

## Pre-computed Global Illumination of MR and DTI Data

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### Introduction:

Current 3D graphics hardware renders polygonal geometry using “local illumination,” a quasi-realistic approximation to the equation of light transport (1). Local illumination neglects physical effects such as shadows and indirect illumination, but experiment has shown that these effects are important to the human visual system for extracting shape from shading (2). “Global illumination” refers to the accurate solution to the equation of light transport, producing photo-realistic images. Global illumination is generally performed by software and may require thousands of seconds per rendered frame; this compares unfavorably with the lower-fidelity local illumination performed by graphics hardware that requires only milliseconds per rendered frame. The 3D shapes extracted from radiological datasets of the brain include the folded surface of the cortex and the intertwined fibers in the white matter; thus an observer viewing a 3D rendering of these shapes may desire to see them rendered with global illumination. We demonstrate techniques that incorporate pre-computed global illumination (using photon mapping) together with hardware-based rendering to permit viewing of globally-illuminated 3D structures from radiological data at interactive speeds.

### Methods:

We pre-compute the effects of globally illuminating the level sets of the scalar-valued anatomical MR data in a 3D volume and store the resulting values in an “illumination grid.” Later, when the volume is explored by sweeping through level sets of the scalar value, each isosurface is displayed by indexing into a 3D texture map derived from the illumination grid (3). For static geometry, such as a bundle of tubes that follow integral curves of the principal eigenvectors of diffusion tensor imaging (DTI), we pre-compute the global illumination solution, then compute and store the resulting colors with the geometry to produce a globally-illuminated scene that can be rotated in real time on a 3D graphics card.

### Results and Discussion:

Figure 1 shows a level set approximating the cortex rendered with local illumination (left) versus pre-computed global illumination texture-mapped onto the same geometry (right). Pre-computing the illumination grid using 17 million illumination samples in the volume of anatomical MR data required 90 minutes on a dual processor Xeon 3GHz Dell Precision 650; applying the resulting 217x217x217 illumination texture to the surface incurred only 10 milliseconds at display time on the same machine (equipped with NVIDIA Quadro FX 2000 graphics). Figure 2 shows white matter tractography derived from DTI data (surrounded by a cut-away of a level set of isotropic diffusion) rendered with local illumination (left) versus pre-computed global illumination stored per-vertex in the same geometry (right). Pre-computing the globally illuminated scene required 18 hours on a dual processor (quad core) HP xw9300 workstation; displaying the scene on the same workstation (equipped with NVIDIA Quadro FX 3400 graphics) required only 0.27 seconds per frame for a scene with tracts represented by 2000 tubes containing 3.8 million triangles.

### Conclusion:

We have demonstrated that the steep cost of global illumination of surfaces derived from radiological data can be amortized by pre-computing and storing the results either in a 3D illumination grid (for scalar data) or per-vertex in polygonal scenes. The human viewer is thus able to rotate the 3D globally illuminated scene at interactive rates using graphics hardware, thereby combining the 3D realism of high-quality illumination with the interactive exploration provided by graphics hardware that implements local illumination.

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### References:

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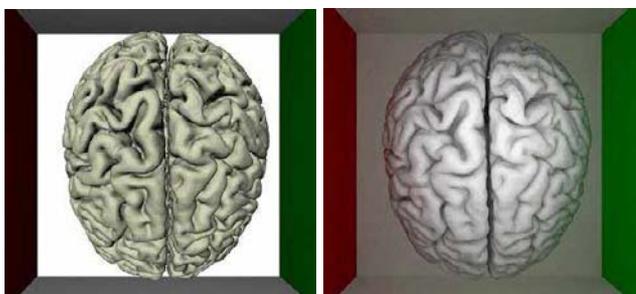


Figure 1. Cortex displayed with local vs. global illumination.

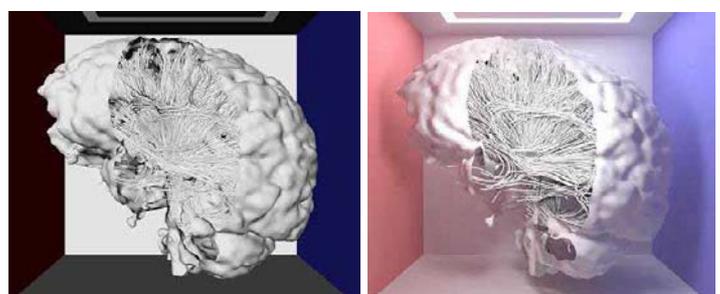


Figure 2. Fiber tracts displayed with local vs. global illumination.