Evaluation of a Tangible Interface for Architectural Daylighting Analysis

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Abstract

We present a study of a tangible user interface (TUI) for architectural design and daylighting analysis. This tool provides an intuitive way for architects and future building occupants to quickly construct physical models and then view a simulation of daylighting in the model at interactive rates. We conducted a user study of both formally-trained architects and non-architects in a set of analysis and design exercises. This study investigates the effectiveness of this interface as an educational tool, the precision and accuracy of the constructed physical models, and the overall effectiveness of the tangible interface. The four part study investigates users' intuitions about daylighting and their interaction with the tool for analysis of an existing space, for proposing renovations to the space, and for designing a totally new space with the same architectural program that better addresses the occupants' needs. These exercises revealed misconceptions in many of the participants' intuitions about daylighting and overall the participants expressed interest in this simulation tool for daylighting analysis in architectural design.

Architectural daylighting design is the use of windows and reflective surfaces to make effective use of natural light from the sun and sky within a physical environment. Increased use of daylighting can reduce the need for supplemental electric lighting during the day, decreasing operating costs and reducing the consumption of non-renewable resources.

The daylighting analysis system simulates the complex interreflection of natural light within a scene and uses a set of six standard office projectors surrounding the table to "paint" the physical primitives with the simulation results. Designing in the tabletop system is done by sketching with physical *wall primitives* to create a closed space with *window primitives* that are placed over the top edge of the walls. A calibrated overhead camera captures the arrangement of these elements and the geometry is converted into a closed triangle mesh. Radiosity, a patch-based lighting method, is used to simulate light propagation within the space and the rendering system displays the simulated natural lighting on the physical model using six projectors positioned in a circle above the table.

The contributions of our work:

- Exploration of participants' fundamental understanding of daylighting design, overlighting, underlighting and glare.
- Quantitative analysis of the users' accuracy in using our physical sketching system to model a room they had just visited.
- Evaluation of the participants' use of our tool and their perception of quantitative and qualitative daylighting from the displayed simulations.
- Demonstration of our tangible interface as a creativity-enhancing tool for architectural daylighting design.

Our study was divided into four consecutive tasks. The first task was designed to prime the user for thinking about daylighting and gauge the user's pre-existing intuition about daylighting. For the second task, users were introduced to the TUI for daylighting simulation and asked to construct and analyze a physical model of the computer lab they had just visited. Then users were asked to propose and evaluate a modest renovation to the existing space to improve the use of daylighting in the space. And finally, the users were encouraged to create a brand new design and use the TUI to evaluate the resulting illumination.

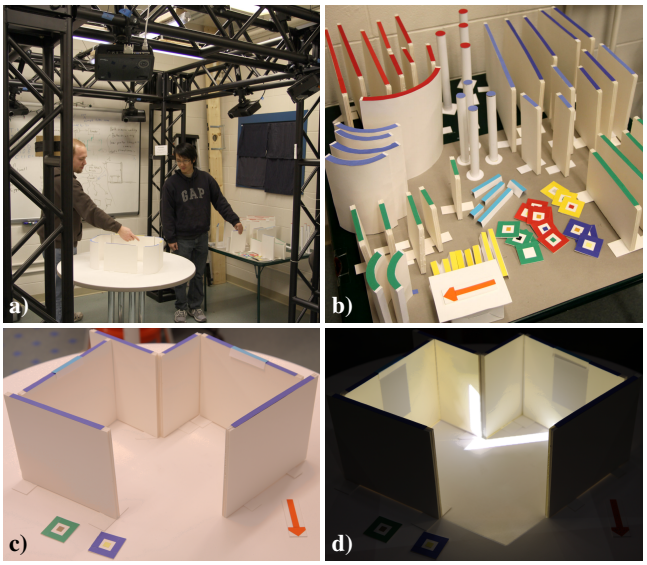

Figure 1: *Our new tangible user interface for architectural daylighting design allows multiple users to a) gather around a physical sketching environment and select from b) a set of wall primitives and window and material markers to c) build a rough sketch of an architectural design. A d) visualization of a daylighting simulation is projected onto these surfaces.*

Participants in this study were significantly and positively influenced by our tangible interface for daylighting simulation. Users consistently claimed that their lighting intuition was improved, their design was aided by the tool, and that the interface was accessible. Many participants used the tool to look at lighting in various seasons to understand how daylighting will vary throughout the year. Despite this, it was clear that users need additional quantitative feedback and visualization to more fully analyze glare in high contrast lighting conditions.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality;

Keywords: augmented reality, daylighting design, user studies.

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