Importance of Real-Time: The Effect of Latency in Scientific Visualization

Nathaniel Jones | Sustainable Design Lab | Massachusetts Institute of Technology | New England Symposium on Graphics | April 23, 2017

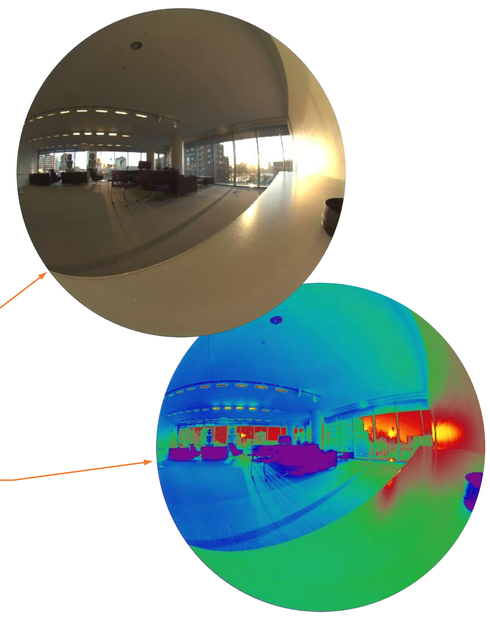
Problem

Glare in buildings is difficult to predict because photometrically accurate simulations are time consuming.

Architects are less likely to make use of building performance simulation if it is not interactive.

Glare caused by direct and reflected sunlight reduces productivity and leads to increased energy use.

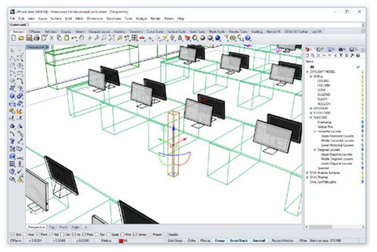
False color display reveals the dynamic range of interior luminance distributions.



Experiment

Forty participants completed a design exercise to **find and mitigate glare issues** in two office spaces.

They used **physically based rendering** to identify glare.



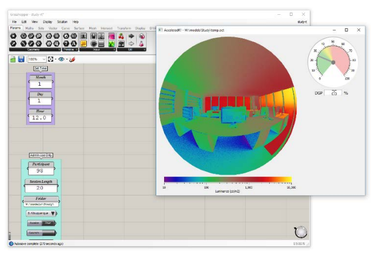
They could interact with the space by changing three factors:

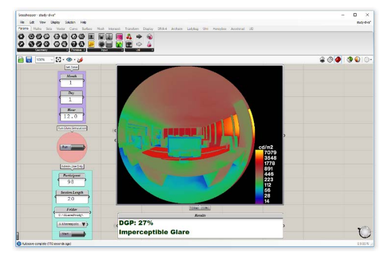
- Time & date (sun position)
- Camera view
- Shading devices

They used two tools:

AcceleradRT

- Progressive path tracer
- GPU-based
- 5 fps
- Responds to mouse navigation





DIVA-for-Rhino

- Radiance-based ray tracing
- 20-30 seconds per rendering
- Industry standard tool for architectural lighting analysis

Results

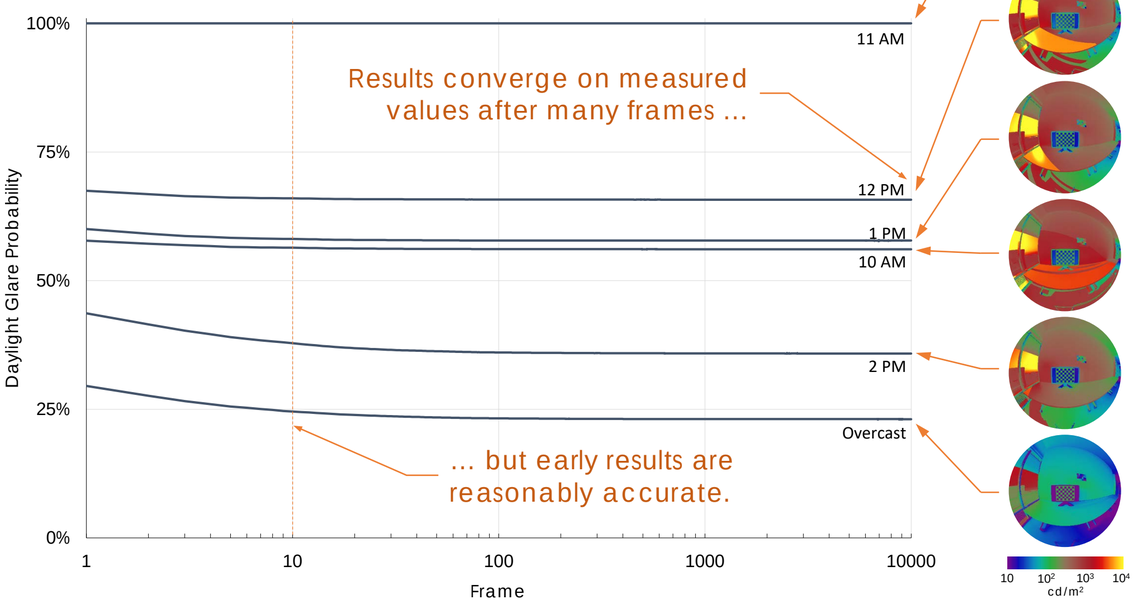
1) Progressive path tracing produces accurate **Daylight Glare Probability** readings within 10 frames (2 seconds).

Daylight Glare Probability (DGP) is the likelihood an individual will experience glare in a given view.

$$DGP = 5.87 \times 10^{-5} E_v + 0.0918 \times \log_{10}\left(1 + \sum_{i=1}^{n} \frac{L_{s,i}^2 \omega_{s,i}}{E_v^{1.87} P_i^2}\right) + 0.16$$

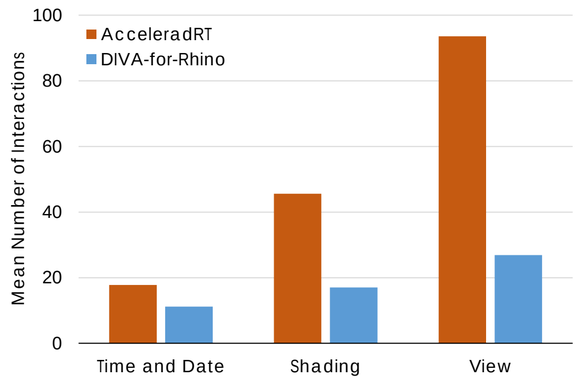
Source luminance
Source solid angle
Guth position index
Vertical eye illuminance

DGP can be predicted using global illumination algorithms such as **progressive path tracing**.

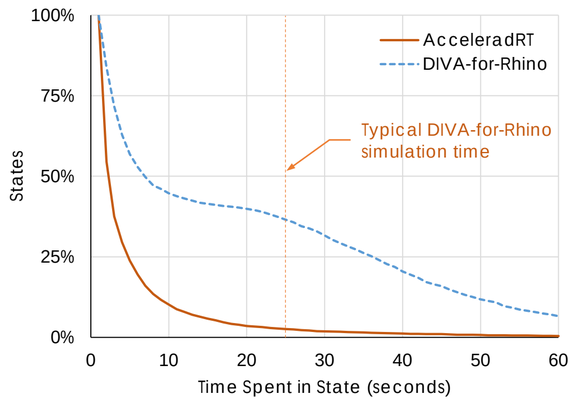


2) Participants who saw progressive rendering **interacted more frequently** with the design tool.

Participants could interact with the model in three ways: changing the **time**, **shading devices**, or **camera position**.

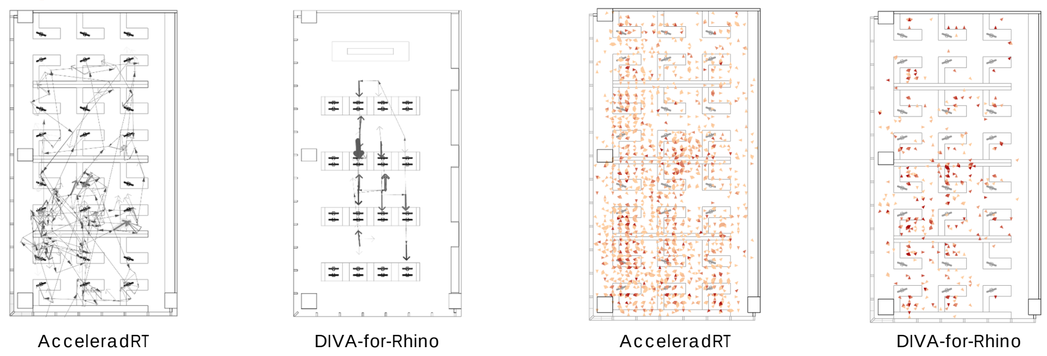


With real-time results, participants **make decisions faster**, even neglecting the time taken to run simulations.



With real-time feedback, participants moved the view to cover a **greater portion of the space**.

In aggregate, participants **analyzed more of the space** when they had real-time feedback.

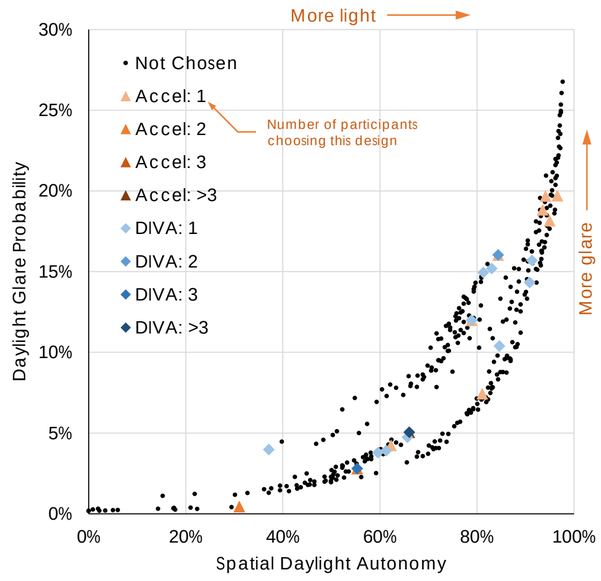


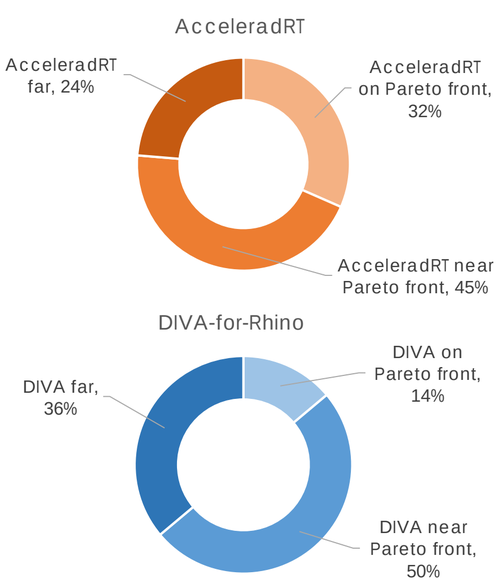
3) Participants who saw progressive rendering created **more optimal design solutions**.

Participants had **two objectives**:

- Provide sufficient natural light
- Reduce risk of glare

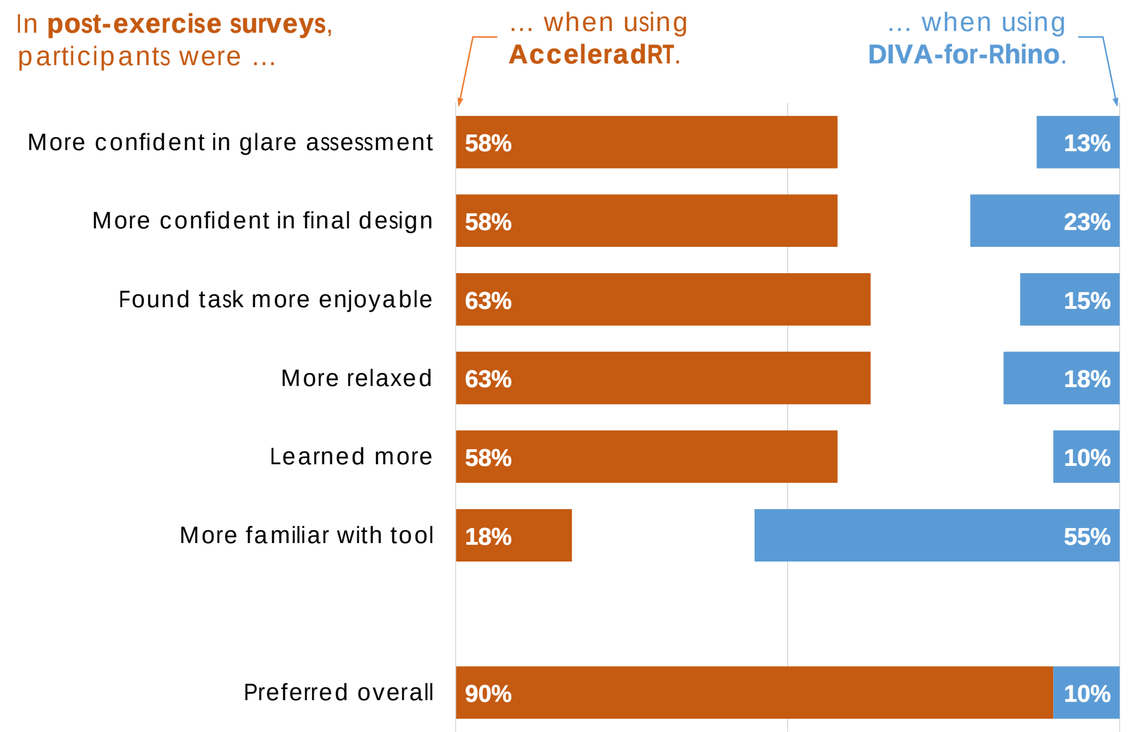
With real-time feedback, participants proposed **more designs on or near the Pareto frontier**.





4) Participants who saw progressive rendering were **more confident and satisfied** with the design exercise.

In **post-exercise surveys**, participants were ...



Conclusions

1) Accurate predictions of glare can be produced at interactive speeds using progressive rendering, even though high-quality visualizations take longer.

2) Real-time results change user behavior and promote interactive user response, resulting in more exploration of the problem and of design solutions.

3) Users with access to real-time rendering tend to produce more optimal designs. At present, they outperform optimization algorithms.

4) Users also prefer the experience of real-time feedback and feel more confident and relaxed, even when the tools are less familiar.

About

Dr. Nathaniel Jones is the developer of Accelerad, a suite of GPU-based lighting and daylighting simulation tools. Accelerad has registered users in fields from architecture and sustainability consulting to psychophysics and spacecraft design. He recently completed his PhD in building technology at the Massachusetts Institute of Technology, where he researched the role that simulation speed plays in how designers choose to use tools. He chairs the IBPSA-USA Emerging Simulation Technology Subcommittee, which seeks to create awareness and promote use of emerging building simulation tools and technologies within the research, industry, and government communities, and to facilitate interaction between these communities.

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The Tesla K40 accelerators used for this research were donated by the NVIDIA Corporation.