Radiance - the Interaction of Light & Matter in Building Simulations

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Anywhere Software
What Is Daylight Simulation?

- Predicting performance of a candidate building design under a given set of daylight conditions
- Input is a building model with materials in suitable detail
- Output is a set of images and/or performance metrics
- Simulation software implements a set of useful approximations to mimic aspects of problem we care about
SFO Air Traffic Control Tower
SFO Air Traffic Control Tower
Requirements

- Geometry (typically converted from CAD software)
- Materials, textures, patterns (scanned/measured/estimated)
- Daylight condition(s) and electric lighting layout & control
- Analysis points and metrics, views, animation paths, etc.
- Calculation parameters controlling time vs. accuracy
What Is *Radiance*?

*Radiance* is a collection of over 150 command-line tools that perform specific functions.

For example, one tool might import the CAD model, then another will compile it together with a set of luminaires that were converted by a third and placed by a fourth tool. A fifth tool will render an HDR picture that a sixth tool will convert to a false color image, and a seventh tool will put it up on the display.

That’s a lucky number of tools.

Standard file formats are an important part of the design.
Most of the 16+ Radiance file types include a preamble of metadata (info header), which can be read using `getinfo`, e.g.:

```plaintext
#?RADIANCE
oconv basic.mat diorama_walls.rad rect_opening.rad front_cap.rad gymbal.rad sunset_sky.rad
oconv -f -i trans2.oct ilXNF2S9
rpict -vf inside.vf -x 2048 -y 2048 -dp 256 -ar 24 -ms 0.27 -ds .2 -dj .9 -dt .1 -dc .5 -dr 1 -ss 1 -st .1 -ab 1 -af
trans2.amb -aa .1 -ad 1536 -as 392 -av 0.062 0.062 0.062 -lr 8 -lw 1e-4 -u+ -st .02 -ss 32 -ps 4 -pt .08
SOFTWARE= RADIANCE 5.3a lastmod Thu Feb 28 18:03:46 PST 2019 by gward on Behemouth
VIEW= -vtv -vp -0.2 3.0728 2.77765 -vd -2.7336 -0.482008 -1.02483 -vu 0 0 1 -vh 45 -vv 45 -vo 0 -va 0 -vs 0 -vl 0
CAPDATE= 2019:03:22 10:05:11
GMT= 2019:03:22 17:05:11
FORMAT=32-bit_rle_rgbe
pfilt -1 -e +3 -r .6 -x /2 -y /2
EXPOSURE=8.000000e+00
```
Radiance Tool Categories

- Geometry generators (10)
- Geometry importers (12)
- Rendering tools (8)
- HDR picture filters (14)
- Image converters (13)
- Visualization tools (12)
- Glare analysis tools (5)
- Matrix/data processing (18)
- BSDF utilities (13)
- Plotting tools (14)
- Animation tools (4)
- Specialty tools (19)
Why Not Combine the Tools?

- Flexibility, mainly - think of a DSLR camera vs. a phone

- However, there are a few “executive” tools in Radiance that call other tools for common tasks, the rad program being a good example
  - trad even adds a simple GUI as a memory aid

- However, you can only do so much with a combined interface, and programmability is critical to solving general problems
Who Uses Radiance, and What Is It Good for?

- *Radiance* is used by Architecture & Engineering firms to predict performance of novel designs and daylighting systems.

- Users of *Radiance* “in the raw” tend to be fairly advanced.
  - Others use it through third-party interfaces, often without knowing.

- *Radiance* excels at solving the really difficult problems…
Cascading frit for stage visibility/backdrop and reflection
Modeling of Prismatic Film Glazing with Climate-Based Weather Data and Field Measurement

Zhen Tian
School of Architecture, Soochow University

Yaping Lei
Suzhou Institute of Building Science Group

Jacob Jonsson
Lawrence Berkeley National Laboratory

2018 International Radiance Workshop, Loughborough, UK
New York Times Building

- Renzo Piano Architects
- Analysis and shade deployment
- Recommendations by Eleanor Lee & John Mardaljevic
Q: Where & when to deploy shades?

~140 Gb of simulated data to post-process / analyze
Examples from Loisos-Ubbelohde

Kol Emeth Synagogue in Palo Alto, CA
Warehouse renovation with sawtooth profile skylights
Valley Children’s Hospital, Outpatient Center, CA Central Valley (Bakersfield and Modesto)
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(Bakersfield and Modesto)
How *Radiance* Became the Premier Daylight Simulation

- Development began in 1985, evolutionary growth since
- Heavily validated against real-world measurements
- Open source invites contributions from daylighting research
- Designed primarily as a calculation engine others could use
- Little incentive to compete when you can adopt & improve
Problems *Radiance* Solves

- Determining how much light arrives at a point and from which direction (*radiance* is the actual radiometric unit)
  - Historically known as “the global illumination problem”
- How light interacts with surfaces, a.k.a. material properties
  - The BSDF is an important part of this
- Surrounding input and output problems
  - Importing, conversion, data manipulation, scripting, image filters, human perception, annual analysis, visualization, etc.
Problems *Radiance* Does Not Solve

- Creating the geometric model of a building
  - Although we import standard formats such as Wavefront OBJ

- Measuring the material properties
  - Although we provide tools to interpolate measured BSDF data

- Connecting to glazing and luminaire databases

- Automating standard analyses such as sDA

- Linking to whole-building simulations
Integrated Tools Using *Radiance*

- DAYSIM
- DIVA for Rhino
- IESVE
- OpenStudio
- LightStanza
- Groundhog
- Ladybug & Honeybee
- Maybe half a dozen others…
Ongoing Research & Development

- Further refinements to data-driven BSDF accuracy
- Glare analysis for scenes where solar orb is visible
- Error analysis for annual simulation matrix methods
- Executive program for running matrix annual simulations
- Integrating *Radiance* daylight simulations into *Spawn*
BSDF Models

Most simulations rely on mathematical BSDF models as the best representation of material reflection and transmission.

For example, here is the widely regarded Ashikhmin-Shirley BRDF model, which describes outgoing radiation as a function of incident radiation and a few parameters:

$$
\rho_s(k_1, k_2) = \frac{\sqrt{(n_u + 1)(n_v + 1)}}{8\pi} \frac{(n \cdot h)n_u \cos^2 \phi + n_v \sin^2 \phi}{(h \cdot k)\max((n \cdot k_1), (n \cdot k_2))} F((k \cdot h))
$$
3D Plot Comparison for Brushed Aluminum
Daylight Redirecting Film
Walter et al. (2007) Model
Our Data-driven BSDF
BTDF measurement points compared to Walter et al. model fit
Our data-driven BTDF
Effect on Rendering

Walter et al. model
Effect on Rendering

Data-driven BTDF
Light Levels

Walter et al. Data-driven
What Is the Future of Radiance?

- New regression tests ensure changes do not break anything
  - These should be more comprehensive than they are now…
- LBNL continues to have a stake, as do EPFL and others
  - DOE funding has been steady for the past few years
- Developers of tools such as Accelerad, Honeybee, or DIVA could eventually take over code maintenance
Collaboration & Community

Radiance owes its success to the individuals who have taken it on over the three decades it has been a shared tool.

Most of the ideas that went into its development did not come from me alone.

A spirit of collaboration is essential to any collection of tools that hundreds of experts use but none completely masters.
Thank You