pages 311–317, 1975.

[SPNP96] M. Sbert, X. Pueyo, L. Neumann, and W Purgathofer. Global multi-path monte carlo algorithms for radiosity. *The Visual Computer*, pages 47–61, 1996.