Indirect illumination on curve surfaces.

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Abstract

In this paper we suggest improved method of photon registration on curve surfaces, presented by triangulated mesh with “true” normals in mesh vertices. Such presentation is widely used for simulation the differing effects of light and color across the surface of an object (Phong shading). It was found that direct photon registration, which does not take into account interpolated (smooth) normal in given mesh point, creates visual artifacts. In the paper the modification of photon registration method is suggested. The modified method cures the problem with artifacts.

Keywords: *Global illumination, photon maps, Illumination maps, smooth shading.*

1. INTRODUCTION

Most of the modern methods of global illumination computation use photon registration on illuminated surfaces. The photon registration is used in photon map methods [1, 2] and in illumination maps technique. Illumination maps technique [3, 4] stores results of global illumination simulation (that is distribution of diffuse illuminance in the whole scene) in view-independent way. These data (called "illumination maps" or i-maps) allows generating a series of high-quality images (differing by observer position and viewing parameters) after time consuming global illumination simulation was done only once. The illumination maps provide also real-time walk-through with account for global illumination results with OpenGL based hardware. Certainly global illumination will be correctly taken into account only for pure diffuse surfaces, but it is acceptable in most cases when indirect illumination is significantly lower than direct one or when diffuse luminance is the dominant one. The two-pass method should be used for global illumination computation in case when pointed above conditions are not satisfied. At the first pass, the lighting distribution over scene surfaces is computed using radiosity [5, 6, 7] or photon mapping [2, 1, 8] methods. The illumination maps also can be used here. They differ from classic photon maps mainly in registration approach. In the second (rendering) pass the so-called final gathering [9, 5, 6, 7] approach should be used to provide high spatial resolution of lighting details for a given camera view. Only photon registration specific on curve surfaces presented by triangulated mesh with “true” normals in mesh vertices is considered here. It is not essential is the registration done in the form of photon map (hit is registered directly) or illumination map (hits are registered on the triangle vertices). The nature of problem is the same. Although in the case of final gathering the artifact problem will be partially hidden by illuminance averaging from different directions. Below the illumination maps will be used for problem illustration, because they are used in our system [4] directly.

2. PHOTON REGISTRATION ON ILLUMINATION MAP

The result of global illumination analysis in our system is represented by the so called "illumination maps" which describes illuminance distribution in the scene. Illumination maps keep illuminance values at each vertex of triangle mesh. Then these values can be linearly interpolated inside each triangle. So, illumination maps can represent an arbitrary continuous piece-wise linear function of illuminance distribution. For global illumination simulation our system uses Forward Monte Carlo Ray Tracing with unit energy photons. Each event that may change ray energy (a partial absorption in material or surface) is treated in the probabilistic way, by the Russian Roulette Rule: either the ray survives with the unchanged energy or it completely disappears. By a proper choice of probabilities of these two events we can simulate any rate of light absorption. In this sense we follow the global idea of using a random choice everywhere without decrease of simulation accuracy [3]. This idea was explicitly stated in [10] (in application to the Backward Monte Carlo ray tracing).

During Forward ray tracing ray-surface intersections (photon hits registration) are processed in the following way: if a ray hits a triangle that keeps i-maps then appropriate element(s) of the i-maps is modified to account the energy brought by the ray.
Let us denote triangle vertices as P1, P2 and P3 and illumination values for these vertices as V1, V2 and V3. These variables accumulate so called raw illumination maps. These values are proportional to the number of rays fired by scene light sources. Finally physical values are calculated multiplying by so called “elementary flux” which is equal to the total scene luminous flux divided on the number of traced rays. Taking into account our approach about linear interpolation of illuminance inside triangle the energy delivered by the given photon hit to the triangle should be distributed between the V1, V2 and V3 according the following formula:

V1 += B1; V2 += B2; V3 += B3; (1)

where **B1**, **B2** and **B3** are barycentric coordinates of ray/triangle intersection point in the triangle coordinate system.

3. CURVE SURFACE PROBLEM

The formula (1) is correct if triangulated mesh represents the flat surface, but it becomes incorrect if triangulated mesh represents curve surface. Let us consider simplified scheme of photon registration on curve surface represented by triangulated mesh with “true” normals in the mesh vertices:

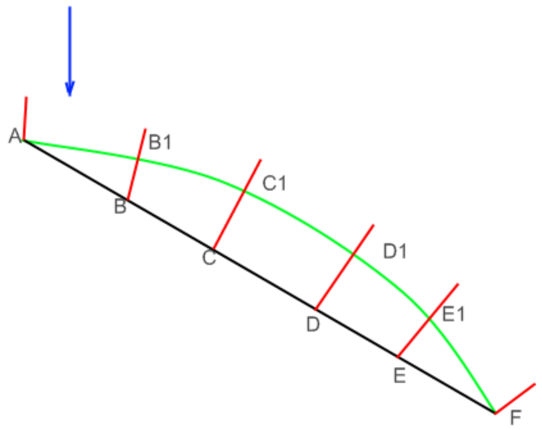

Fig. 1. Simplified scheme of photon registration.

We illustrate the problem on 2D drawing (fig. 1) instead of 3D one. The green curve AF denotes the curve surface from initial scene geometry. The set of grey segments (AB, BC, and so on) denote the triangulated mesh representing the green curve surface. The red segments (BB_1, CC_1, and so on) denote the "true" normals in triangle vertices of AF mesh. Let us blue arrow is the direction of parallel light illuminated our curve surface. From the fig. 1 we have that illumination of segment AB is proportional to the cosine between illumination direction and the segment AB normal, while illumination of curved segment AB_1 (let us consider it as sufficiently small one) is proportional to the cosine between the illumination direction and normal to the segment AB_1. Unfortunately the formula (1) does not take into account "true" normals in the triangle vertices. It corresponds to the appropriate flat geometry described by the triangulated mesh. So indirect illumination calculated by Forward Monte Carlo Ray Tracing will produce the "flat" image as it is presented in fig. 2 for test scene with cylinder and sphere. In the same time the image calculated for the curved surface illuminated by the parallel light using Phong shading is smooth (illustrated in fig. 3 for test scene).

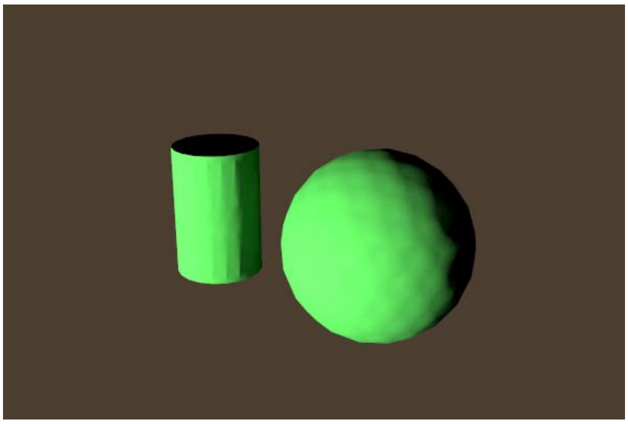

Fig. 2. Image obtained by Forward Monte Carlo Ray Tracing.

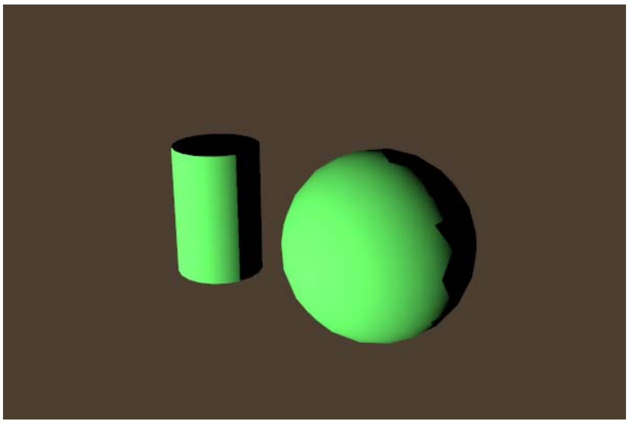

Fig.3. Image obtained by using Phong shading.

4. PROBLEM SOLUTION

As it was already pointed the illumination of the small surface area (fig.1, segments AB_1, B_1C_1, and so on) should be proportional to the cosine between the illumination direction and the "true" surface normal in the given point while the formula (1) uses in fact the cosine between illumination direction and the "flat" surface normal. So this difference can be compensated by multiplying the registered photon energy by the ratio of the cosine between illumination direction and the "true" surface normal to the cosine between illumination direction and the "flat" surface normal:

m = DotProd(ray, s_norm)/DotProd(ray, s_norm) **(2)**

Finally instead formula (1) we should use the formula (3):

V1 += B1*m; V2 += B2*m; V3 += B3*m; **(3)**

Fig. 4 shows our test scene calculated applying "true" normal compensation (formula (3)) during i-maps calculation. It is visible that artifacts disappear and surfaces look smooth.

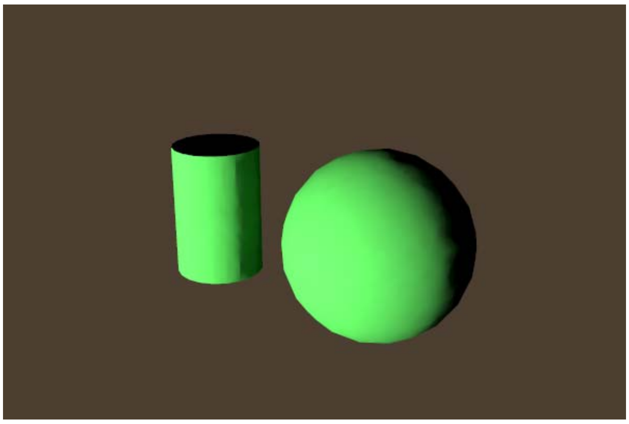

Fig. 4. Image obtained by modified Forward Monte Carlo Ray Tracing.

Using Forward Monte Carlo Ray Tracing for direct illumination calculation is inefficient and was done for problem demonstration only. More realistic example is illumination of this scene by secondary light – by light reflected from a surface. We replace the parallel light source in this scene by the disk which reflects light. The obtained results are shown on fig.5 and fig.6.

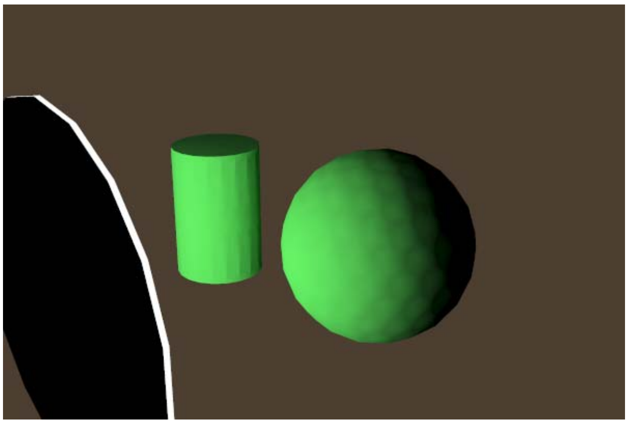

Fig. 5. Image obtained by original Forward Monte Carlo Ray Tracing.

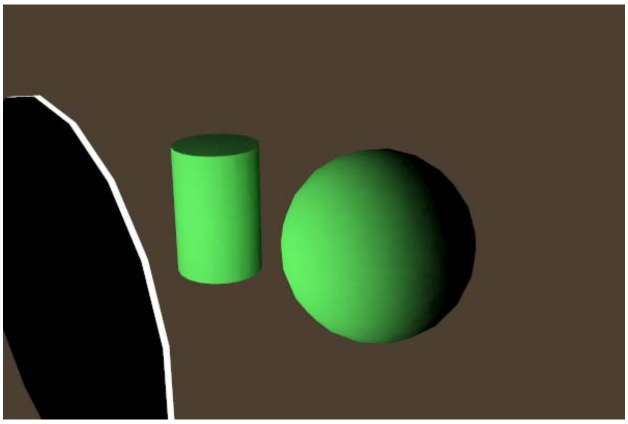

Fig. 6. Image obtained by modified Forward Monte Carlo Ray Tracing.

It should be noted that suggested method compensates artifacts produced by triangulated mesh representation of curve surface only partially. First of all it can not compensate the artifacts produced by some "shading" of triangulated mesh edges, which does not exist for real curve surface. At the second it also can not correct the artifacts produced by difference in ray paths for real and triangulated surfaces. This difference is critical for rays close to the tangential one to the real surface. The ray can miss the triangulated surface while intersect the real one and vice versa. Nevertheless overall image quality is significantly improved by the suggested method.

5. PRACTICAL RESULTS

The problem described above takes place for real scenes, when the curve surfaces are illuminated mainly by indirect illumination. The images below were obtained for the cabin of aircraft by original (fig. 7) and modified Forward Monte Carlo Ray Tracing (fig. 8). The whole illumination in cabin of aircraft is indirect one. It is typical illumination for the cabin of aircraft.

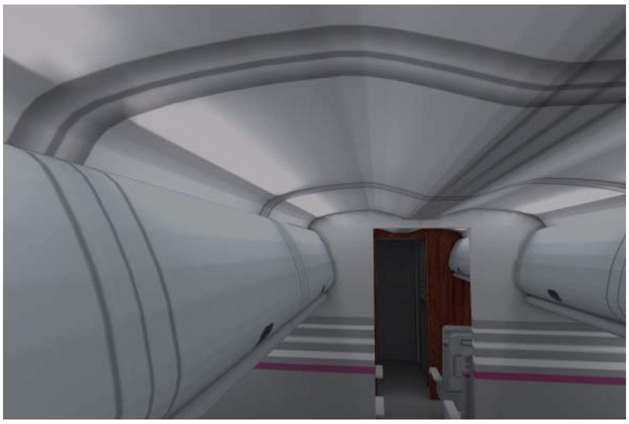

Fig. 7. Image obtained by original Forward Monte Carlo Ray Tracing.

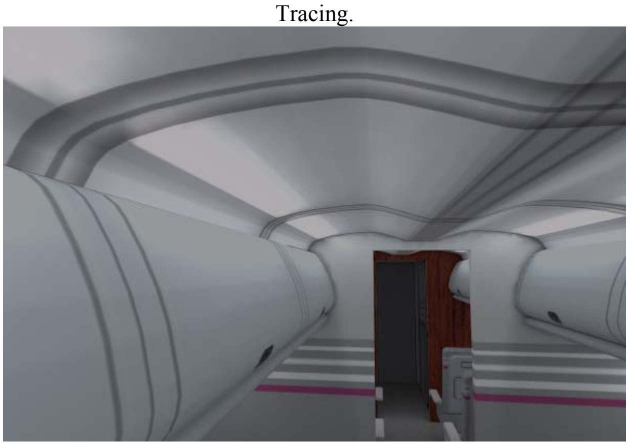

Fig. 8. Image obtained by modified Forward Monte Carlo Ray Tracing.

Image quality was essentially improved, but some artifacts are still visible. These artifacts can be removed almost completely by using illumination maps filtration. The result is shown on fig.9.

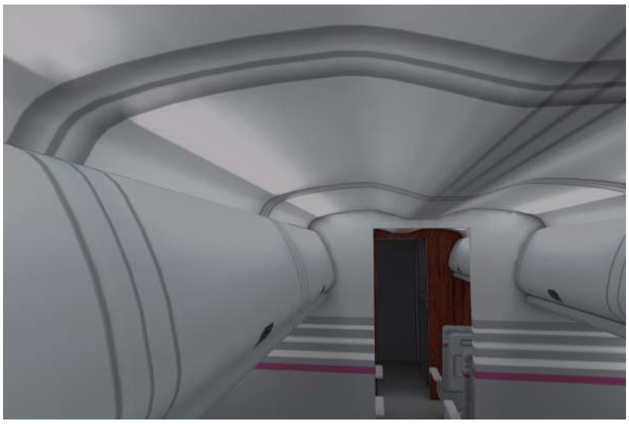

Fig. 9. Image obtained by modified Forward Monte Carlo Ray Tracing with illumination maps filtration.

6. ACNOWLEGMENTS

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7. REFERENCES

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