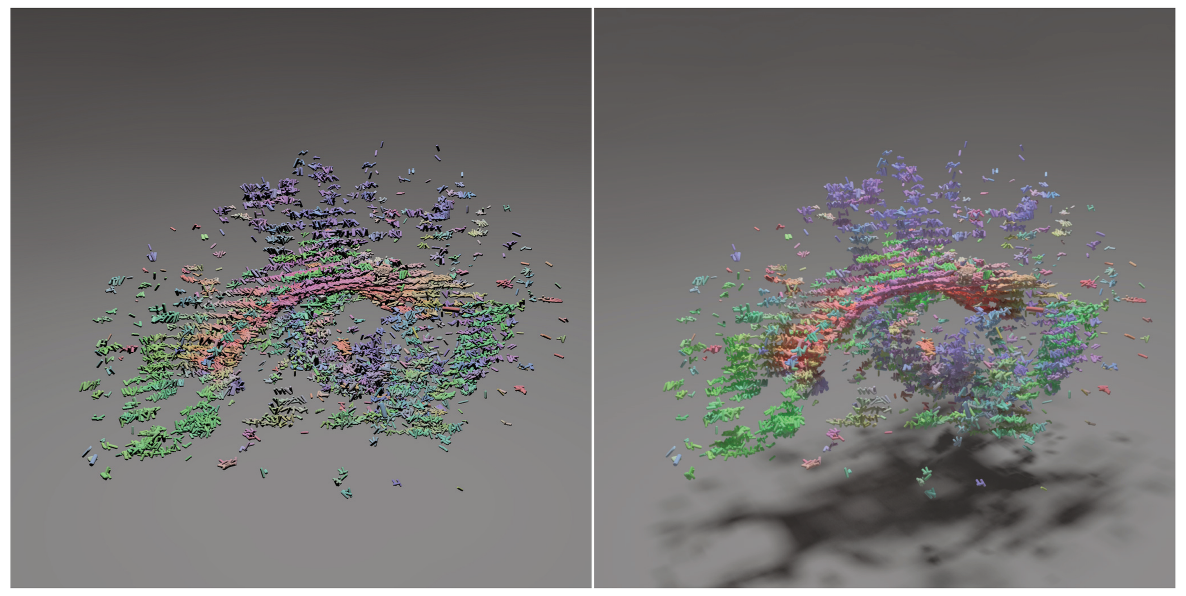

Tensor glyphs from diffusion-tensor MRI imaging of a human brain. Left: local illumination. Right: physically-based illumination. Data courtesy of G. Kindlmann, Harvard Medical School.

Physically-based Illumination Improves Geometric Inference

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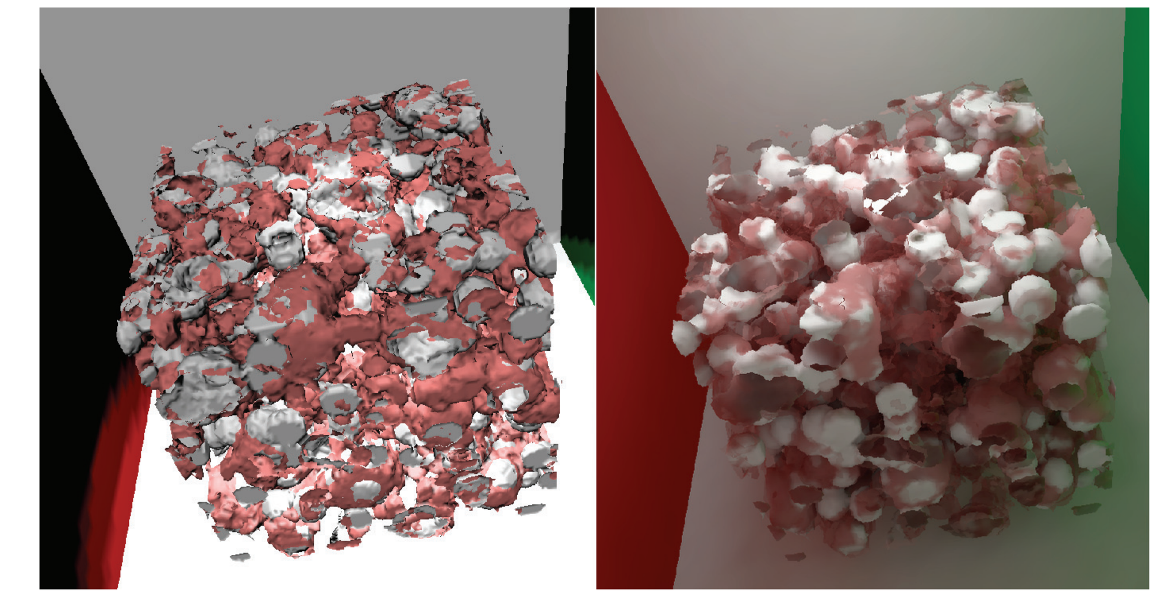


Isodensity surfaces of protons (red) and neutrons (white) in computational simulation of stellar crust. Left: local illumination. Right: physically-based illumination. Data courtesy of J. Piekarewicz, FSU.

Abstract

Current software tools for visualizing 3D datasets in science, engineering, and medicine almost exclusively rely on "local" illumination for rendering images. Although local illumination is fast and ubiquitous (because it is implemented in hardware on every desktop computer), it is not physically accurate.

We present our recent findings in quantifying the effects of physically-based illumination on the perception of scenes with multiple objects. Using a gaze-tracking device, we analyze not only accuracy and reaction time but the time-course of a user's gaze across the scene. We explore whether physically-based illumination enables improved scene perception over local illumination models provided by desktop graphics cards.

Introduction

Local illumination considers only the contribution of direct lighting from luminaires, neglecting shadows and indirect reflections from other geometry in the scene. All modern desktop computers include dedicated hardware capable of accelerating the local illumination computation for 3D graphics. Although this technology originated to meet the needs of CAD/CAM tools, it is now primarily driven by the needs of video game companies.

Physically-based illumination models consider the contribution of incident light from all possible directions, including light reflected off other scene geometry. We call such models "global". Accurate, physically-based global illumination models are not currently accelerated by dedicated hardware and may require minutes or hours to produce a single image. Animation studios (e.g. Pixar™) are currently the largest users of physically-based illumination. The cost to the studio of assembling a "render farm" of thousands of computers to make a feature-length film is a small part of the total budget.

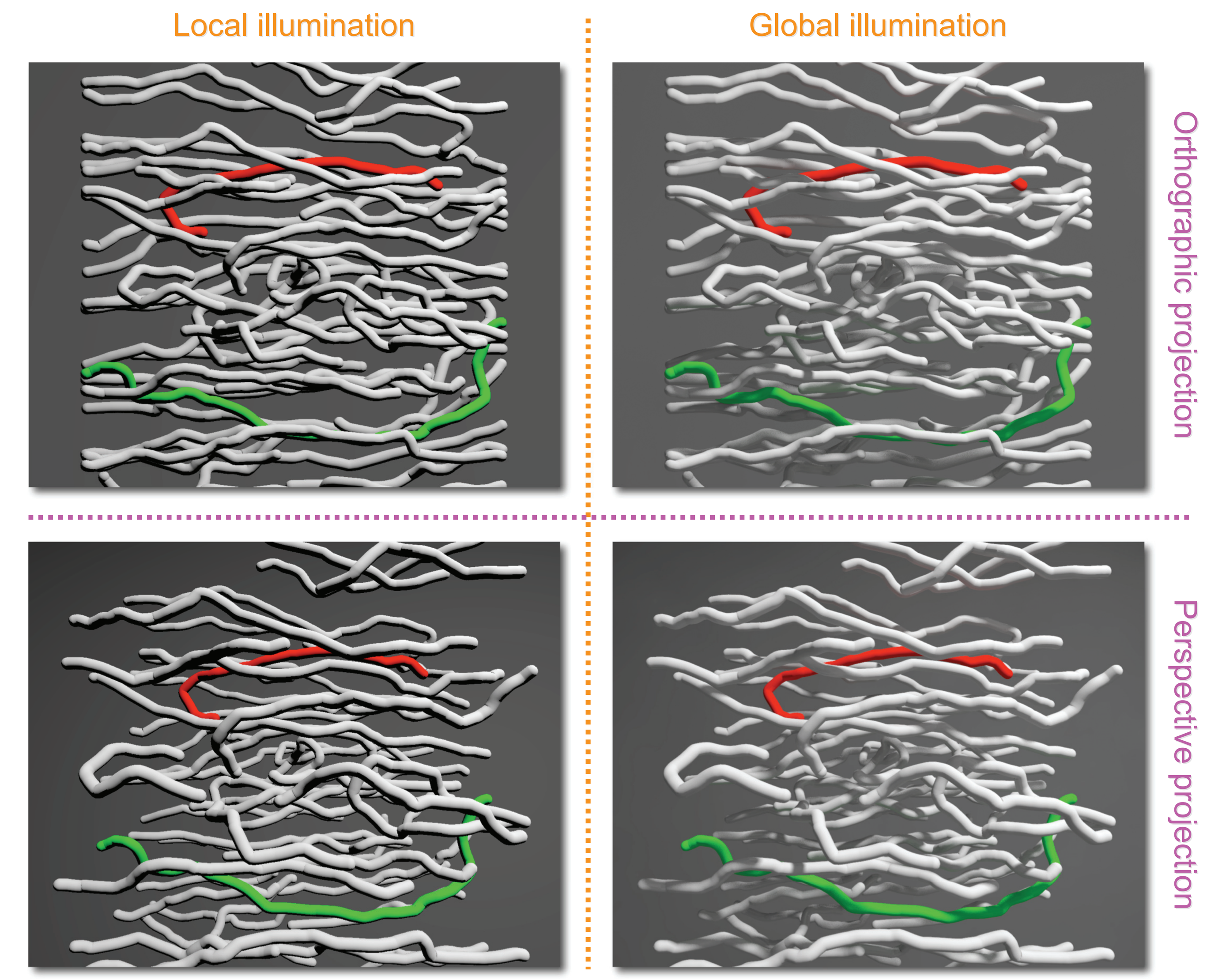
Visualization software tools are written to exploit the available graphics hardware. This means that users of visualization tools rarely see their data rendered in a physically realistic manner. Further, visualization practitioners report that users rarely request physically-based illumination. Is there any benefit to the end-user in physically-based illumination models?

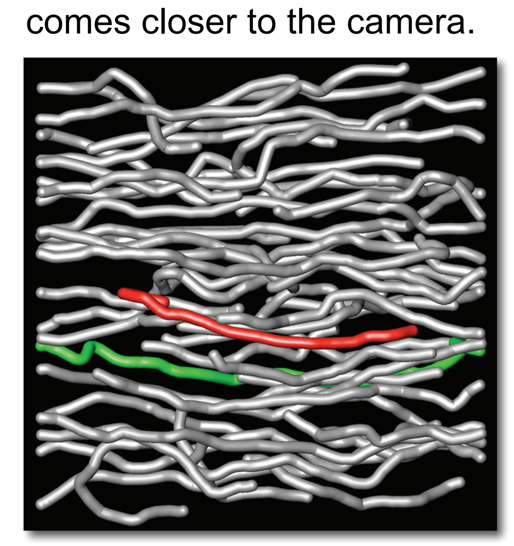
We conducted a pilot study (*N*=3) to determine whether physically-based illumination enables improved performance for a scene perception task.

Methods

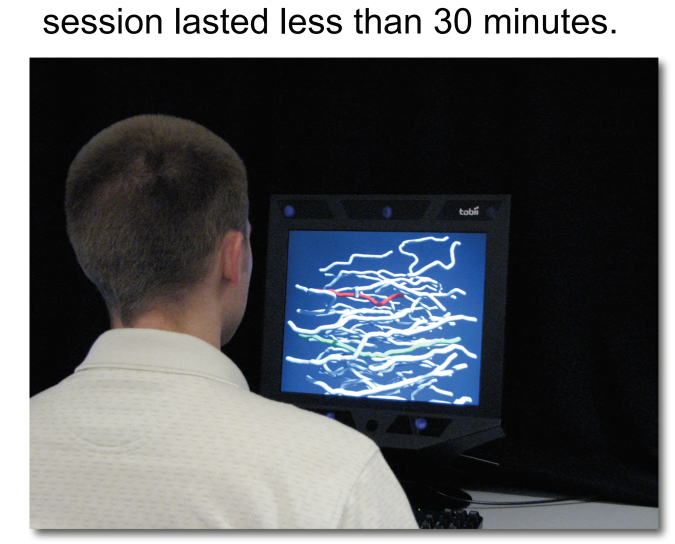
The study used a repeated-measures, forced-choice, within-subjects design controlling for both the effect of the illumination model (local vs. global) and for the projection model (orthographic vs. perspective).

Scenes consisted of 50 tubes with uniform radius. The tubes were constructed to follow a noisy flow field that predominantly flowed left-to-right across the scene. The tubes did not intersect. Two tubes were color coded, one red and the other green; the remaining tubes were gray. In each scene either the red or green tube approached closer to the camera position, with the red tube making the closer approach in half the scenes. Sixteen scenes were rendered once each with local or global illumination and with orthographic or perspective projection, producing a total of 64 stimuli.





Scene viewed from above reveals that the green tube comes closer to the camera.



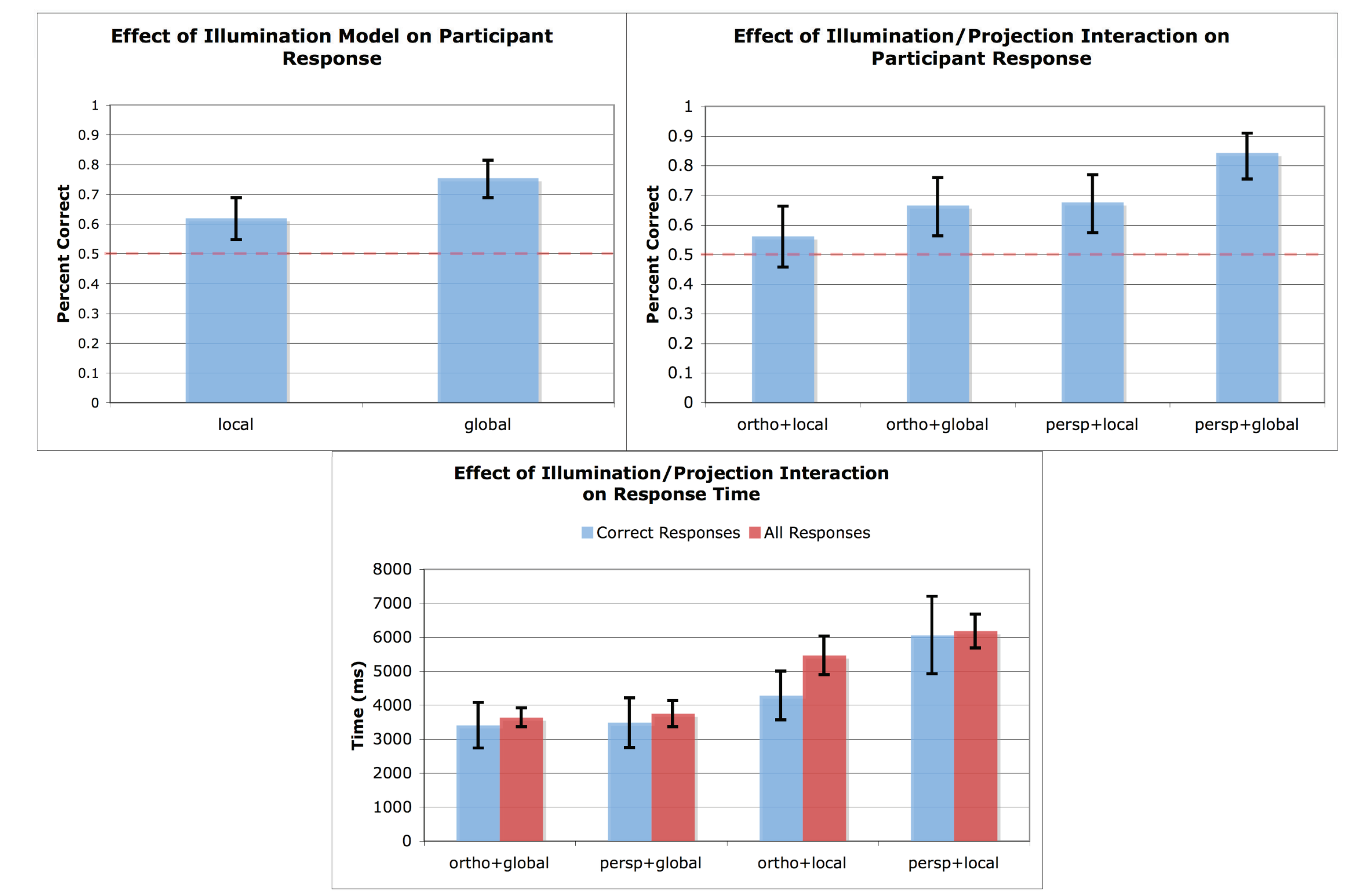
Example of participant performing experiment. A typical experiment session lasted less than 30 minutes.

Participants viewed the stimuli on a 17" LCD display. Stimuli were displayed at 1280x1024, with participants seated approximately 65cm from the display. Stimuli were presented twice each and in random order (with the constraint that the second presentation of a stimulus could not immediately follow the first) for a total of 128 trials.

Participants were asked to report if the red tube or the green tube appeared to be closer. Participants responded by pressing the R or G key on the keyboard, respectively indicating that the red or green tube appeared closer. Response, response time, and eye-gaze position were recorded.

Results

A factorial ANOVA test reveals that the effects on participant response of both the illumination model and the projection model are significant ($p<0.004$ and $p<0.002$, respectively). A similar analysis for effects on response time finds significance only for the projection model ($p<<0.001$). The difference in response time between local and global illumination is not found to be significant.

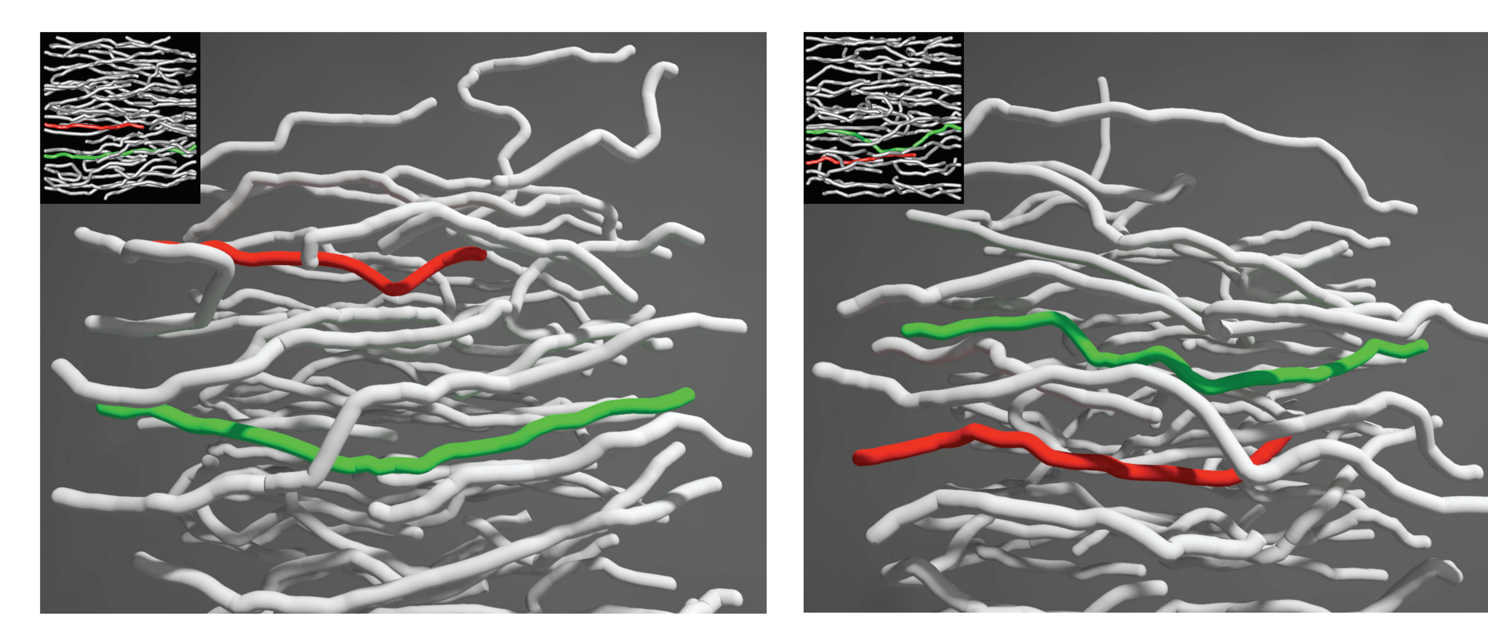


The graphs show the relative effectiveness of local and global illumination models. We see that participant response is sensitive to both projection model and illumination model.

Discussion

We find that task performance does improve with global illumination. Further, we find that the combination of perspective and global illumination provides the best performance in terms of both response correctness and response time (the response time difference between the two projection models combined with global illumination is not statistically significant).

The percentage of correct responses in the case of orthographic projection and local illumination is not statistically different from chance, suggesting that participants may have been guessing in that case. Additionally, we find that the combination of perspective and local illumination provides the slowest response times for this task. This result is particularly interesting, as this combination is exactly that provided by current graphics hardware.



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