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TITLE: Simulation of Partially Obscured Scenes Using the Radiosity Method

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Abstract

Simulation of Partially Obscured Scenes

Using the Radiosity Method

by

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Using the extended radiosity method [1, 2] or zonal method [3, 4] realistic synthetic images are constructed of visual scenes in the visible and infrared containing radiatively participating media such as smoke, fog and clouds. Computational methods will be discussed as well as the rendering of various scenes using computer graphics methods.

Our extended radiosity method for illuminated surfaces A_i and volume elements V_k is based on the two following coupled linear systems of equations for monochromatic radiation:

$$B_i^s A_i = E_i^s A_i + \rho_i \left[\sum_{j=1}^{N_s} B_j^s \underline{S_j S_i} + \sum_{k=1}^{N_v} B_k^v \underline{V_k S_i} \right], \quad i = 1, \dots, N_s, \quad (1)$$

$$4 \kappa_{t,k} B_k^v V_k = 4 \kappa_{a,k} E_k^v V_k + \alpha_k \left[\sum_{j=1}^{N_s} B_j^s \underline{S_j V_k} + \sum_{m=1}^{N_v} B_m^v \underline{V_m V_k} \right], \quad k = 1, \dots, N_v, \quad (2)$$

where B_i^s is the surface radiosity in $[W m^{-2} s^{-1}]$, E_i^s is the emission and ρ_i is the reflectance of surface patch i with area A_i . The flux density leaving a volume element k is given by $4 \kappa_{t,k} B_k^v V_k$ where $\kappa_{t,k}$ is the sum of the absorption coefficient $\kappa_{a,k}$ and the scattering coefficient $\kappa_{s,k}$, and B_k^v is the volume radiosity. The scattering albedo of the k -th volume element is $\alpha_k = \frac{\kappa_{s,k}}{\kappa_{t,k}}$. The volume and surface radiosities are given by the sums of the emission and the scattered and reflected radiosities from all other surfaces and volumes. The fraction of energy reaching a surface or volume from another surface or volume through an absorbing medium is given by view factors. The view factors from a surface k to surface j is $\underline{S_k S_j}$, the view factor from volume k to surface i is $\underline{V_k S_i}$, the view factor from surface j to volume k is $\underline{S_j V_k}$, the view factor from volume m to volume k is $\underline{V_m V_k}$. The view factors depend on the geometry and attenuation of fluxes between elements and are usually difficult to evaluate.

Eqs. (1) and (2) assume that the surfaces are Lambertian reflectors so that the light is scattered equally into all directions. Three dimensional structures like clouds, fog and smoke can be simulated, by assigning absorption and scattering characteristics independently for each volume element V_k .

To illustrate the use of the radiosity method we considered a simple case where a parallelepiped of a homogenous participating medium is located above a flat Lambertian surface. The surface consists of $N_s = N_x \times N_y$ rectangular patches with varying reflectance. The parallelepiped is divided into $N_v = N_x \times N_y \times N_z$ volume elements. As illumination source we chose a point source at infinity with illuminating rays from the direction (θ_s, ϕ_s) . The observer is located at (x_0, y_0, z_0) . The solution of eqs. (1) and (2) can be obtained using a Gauss-Seidel iteration scheme. Since we assumed a homogeneous participating medium we had to compute only form factors from one volume element to all others and from one surface to all volume elements. The surface to surface view factors are

all zero because of the flat surface assumption. Calculations with $N_x = N_y = N_z = 10$ through 14 were performed for various cases and the solutions were rendered to produce synthetic images. The intensity of the light reaching the observer from a certain direction or along a ray is given by :

$$I(L) = \exp(-\kappa_t L) \frac{B_i^s}{\pi} + \int_0^L \exp(-\kappa_t l) \frac{B^v(l)}{\pi} \kappa_t dl, \quad (3)$$

$I(L)$ is the intensity on the outside of the imaged parallelepiped, L is the distance between the entrance point of a ray to the exit point. If the exit point lies on the surface the attenuated radiosity B_i^s must be added to the integral. The volume radiosity $B^v(l)$ along a ray from 0 to L can be found by trilinear interpolation of the volume radiosities.

Although computationally intensive the extended radiosity method is shown to be useful to generate highly realistic scenes taking multiple scattering between surfaces and a participating medium, like smoke or another obscurant, into account which would be hard to compute otherwise.

References

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