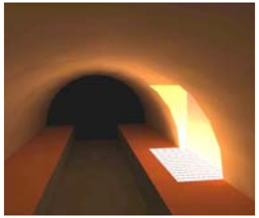

Interactive Rendering of Fenestration Materials for Architectural Design

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ABSTRACT

We present a method for the interactive global illumination rendering of advanced fenestration materials in architectural design. These window panels can be used to redirect illumination from the sun; however, the transmissive properties of these materials result in non-intuitive interactions with the built environment.

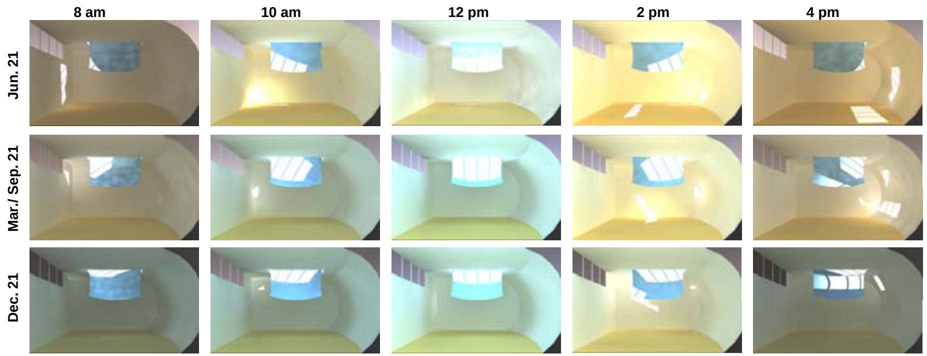
Broader Impact / Motivation: Electric lighting in the U.S. is estimated to be 22% of the total electricity consumption [1]. Only if daylighting is accounted for early in the design process can it have a significant positive impact on the sustainability of the building. Architects have access to global illumination packages such as Radiance [2], but rarely use them during the design process because the renderings often take hours to produce.

We simulate the direct and indirect illumination from the sun and sky throughout each day for different months of the year. Having accurate quantitative and qualitative data about the natural lighting allows the designer to explore different window material choices for the design that reduce the need for supplemental electric lighting.

We demonstrate our system on several models inspired by field observations and the designs of architecture students we have consulted during the development of this project.

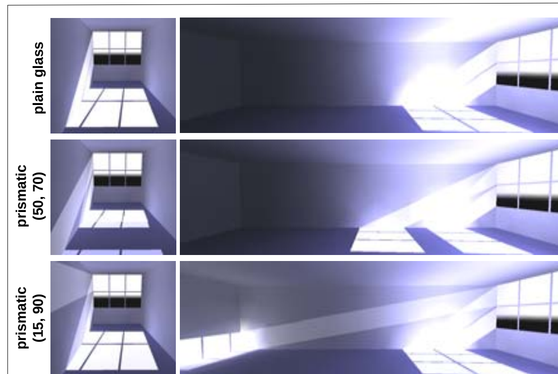
Keywords: Interactive rendering, architectural daylight design, radiosity, shadow volumes, green building design.

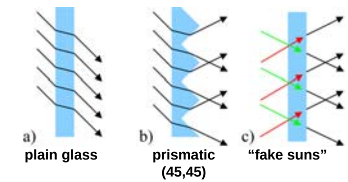
RENDERINGS OF DIFFERENT TIMES AND DAYS



Using the standard CIE Sky Model [5], the system can render qualitatively accurate images. In designing the interesting curved geometry for the living space in this residential design, the architects are able to see the effect of the deflectors and windows. The curved diffuse blue deflector redirects the strong overhead noon sunshine from skylights, and additional windows on the western wall allow the warm late afternoon sun to penetrate deep into the room and wash over the far wall.

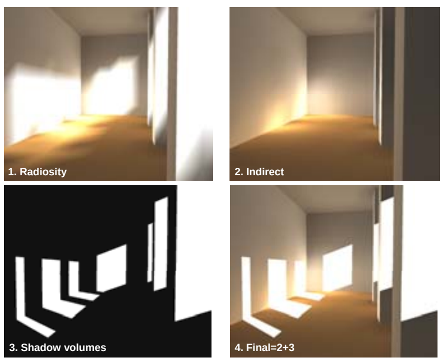
REDIRECTING DAYLIGHT





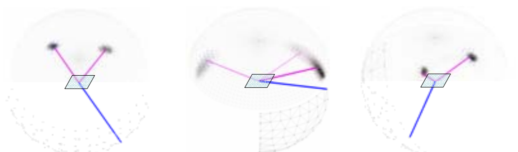
In a flat pane of glass, light rays are refracted, but exit parallel to the input rays. Light rays that pass through a prismatic panel are refracted differently and exit in two different directions due to the microfaceting. We can reverse engineer the directions of two "fake suns" allowing us to render the specular refractions efficiently.

HYBRID RADIOSITY / SHADOW VOLUMES



To achieve interactive rendering rates, we use a hybrid method of shadow volumes [3] for direct illumination and radiosity [4] for indirect illumination. We first calculate the indirect illumination, which is the difference between the first bounce initialization of radiosity and the final radiosity solution. Then we blend the direct illumination rendered by shadow volumes with the indirect illumination to generate the final result.

ADVANCED FENESTRATION BTDF



BTDF Modeling : We use 4D Bidirectional Transmission Distribution Function (BTDF) data [6] to model advanced specular fenestration materials. For each measured incoming light direction (θ , ϕ), we greedily select k (<=3) outgoing directional lobes subtending α (<=20°) degrees that minimize the unrepresented transmissive illuminance. We calculate the transmission for an arbitrary direction by interpolating the BTDF value of the three nearest measured incoming directions.

Optical film (exterior) | Optical film (interior) | Holographic film | Perforated blind (open) | Perforated blind (closed) | Mirrored Venetian blind

Lumitop™ | Laser cut panel | Serraglaze™

We loop through the distinct materials in the model, and for each of the k specular lobes, we position a "fake sun" and set the brightness to the transmittance value. Using our hybrid method, we can render the result interactively. When the day or time is changed, or the parameters of fenestration materials are changed, it takes 1-2 seconds to re-render a scene with more than 1000 triangles on a standard PC.

ACKNOWLEDGEMENTS

Marilyne Andersen, Julie Dorsey, Mark Cabrinha, Magali Bodart, Sian Kleindienst, Tim Herrman, Zachary Cross, and Matthew Ficket.

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