

BUILDING WITH LIGHT

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Computer simulation of architectural lighting is emerging as a powerful tool for the visual interpretation of predictive illuminance calculations, and to provide new methods for complex interiors. Many types of lighting environments can now be simulated, and much higher scene complexity is possible with recent advances in the computer algorithms. This paper offers an explanation of some of the techniques and is illustrated by a video animation of architectural interiors.

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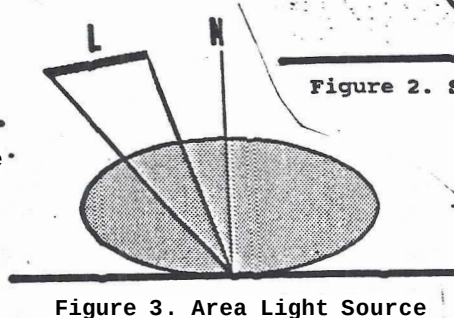
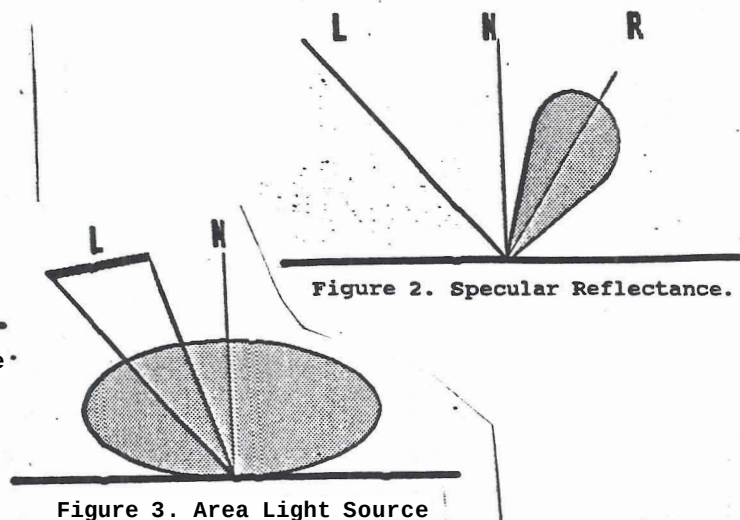
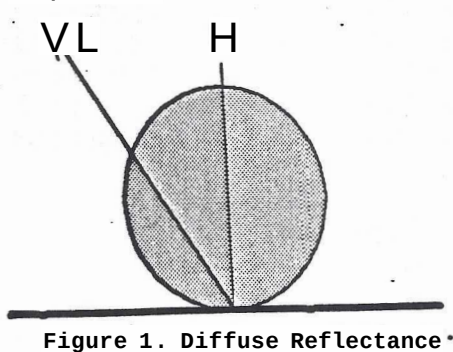
Computer Graphics in Architectural Visualisation

Computers are in common use for architectural CAD, and are well established as an important tool for lighting design. Sophisticated lighting calculations, which a few years ago were beyond the means of most practices, are now readily available on PCs [7]. While generating illuminance data in table form is now fairly easy, deriving meaning from the tables is not. Using techniques from advanced computer graphics provides an important additional tool for the visual interpretation of lighting predictions. The new computer graphic tools add significantly to the complexity of the environments for which global illumination can be computed, including arbitrarily placed obstructions.

Illumination Models

Many ways exist to approximate the shade of an illuminated surface. If the surface is perfectly diffuse, then there is no dependence on the view point, only on the angle of incidence. The illuminance at the surface is the light source luminance multiplied by the cosine of the off-axis angle. In practice this is simply a dot product with the surface normal (see figure 1).

To account for specular reflection, the view point as well as the incident light direction must be evaluated. Pure specular reflection from a smooth surface acts similar to a mirror, where light returned into the scene along the reflection direction (see figure 2). Most scenes, however, have surfaces which are some mixture of diffuse and specular. Various computational models are available to simulate specular scattering, such as PHONG, Torrance-Sparrow, Blinn, Hall, etc. These approximate the reflection function by a continuous analytic function, with varying degrees of physical basis, and computational expense.



Most surface reflection functions are also based on point light source models. To achieve higher realism, area light sources must be properly simulated. Fluorescent fittings with diffusors or baffles are in such common use, that area light source simulation is a prerequisite for high quality interior simulation. Area light sources have the effect of creating a wider distribution pattern for the diffuse reflection (see figure 3).

Indirect Reflection

The big difficulty with simulating indirect reflection is that at least TWO surfaces must be evaluated in the path from the light source to the synthetic camera. This is much worse than doubling the computation, because one cannot determine in advance which other surface may be involved. The seemingly simple extension to indirect lighting forces an evaluation of the entire global light distribution within the scene (see figure 5). The technique in current research for approximating the global illumination is called Radiosity [3,5]. The Radiosity of a particular surface patch is defined as the unit energy leaving the patch per unit time. Since the energy leaving the patch depends on the total energy arriving from other patches, this implies solving for the global distribution.

Converting Illuminance to Visual Intensity

Once the visible surface illuminances are determined, some method of display must be devised. Most systems simply do some form of linear mapping from black to white, in order to read illuminance levels compared to a fixed scale. To create high realism images, a more sophisticated system is needed. The process of making images from the imaginary scene has been described as 'synthetic photography' [4]. This implies a synthetic camera, with lens, film, processing, printing, and viewing. The camera can be simulated with three processes; (1) converting the surface illuminance into camera received energy, (2) taking this energy through a 'film response' transfer function, and (3) display on the output media, say video tape, with appropriate gamma correction (see figure 4).

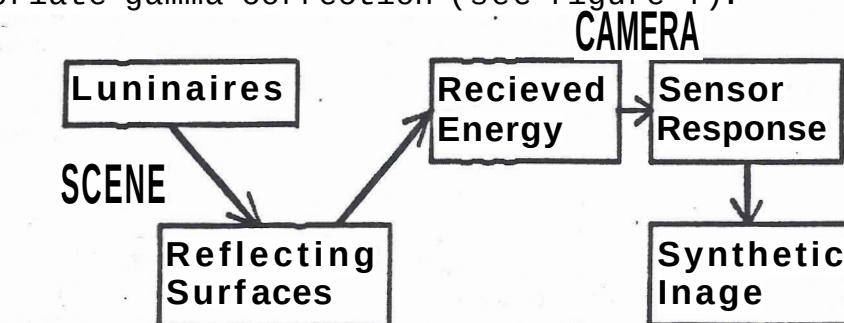


Figure 4. Synthetic Photography.

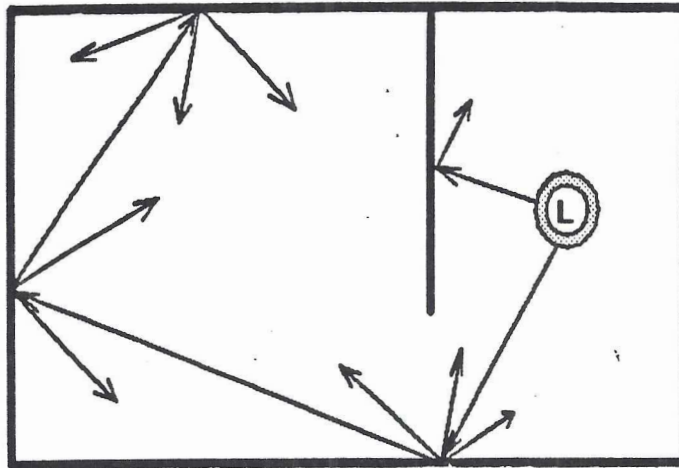


Figure 5. Indirect Reflections.

Applied Radiosity

The Radiosity method models the interaction of light between diffusely reflecting surfaces and accurately predicts global illumination effects. Procedures are now available to simulate complex environments including occluded and textured surfaces. As an architectural visualisation method, Radiosity can more accurately account for important lighting effects from fenestration and indirect illumination. With daylighting and large area luminaires, this can make a dramatic difference in simulated light distribution.

For accurate rendering, the environment must be discretized into a fine mesh, particularly in areas of high shading gradient [1], otherwise discontinuities may appear in the image. The global interdependence between surfaces implies a class of solution techniques which are very computationally expensive, all the more so with large geometric models.

The Radiosity method solves the scene rendering problem in two steps. First, an estimate is made of the global light distribution within the scene. Second, an image is generated from a particular point of view, using the precalculated light distribution. This two stage technique has enormous potential in architectural visualisation, where there is no geometric movement of objects in the scene, only a moving view point. In this case only the second rendering stage is repeated to create a 'walk-through' animation.

The first step, creating the object mesh and solving for the global illumination, is vastly more computationally expensive than the second rendering step. This part of the problem involves computing 'form-factors' and solving very large sparse systems of linear equations. The computations

have so far been performed on large main-frame systems. In addition, it is important to note that the Radiosity method has significant coding and algorithm complexity. This factor has limited the number of organizations that have so far contributed to this research area.

Recent algorithmic advances, however, bring the possibility of affordable Radiosity computations. The most interesting advance is the technique of computing a partial step of the global illumination, and displaying the results as an approximation to the final converged solution [2,7]. In this way, early approximations can give a very good idea of the overall lighting effects. The computations for the solution and display of simple scenes can be less than a minute per iteration on modern workstations. A visually convincing display can be generated in only 20 to 100 iterations for simple scenes.

The central idea in the new approach is to reorganize the steps in the algorithm such that a usable image is generated very quickly, and that subsequent images progress gracefully to a complete radiosity solution. The key idea behind this is to make an initial estimate of the final radiosity from all available information at each step. The computation then distributes the total energy in the scene beginning with the most important luminaires in the environment and continues in sorted priority order. Not only is the convergence much faster, but also dramatically reduces the storage required as information is used at the time it is computed.

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