Will Anyone Really Use Radiosity?

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Abstract

The radiosity technique for the simulation of energy exchanges in synthetic models has been continuously improved in the past 15 years, to the point where impressively realistic images can be produced, and the technology is being offered in commercial products. Does this mean it can be used in practice? Many obstacles remain, obviously, for non-expert users who may want to produce meaningful simulations, and radiosity can hardly be described as a mature technology. We consider here the potential applications where a user will want to use radiosity: we identify the remaining technological barriers, and present some avenues being explored to lift them.

Key words: Radiosity, lighting simulation, Hierarchical techniques, Clustering, Radiosity refinement, Dynamic radiosity, Multi-resolution models.

Résumé

La technique de radiosité pour la simulation des échanges énergétiques dans des modèles synthétiques a été améliorée tout au long des 15 dernières années, à un point tel que des images d'un réalisme impressionnant peuvent maintenant être produites, et que cette technologie est intégrée à des produits disponibles commercialement. Peut-on affirmer pour autant que cette technique est utilisable en pratique ? Clairement, il reste extrêmement difficile pour des utilisateurs non-experts de créer des simulations utiles, et la technologie de la méthode de radiosité n'a pas atteint un stade de maturité suffisant. Dans cette présentation, nous nous intéressons aux applications potentielles de la radiosité : nous identifions les verrous technologiques qui subsistent, et présentons certaines directions de recherche prometteuses pour réduire ces obstacles.

Mots Clés : Radiosité, Simulation de l'éclairage, Méthodes hiérarchiques, Regroupement, raffinement, radiosité dynamique, modèles multi-résolution.

1 The radiosity method

The radiosity method, extended from its original heat-transfer simulation domain to Computer Graphics and synthetic imaging in the 1980s, is a computational tool that simulates the distribution of energy in a three-dimensional scene. The method relies on an explicit discretization of the illumination, reducing the computation to the resolution of a balance equation, with coupling coefficient called *form factors*. Recent developments of radiosity include the simulation of non-diffuse reflectors, the introduction of hierarchical formulations, and the definition of improved computation strategies.

The essence of radiosity methods is to build a spatial data structure (usually a surface mesh), based on the scene geometry, to represent the illumination. Stochastic methods can also be used to record light paths, instead of enumerating form factors. Such "Monte Carlo radiosity" and "photon map" methods are therefore included in this discussion.

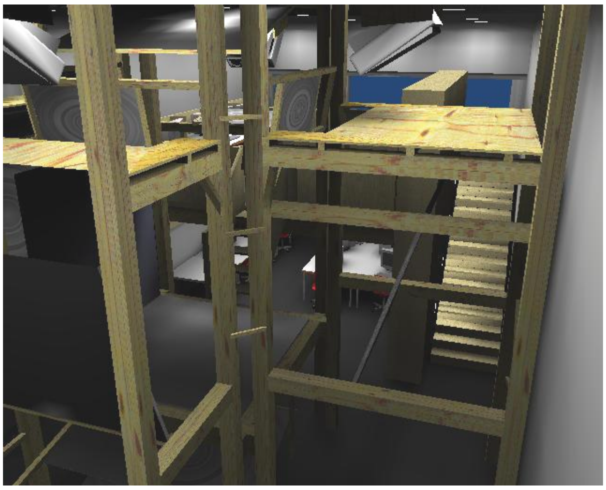

FIG. 1: A radiosity solution of the VR Laboratory at Fraunhofer-IGD (Darmstadt). The complex geometry of the room produces mostly indirect lighting.
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2 Why should one want to use radiosity?

Radiosity techniques have a number of interesting properties, which make them very useful for a variety of applications:

- By construction, they compute a global illumination solution, including indirect lighting and "color bleeding" effects, responsible for the visual ambiance in a scene.

- Hierarchical radiosity methods offer the ability to compute solutions of varying accuracy, with a corresponding difference in speed.
- They are well suited to interactive applications, with frequent modifications of lighting or geometry.
- Their ability to pre-compute diffuse lighting makes them ideal for the creation of pre-lit environments for virtual reality.

3 Current limitations

Still, radiosity techniques suffer from a number of problems, which have restricted their diffusion and use in real-world applications.

- Since they rely on a spatial data structure to record illumination, they have difficulty adapting to the variety of input descriptions found in practice.
- Rendering directly from the computational mesh can generate visual artifacts.
- Controlling the trade-off between accuracy and speed can prove difficult for non-expert users.
- Memory consumption is often quite high, limiting the use of radiosity in complex scenes.

None of these problems should be considered an intrinsic limitation of the radiosity approach, however, and we claim here that they constitute interesting areas of research, that should all be resolved in the near future. Several research directions are reviewed below, with some ideas about possible solutions.

4 Hierarchical radiosity and Clustering

There is no hope of performing a useful radiosity calculation on any significantly-sized scene without using a hierarchical formulation of radiosity, most probably with some form of *clustering*. What is, however, an appropriate clustering strategy? Easy, top-down approaches that insert objects in a spatial subdivision structure may tend to ignore the actual properties of the scene, while more sensitive bottom-up approaches are likely to prove too expensive. In addition, different clustering methods will impact the results of the radiosity simulation, as soon as some energy transfers are computed to/from clusters.

5 Visual quality

Is it possible to create beautiful pictures from radiosity solutions? A large body of work has been devoted to the reconstruction of radiosity function from meshed solutions, as well as to the optimization of the mesh boundaries. Here again, however, practical constraints mean that the theoretical solutions based on additional mesh refinement are not always applicable in large scenes. Still, several promising avenues should lead to robust and practical radiosity-based rendering systems. E.g. using the radiosity solution as a source of illumination from which to illuminate visible parts of the image; incorporating knowledge about the reconstruction process in the mesh refinement (see below); or replacing expensive meshes by carefully computed textures.

6 Hierarchical refinement

How should one control the placement of radiant exchanges in a hierarchy of clusters and surfaces? This is certainly one of the most difficult remaining questions; probably because there is no single answer, but a collection of application and data-specific answers. When computing a radiosity solution for use in an immersive VR application, avoiding visually disturbing artifacts is more important than the accuracy of the energy calculation. Conversely, applications whose main purpose is simulation (lighting engineering, non-visible light imaging) will not care about visual quality but rather insist on quantitative faithfulness.

The challenge then becomes that of packaging the complexity of all the refinement strategies and options in a form that can be easily controlled by the targeted user.

7 Dynamic environments

Changing environments are an application area where the specific algorithmic choices of radiosity methods (i.e. the idea to maintain an explicit representation of energy transfers) can be turned into definite advantages. For interactive applications, in which the user can modify the scene properties, well-designed hierarchical techniques can concentrate the computation to the areas of the scene most affected by user changes. When the sequence of modifications is known in advance, radiosity techniques could be used to take the best advantage of temporal coherence, ensuring that the illumination will vary in a smooth manner across the animation.

8 Conclusions

Why is radiosity not used more today, despite the beautiful images published over the years in research papers? Because potential users need robust, easy-to-control tools! These require algorithms that have yet to be invented for hierarchy creation and clustering, control of hierarchical refinement and visual quality, and fully integrated treatment of dynamic environments.

9 References

Obviously there are too many relevant references to list in this short abstract. The interested reader will find more pointers at the following address:

[1] ARCADE (Automatic Radiosity for Complex and Dynamic Environments), "*Making Radiosity Usable*". `http://www-imagis.imag.fr/ARCADE`.