A Progressive Global Illumination Solution Considering Perceptual Factors

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Realistic image synthesis usually involves some iterative methods for solving the global illumination problem. The fully converged solution may be quite time consuming for complex scenes, but taking into account basic properties of human perception such as poor sensitivity to the absolute luminance values, high quality images can be obtained on the order of single minutes or seconds using physically-based partial solutions. In this sketch, we describe a progressive technique designed along these guidelines.

We use a hybrid of stochastic and deterministic techniques. At first, a Monte Carlo Photon Tracing algorithm is used in which photons are bucketed directly into a mesh (making immediate image display possible). To reduce the problems of low-frequency noise at early stages of computation [1], the adaptive filtering of illumination at the mesh vertices is performed, taking into account illumination in the local neighborhood. If we were to relay on the neighborhood relations between the mesh elements, the result would strongly depend on the geometrical model and would not provide complete information for separate objects. Instead, we build a static and balanced 3D kd-tree structure for all vertices. The filtering is used at the intermediate stages of computation, and filter size is adaptively reduced as variance of the illumination estimate decreases for a given vertex. Figure 1a shows the result of the particle tracing phase after 6 seconds of computations (Pentium-200 MHz) for the scene containing over 17,000 polygons.

The appearance of images obtained at the first stage of lighting simulation approximates well the final images with the exception of views that contain many areas with strong direct lighting. To overcome these drawbacks, deterministic calculations of direct lighting are performed. In contrast to traditional approaches, the adaptive mesh subdivision for the deterministic calculations of direct lighting can be based upon predicted visible differences using the available stochastically-derived estimates of indirect illumination. Here we introduce perceptually-based mesh splitting criteria. For each mesh vertex we transform the stimulus luminance values to predicted perceived brightness using Stevens' power law, and a decision on the mesh splitting is made based on the local differences in brightness. Figure 1b shows a result of this stage of lighting simulation which took about 30 seconds.

The next stage of computation replaces the finished direct computations with additional stochastic particle tracing, which is then performed until a criterion accuracy is reached (Figure 1c). The final images can be rendered using ray tracing.

Another way in which perceptual factors were considered in this research was to use the Visible Difference Predictor, or VDP [2], to generate quantitative measures of the differences in the appearance of two images. Figure 1d shows, as a function of computation time, the percentage of pixels in the two images for which the differences should be detected at high probability (refer to [1] for visualization of the VDP predicted differences). As can be seen, the current technique converges quite rapidly.

References:

1 http://www.u-aizu.ac.jp/~k-myszk/progress - the Web page that provides more information on this work.

2 Scott Daly. The Visible Differences Predictor: An algorithm for the assessment of image fidelity. In A.B. Watson, ed., Digital Image and Human Vision, pp. 179--206. MIT Press 1993

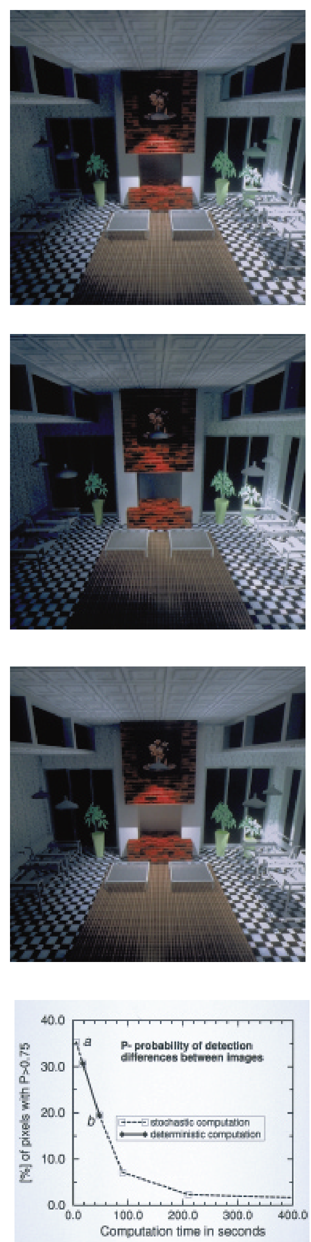

Figure 1 Progressive rendering:

a) Photon tracing (6 seconds)

b) Photon tracing (18 seconds) + deterministic direct lighting (30 seconds)

c) Fully converged solution (2 hours)

d) "Perceptual convergence" of the image quality as a function of computation time. The predicted differences between the intermediate images and that for the fully converged solution are computed using the VDP. Images a and b in this figure correspond to the time points *a* and *b* marked in the graph.