

The workflow challenges in daylighting calculations with RADIANCE for huge architectural structures



DAYLIGHT PLANNING



EDUCATION



SHOPPING

Location Aldrans

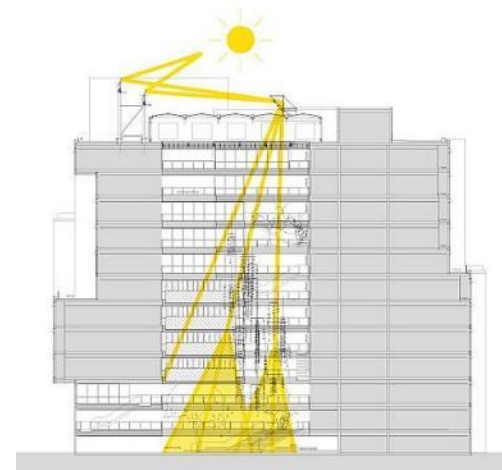
Bartenbach GmbH
Lighting design / Research / Development
Location Austria



Range of Services Daylight Planning



- Daylight planning: from conception to execution
- As-is analyses: actual state analyses, building analyses
- Daylight simulation in artificial sky
- Examinations of sunlight and shading
- Daylight calculations and simulations, g-value measurements
- Competition supervision, expert opinions, studies
- Building certifications according to DGNB, BREEAM, LEED, ASHRAE etc.



BUILDING WITH DAYLIGHT



Architecture is the basis of
light, light is the basis of
architecture.

Building with daylight

Energy saving through efficient use of daylight



Changi Airport Terminal 3, Singapur

City Library, Augsburg

Genzyme Headquarters,
Cambridge/Boston

Trade Association,
Augsburg

Building with daylight

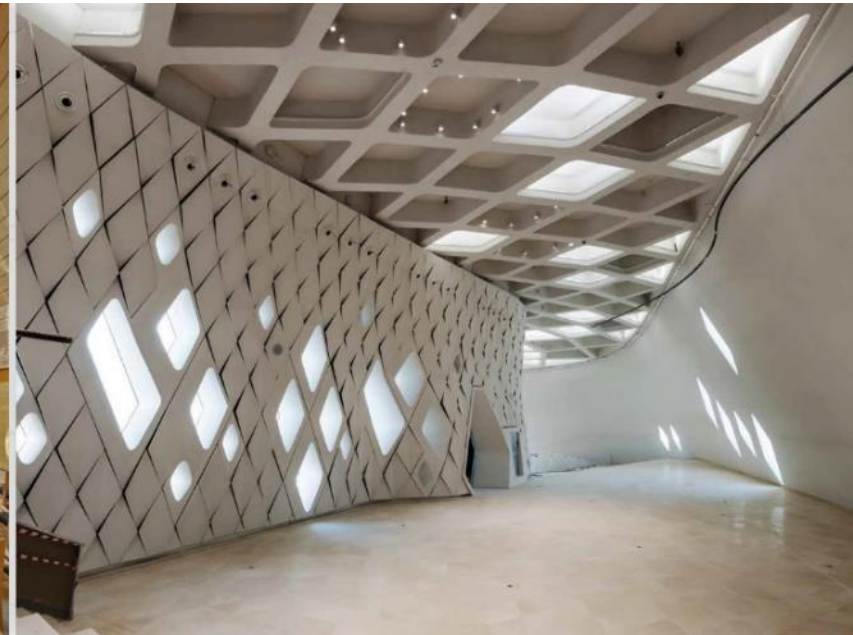
Daylight is dynamic and shapes the architecture



Fair, Basel



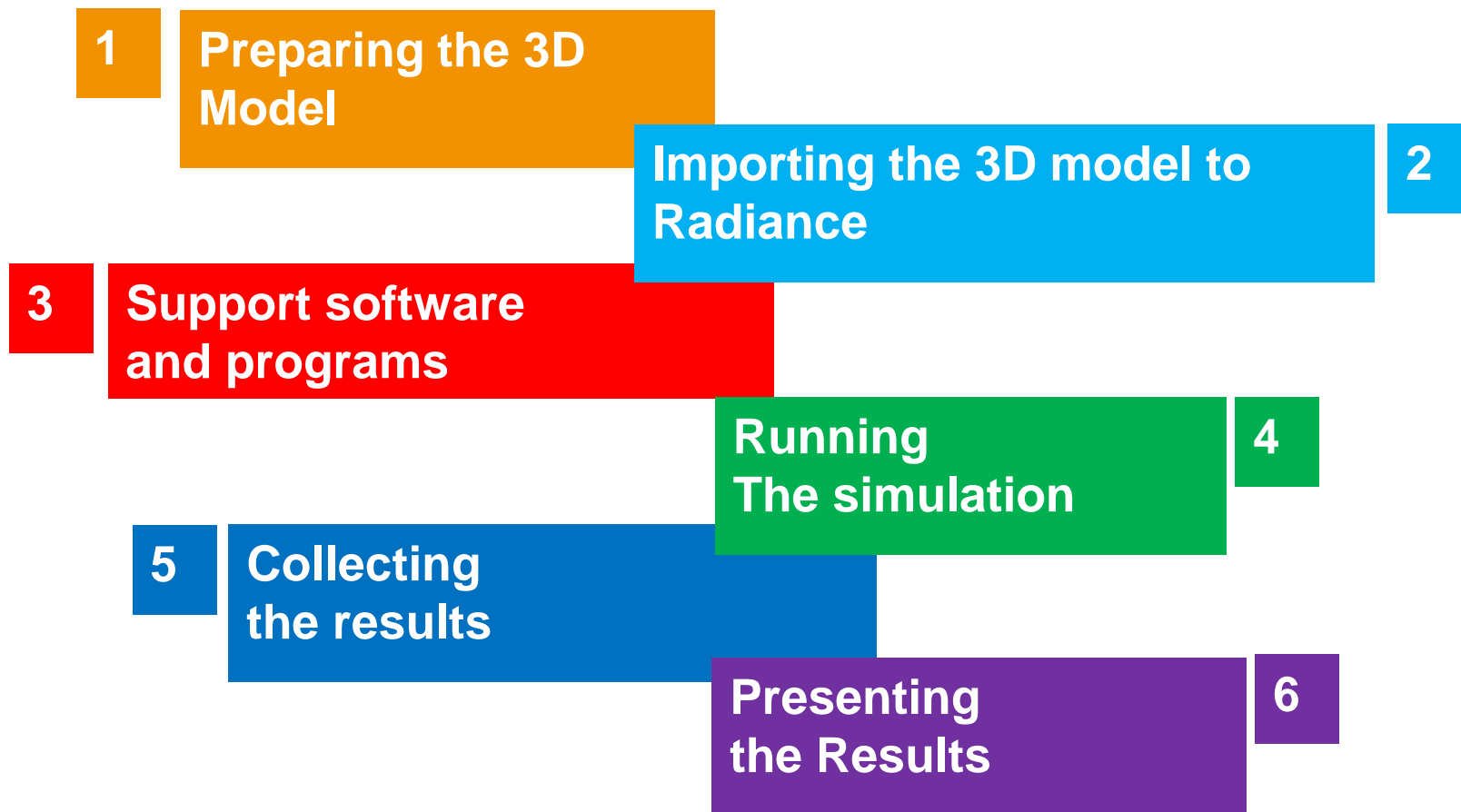
Chapel St. Hedwig,
Augsburg



Sheikh Zayed Desert
Learning Center, Al Ain



EXPO Bridge,
Zaragoza



PREPARING THE 3D MODEL



Preparing the 3D Model

- Changing all surfaces into 3D Mesh
- Simplifying the geometry (reducing the detail, changing the glass to a single layer, omitting unnecessary parts e.g. door handles, etc)
- Distribution of the geometry into layers based on materials, systems, and functions.
- Creating the measurement surfaces

Example:

The example structure on the right side shows a part of a facade that is used to limit daylight entering into the space.

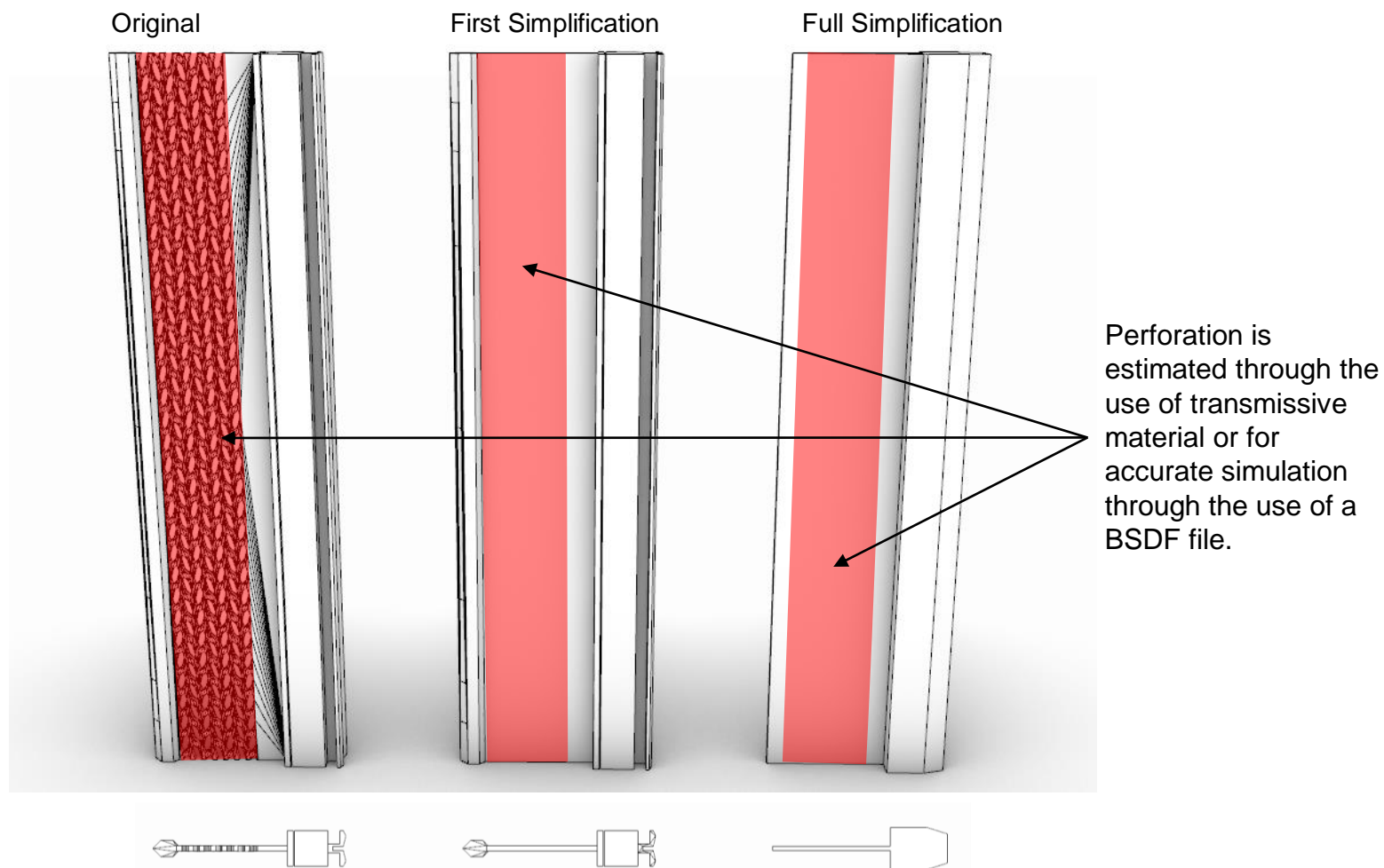
The pieces shown occur about **36.000** times within the main model.

The amount of surfaces that can be reduced by simplifying this structure is immense.

Original Model: 181.332.000 surfaces

First Simplification: 6.372.000 surfaces (3,5% of original)

Full Simplification: 432.000 surfaces (0,24% of original)



perforated metal

different methods of realization and their effect (geometry, function file and material)

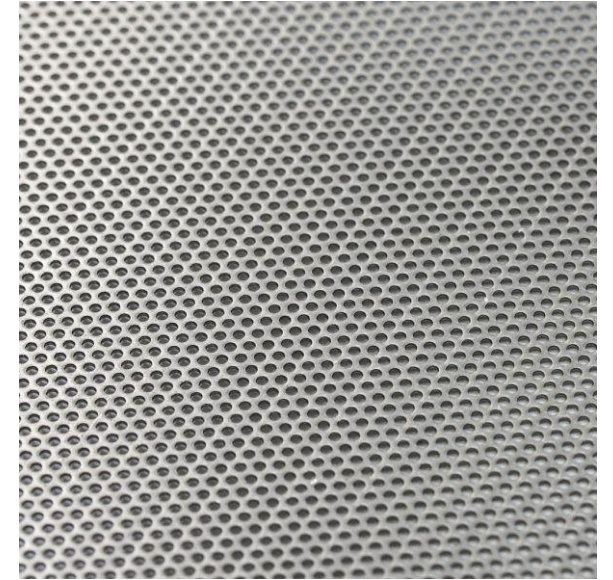
geometry: 3d-model

- huge files, programs even might crash
- accurate calculations time consuming, problems with RAM

function file: perforate.cal + mixfunc

- perforate.cal (Bruce Sounes / Georg Mischler?):
 $xn = \text{mod}(Px, 1) - 0.5;$
 $yn = \text{mod}(Py, 1) - 0.5;$
 $\text{outofcirc}(x, y, r) = \text{if}(\text{sqrt}(x*x + y*y) - r, 1, 0);$
 $z_hole = \text{outofcirc}(xn, yn, A1);$
- mixfunc:

```
void mixfunc perforate_alu
6 alu void z_hole perforate.cal -s 0.1
0
1 0.3989422804
```
- perforate_rand.cal, random perforation (used recently in a large project; A1 - fraction of holes in the material, e.g. 0.4 = 40%):
 $\text{perforate_x_rand} = \text{perforate_x_rand} + 1;$
 $\text{out_of_hole} = \text{if}(\text{rand}(\text{perforate_x_rand}) - A1, 1, 0);$



material

- trans, BSDF, ...

pillars as a path to the abyss

the columns of heracles (αἱ Ἡράκλειοι στῆλαι)

how cylinders can make life easier: obj2rad versus export from ClimateStudio

Rhino: Usage of a simple object such as a cylinder instead of a polysurface or NURBS surface that is (almost) a cylinder

standard method

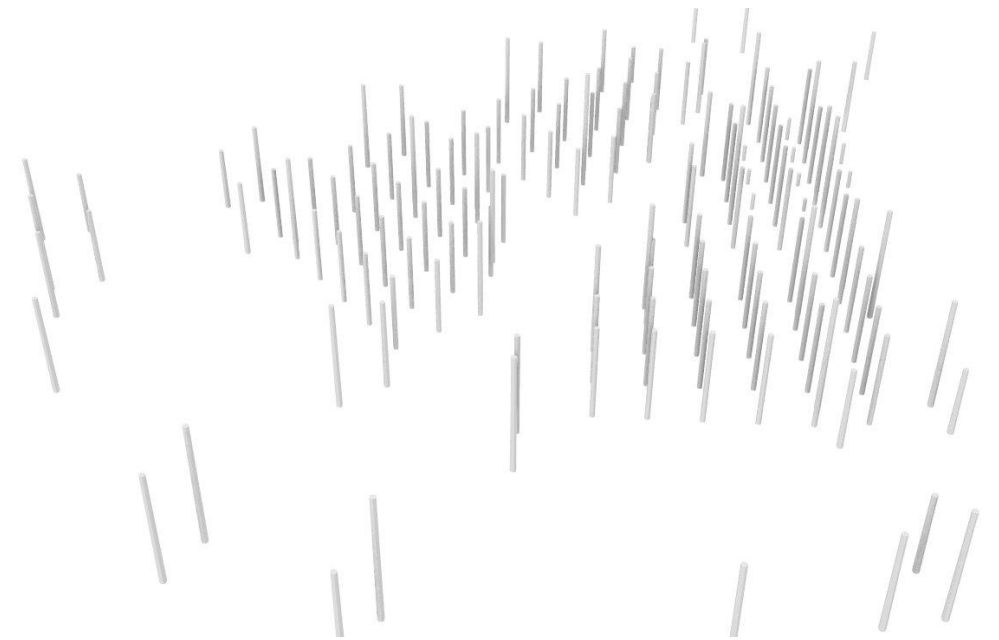
- export to Wavefront obj-file in Rhino: polygonal faces (typically triangles and quadrangles)
- conversion to RADIANCE (*obj2rad*: polygons; *obj2mesh*: compiled RADIANCE mesh file)

export using ClimateStudio

- start a calculation
- during the calculation the RADIANCE-file *scene.rad* is created in a temporary directory
- a cylinder (“volume”) is converted to *cylinder + 2x ring*

This RADIANCE-file *scene.rad* created by ClimateStudio frequently is much smaller than the results from the standard method. It can also be used for calculations on a Linux server.

Using native RADIANCE geometry helps to reduce file sizes and calculation time as well.



escalators to desperation

obj2mesh: internal - too many patch triangles in addmeshtri

Calculations for 221201_Baggage

Rhino-file (3dm) 1.2 GB

Wavefront obj-files: 30 files (layers); largest obj-file: Escalator.obj, 132 MB

Conversion to “compiled RADIANCE mesh file” (RADIANCE triangle mesh, rtm)

```
obj2mesh -v -w Escalator.obj >Escalator.rtm
```

Error message: “obj2mesh: internal - too many patch triangles in addmeshtri”

Solution for the calculation in December 2022 (deadline pressure in project)

These escalators had no significant influence on the results of the daylight calculations. Therefore this geometry was removed.

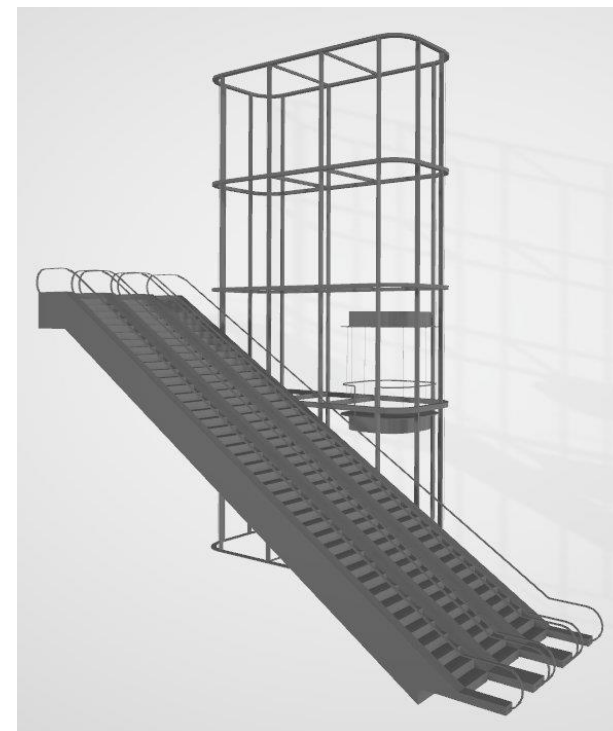
Alternative

```
obj2rad Escalator.obj >Escalator.rad
```

The resulting rad-file is 501 MB large and the standard calculation process is no longer applicable (no rtm-file for objects on layer)

Background: Bounding box for all 11 escalators is 284 m x 602 m x 28 m, smallest length in geometry is 0.4 mm

See manpage for obj2mesh (Option `-r`): “The `-r` option specifies the maximum octree resolution. This should be greater than or equal to the ratio of the mesh bounding box to the smallest triangle. The default is 16384.”



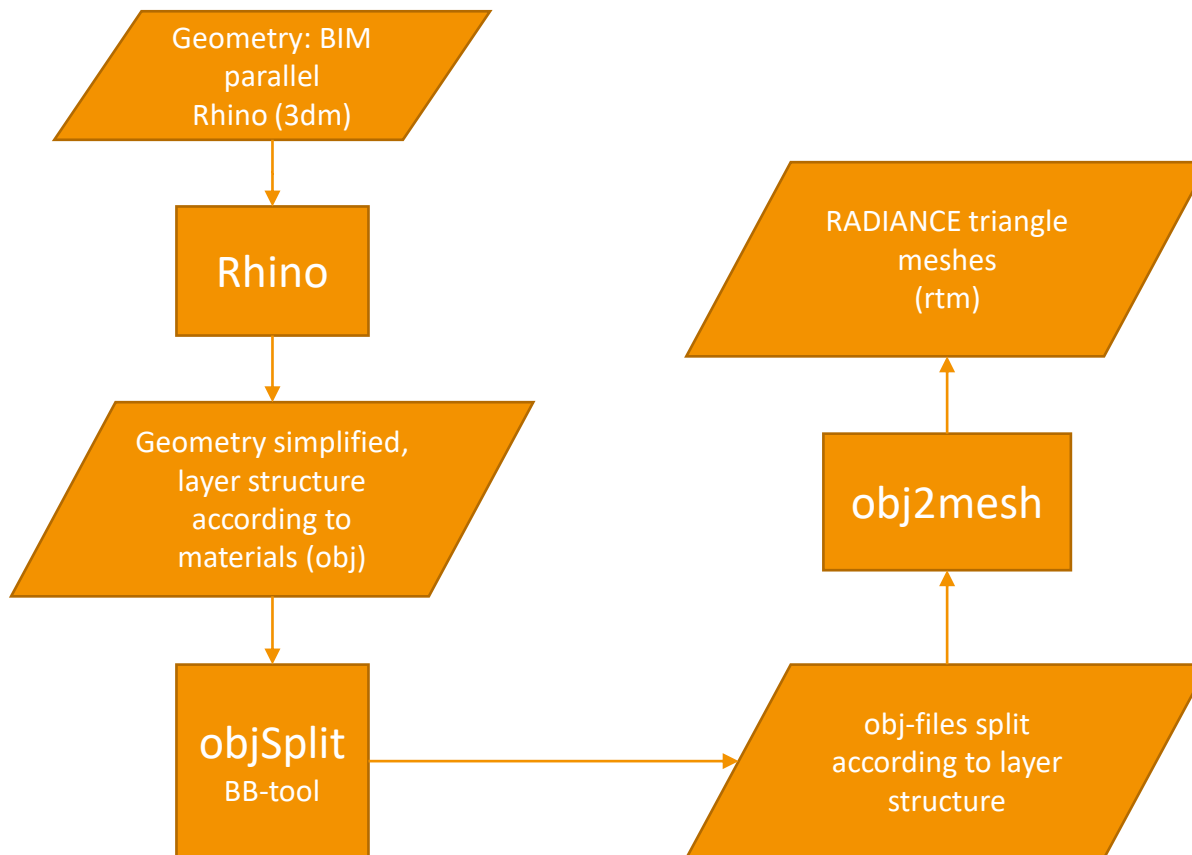
Escalator (1 out of 11)

IMPORTING THE 3D MODEL TO RADIANCE

typical workflow for a recent huge project

Importing the 3D model to Radiance

- export from Rhino
- converting the geometry from obj to rad:
obj ⇒ obj2mesh ⇒ rtm ⇒ rad
- material definition
- daylight systems (BSDF)
- measurement points
- sky condition
- calculation method
- choice of RADIANCE options



Methods to run RADIANCE

For lighting designers, scientists, programmers and nerds

Command line

- Linux (uses all cores)
- Windows (single core)

Remote, simplified workflow (BB: Greenwich)

Programs with a GUI using RADIANCE internally

- Early efforts: ADELINe, Desktop Radiance
- ReluxDesktop (special version)
- DIVA for Rhino, ClimateStudio
- Ladybug Tools: Honeybee
- Pollination

Grasshopper allows the user to customize Rhino Plugins.



LADYBUG



HONEYBEE



RUNNING THE SIMULATION

Linux Server, openSUSE

Used computer software

- standard-version of RADIANCE (e.g. RADIANCE 5.4a)
- shell-scripts

Used computer hardware: aldrk01, aldrk02, aldrk03

- Bull server: 2 racks, each with Intel Xeon CPU E5520 (4 Kernels, **8 Threads**, 24 GB), thought for HPC with Message Passing Interface (MPI; distributed memory parallelization)
seperate servers (rtrace -n 8)
- HPC-Host-System: 2 x Intel Xeon CPU X5650 (6 Kernels, 12 Threads, 24 GB) with 2 x NVIDIA Tesla M2090 (for GPGPU, General Purpose Computation on Graphics Processing Unit)
24 threads directly usable by RADIANCE (rtrace -n 24)
GPU (NVIDIA Tesla) not used in RADIANCE-calculation

rtrace **option -n** nproc

execute in parallel on nproc local processes
not available in Windows-version of RADIANCE

What are the challenges?

- employees work on windows computers mainly using software with a graphical user interface
- usually no Linux knowledge available
- usage of many different command line programs versus graphical user interface GUI

Solutions

- automation of the workflow, usage from Windows (batch-jobs), calculation on Linux server
example: Greenwich (2010)
- delegation of the calculation to specialists (R&D-department, ...)
- usage of tools based on RADIANCE with GUI (Honeybee / Pollination, DIVA for Rhino / ClimateStudio,)

Depicting the results

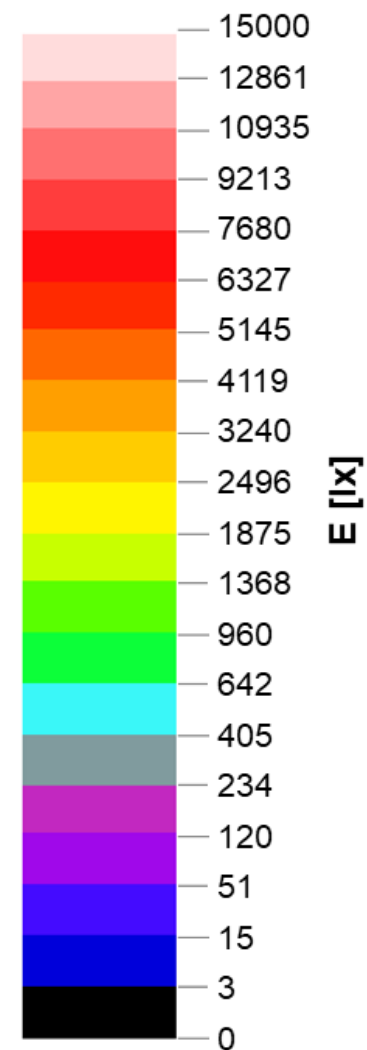
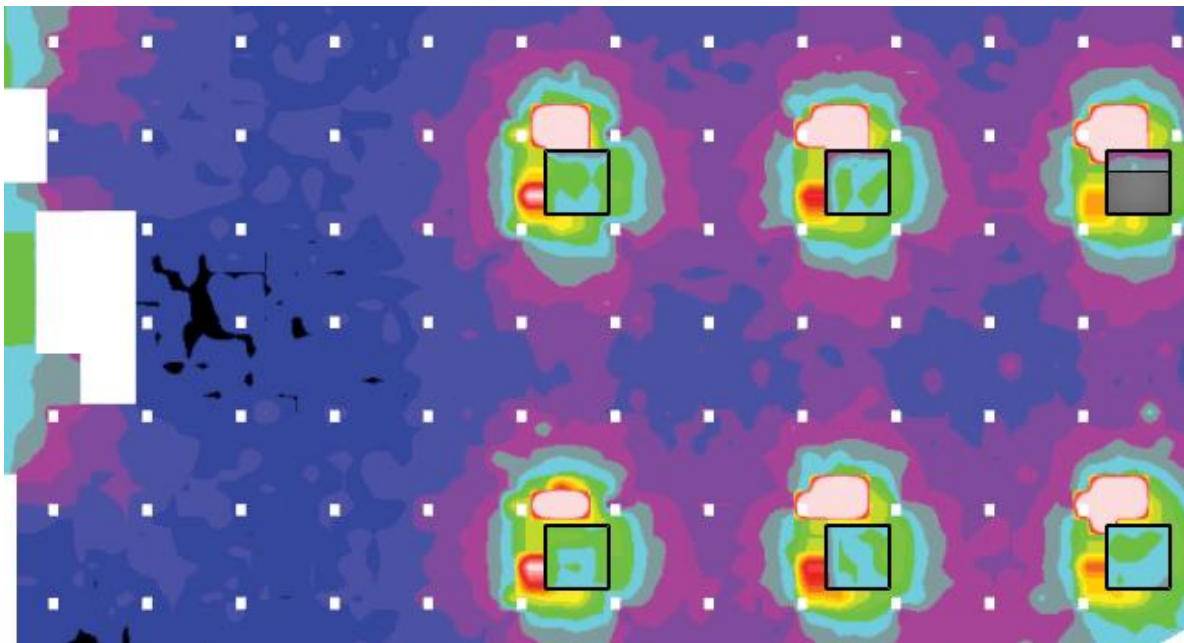
Increase comprehensibility

Communication to other Fields

The best simulation cannot achieve its goal if the results cannot be communicated in an understandable way. In projects where several other fields work with the results of the daylight simulation, the right choice of color palettes is crucial to make the information accessible to them.

In this specific project the choice was to pick a logarithmic scale.

With this scale we can visually show the difference between the high intensity lighting on the plants as well as the lower intensities on the ground floor.



Depicting the results

Customization with Grasshopper

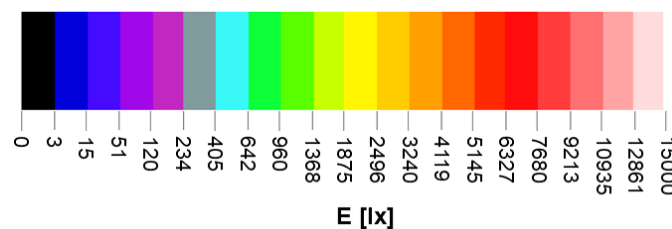
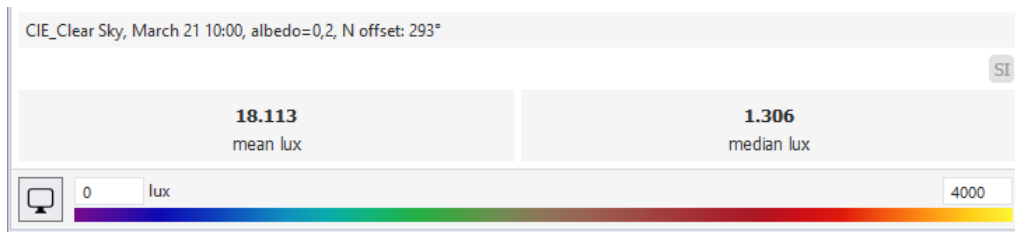
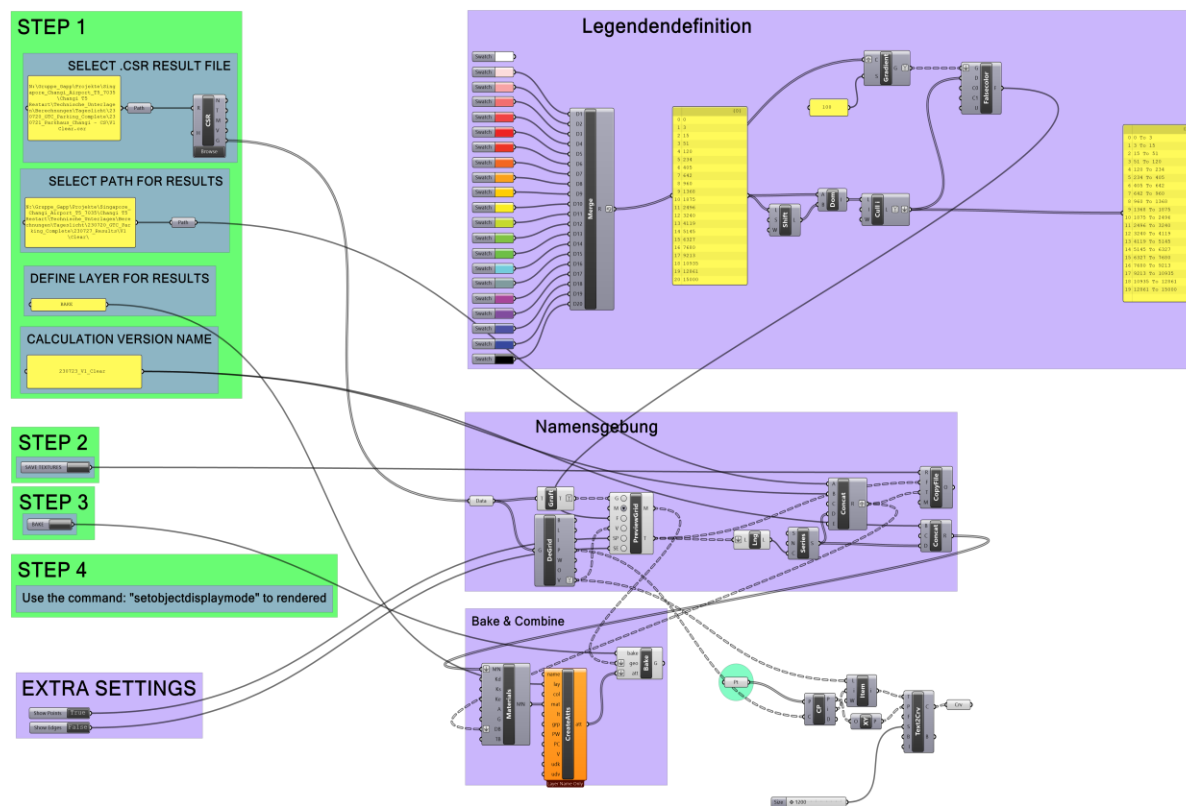
Other third-party software sometimes restricts the possibilities to visualize the results in a consistent manner.

By using Grasshopper as a tool to change the raw results to our custom pallet we can depict the simulation exactly as needed.

Additionally, this allows us to use multiple different tools to simulate different areas while having the same look within presentations.

Example:

- Complicated and large areas are simulated in RADIANCE directly.
- Smaller excerpts of the big project can be simulated e.g. within ClimateStudio.





Let it  light

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