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De Luminae

Consultancy in daylighting,
energy savings and comfort

Progressive evaluation of daylight ambiance in architectural projects with Radiance

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Overview

- Introduction
- Certivéa and HQE labels
- Case study description
- Architectural project:
  - Sketch phase
  - Basic preliminary phase
  - Detailed preliminary phase
  - Dynamic daylight calculations
- Conclusion

Introduction

- **Radiance** provides excellent basis for implementation of additional methods and algorithms for complex lighting calculations
- Not easy to master - novice users give it up easily

- For complex calculations:
  - **Scripts** – flexible but not easy to understand and change by typical user
  - **GUI based tools** – adapted for specific calculations, not so flexible, but understandable for typical users. Examples: Daysim, Ecotect, IES module VE, falsecolor2

- Most of GUI tools extend classic Radiance calculations: additional analysis and presentation of Radiance results, dynamic calculations, energy consumption calculations etc.

De Luminae

- **De Luminae** - consultancy and research in natural and artificial lighting, its impact on energy savings and comfort of interior and urban ambiances.
- We have been working on various research and commercial projects in France, in the field of daylighting and sustainable architecture.

- To calculate buildings' static and dynamic daylight performances, we use numerous Radiance-based software tools.
- We develop GUI based tools, for various phases of Radiance analysis: input data preparation, execution of Radiance calculations and results analysis.
- All our tools are written in Python (wxPython) and C.
- We distribute software under GPL Open Source license on our site www.deluminaelab.com

Architectural project

- Architectural design is a process, where level of future building details is gradually increased: from idea and first sketch, through basic project design and detailed project phase, to building construction, usage and maintenance.
- As project evolves, definition and calculation of various daylighting performances of the future building become possible.
- Radiance and additional tools can follow architectural project in each phase and give adequate results and their interpretation.
- Analysis and visual presentation of results enables better communication between lighting specialists and clients.

Certivéa and HEQ labels

- **High Environmental Quality (HEQ)** - French national certification label defined by **Certivéa** institute for residential and non-residential buildings: hotels, schools, residential buildings, offices, health centers, etc.
- The system identifies 14 environmental targets:
  - Site and Eco-construction: relation between the building and its immediate surroundings; integrated choice of products and construction materials; low-impact construction site
  - Eco-management: energy, water and activity waste management, maintenance-environmental performance conservation
  - Comfort: hygrothermal comfort, acoustic comfort, **lighting**, odors
  - Health: sanitary quality of spaces, indoor air quality, sanitary water quality
- Three levels of performance are defined for each target: **basic**, **good**, and **very good**.
- Minimal requirements: "very good" rating for at least three issues, "good" for at least four and "basic" for no more than seven.

HEQ daylighting

- HEQ daylighting – Daylight factor
- For each interior space, a zone is identified covering a surface from the facades to a given limit distance in the interior space. Inside that zone, daylight factors must reach defined levels

Label name	Conditions
Basic	**DF >= 1.5%** in 80% inside the zone for 80% of all spaces
Good	**DF >= 2%** in 80% inside the zone for 80% of all spaces **DF >= 1.5%** in 80% of the remaining 20% of the spaces
Very good	**DF >= 2.5%** in 80% inside the zone for 80% of all spaces **DF >= 1.5%** in 80% of the remaining 20% of the spaces **DF >= 0.7%** in 90% of the spaces

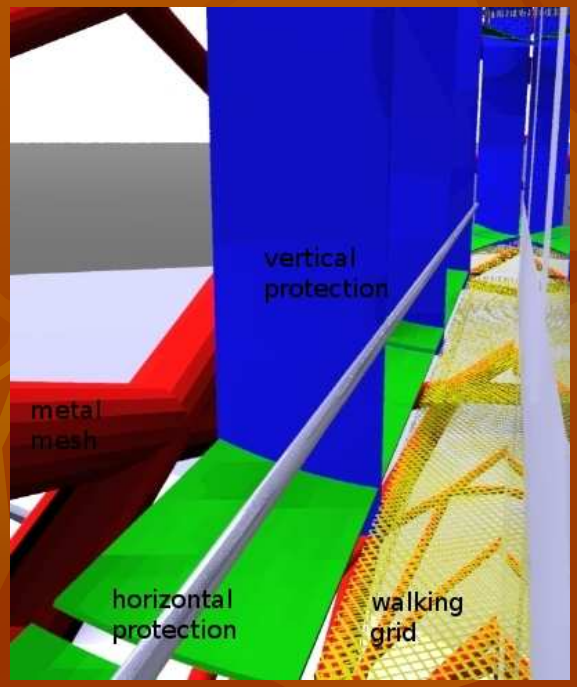
It has its limits and can be criticized but as the immense advantage to exist

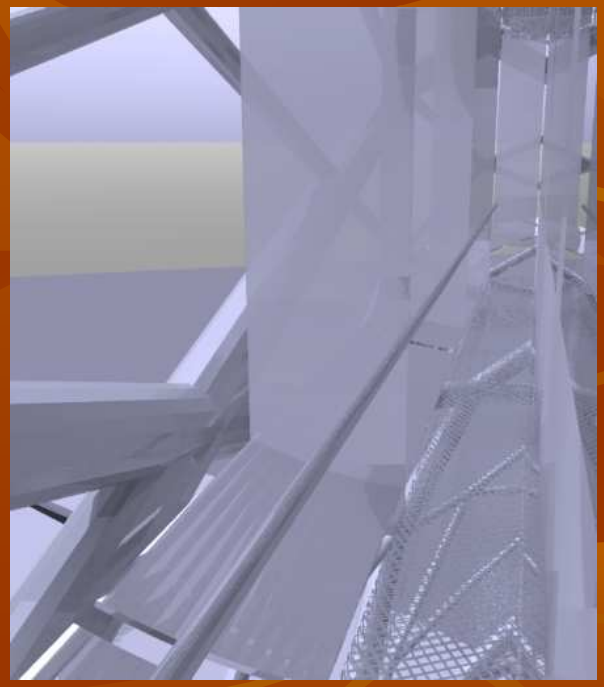
Case study – project description

- Office building North of Paris
- Tower + 4 small buildings
- Calculations performed for 19th floor (72m from ground level)

Case study – project description

- Architects proposed building envelope made of metal mesh, with additional vertical translucent light shelves for sun protection and horizontal curved specular shelves for light redirection into the building interior. These sun protections and mesh are designed in front of east, west and south facades.





Case study – calculated values

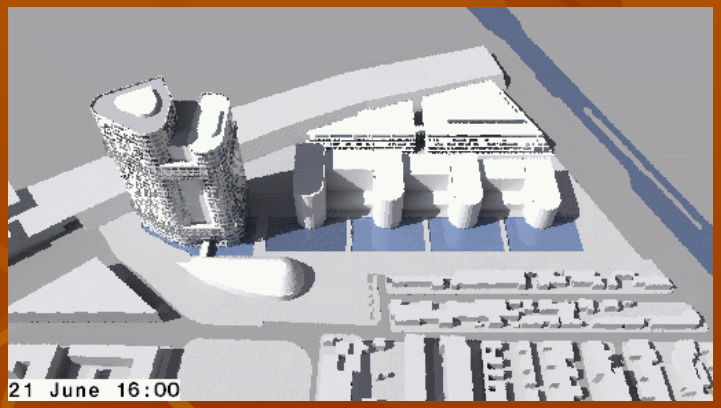
Level of project details	Calculated value	Software
Site description + building basic geometry and position	Shadow paths	RadSunpath
Facade geometry with few sun protection alternatives defined	Exposure to direct sun	SunExposure
Basic inside geometry + basic materials (gray reflectance values) + few sun protection alternatives with materials defined	Daylight factor and HEQ labels	Radiance (dayfact script) + RadDisplay (false color images, comparison of alternatives, HEQ calculations)
Materials details are specified + typical view points (work planes positions)	Visual comfort + contrasts	Radiance + RadDisplay
Occupation profiles and user behavior	Annual calculations (illuminance profile, daylight autonomy, etc)	Paclight

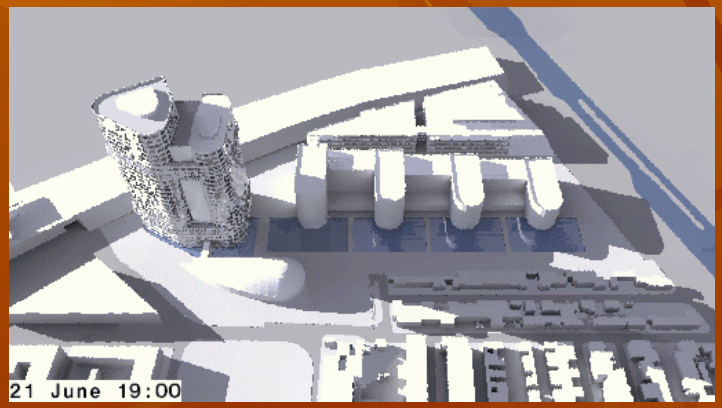
Architectural project: sketch phase

- Decisions made in early project phases regarding daylighting strategy, have great influence on final daylight ambiance.
- Calculations performed in later project phases, although potentially more accurate, can only be used to describe building ambiance, since alteration of building geometry and materials is far harder and more expensive than in earlier phases.
- In sketch phase of a building design, only site characteristics (geometry, climate, landscape) and global envelope geometry are defined, without facade and inside area details.
- What can be calculated?
  - **Shadow paths** - calculate impact of the future building on natural lighting of surrounding areas,
  - **Sun exposure** - calculate availability of direct sun on the facades.

Shadow paths

- Impact of tower on shadows of surrounding area: 4 smaller buildings in the project complex and existing buildings.
- Calculate with **RadSunpath** program

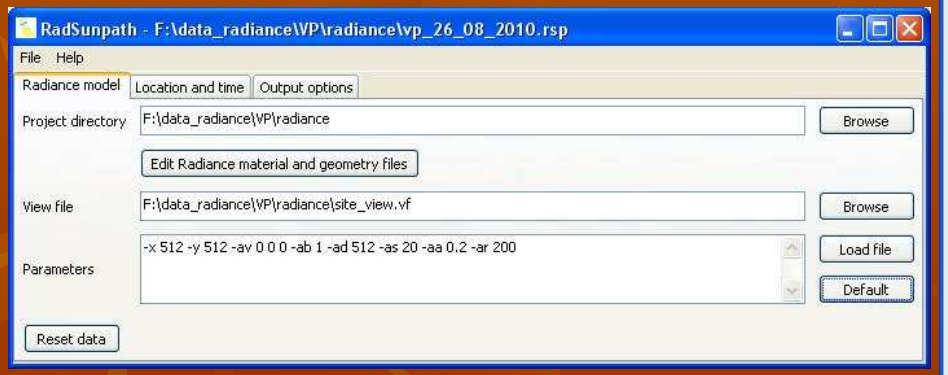


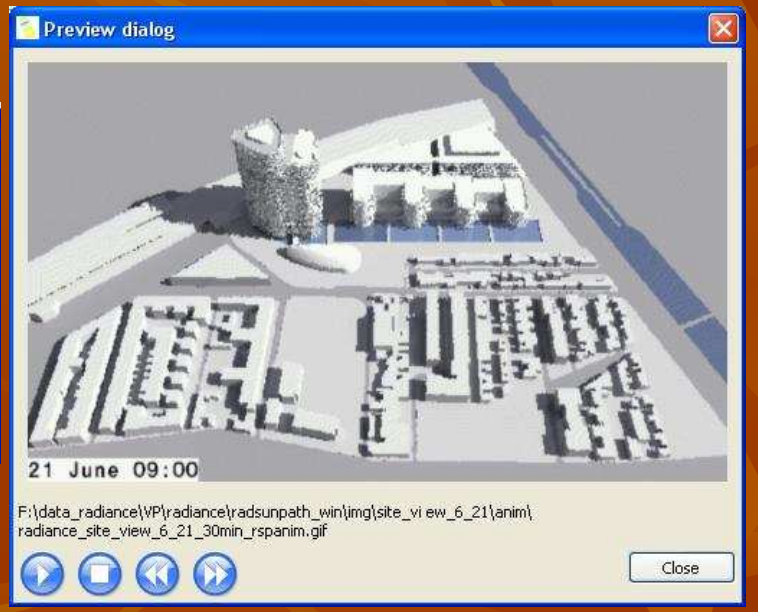


Shadows for 2 time moments during summer solstice: 4PM and 7PM.

Shadow paths - RadSunpath

- **RadSunpath** - enable easier sun and shadows path calculation and visualization with Radiance.
- Program creates a set of Radiance images for a project, for selected view, date and time step, and include them into final gif animation file which represents the sun and shadows path during the selected date.
- Developed SketchUp plugin for import into RadSunpath, with help of Thomas Bleicher.





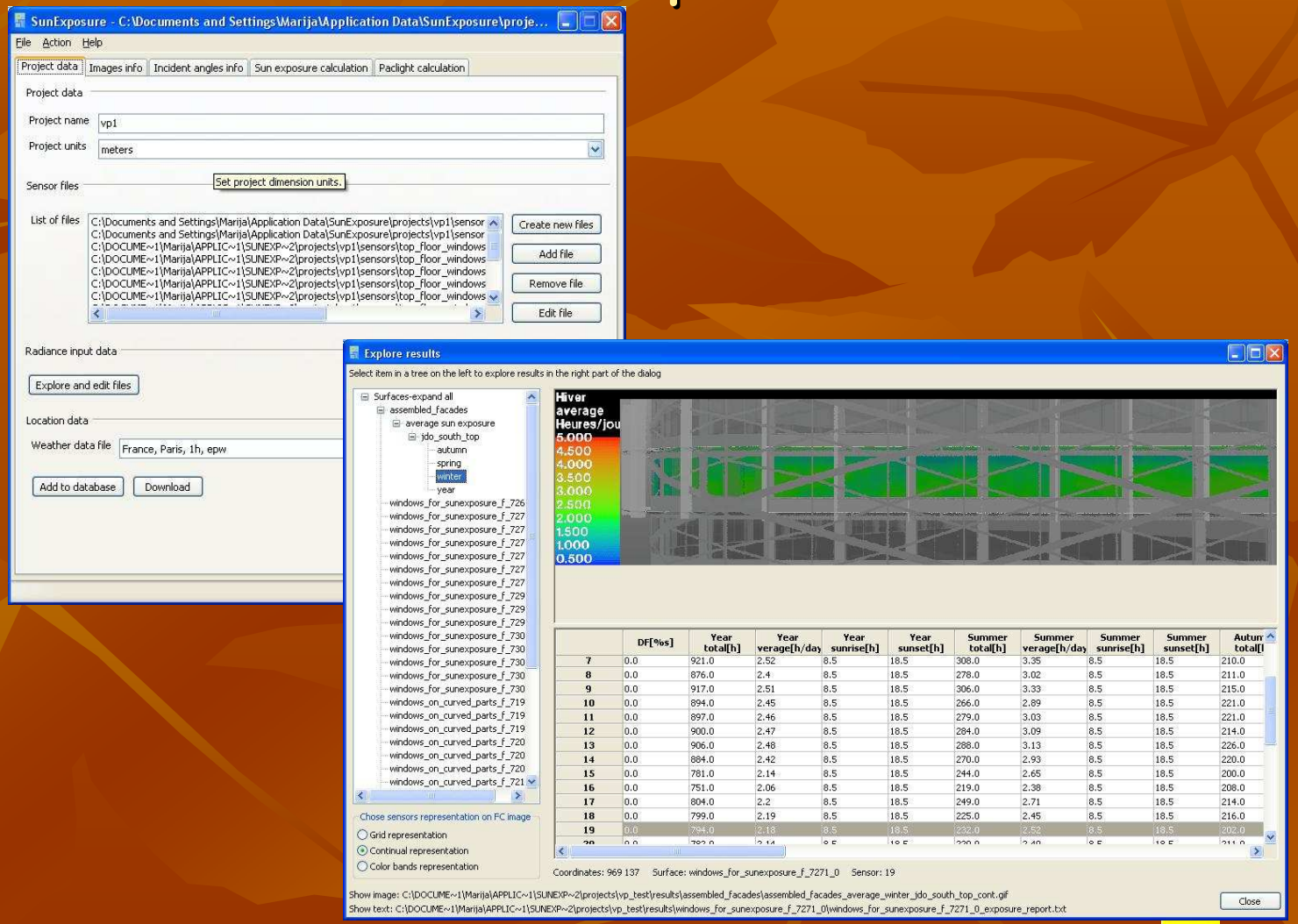
SunExposure

- **Sun exposure** - number of hours during some time period, when direct sunlight strikes building facades ; dynamic calculation
- According to World Meteorological Organization, direct sun is visible on the sky if direct normal irradiance of the sky is above 120W/m2.
- Sun exposure for facades, can be calculated during early phases of a building design, and influences important decisions related to building lighting and thermal strategies:
  - Selection of facade materials
  - Position of windows on the facades
  - Areas of the building for passive solar heating -"greenhouse effect"
  - Evaluate the efficiency of sun protections, potential risks of overheat
  - Parts of the building which need special sun protection to avoid glare
  - Best places for photovoltaic cells
  - Areas of the facade that should be insulated to prevent overheating or over-cooling of the building.

SunExposure

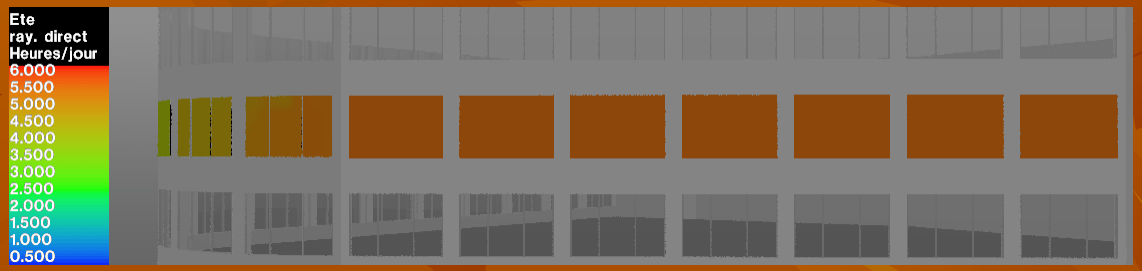
- **SunExposure** - calculates sun exposure of sensors on building facades. It enables fast lighting calculations in early phases of the design.
- Input: building and environment geometry, weather data file and facade surfaces (polygons in Radiance format),
- Calculations: Program generates sensor points on the facades and calculates if sensors are exposed to direct sunlight or not, for each hour during one year period.
- Additional calculations: incident angle of the direct sunlight onto façade surfaces. These results are used as a criteria for estimation of sun penetration depth into the building interior.
- Output: textual file with results summary for each season and year period, and also images with results presented in false colors.
- SunExposure is officially not released, since program GUI is still under construction.

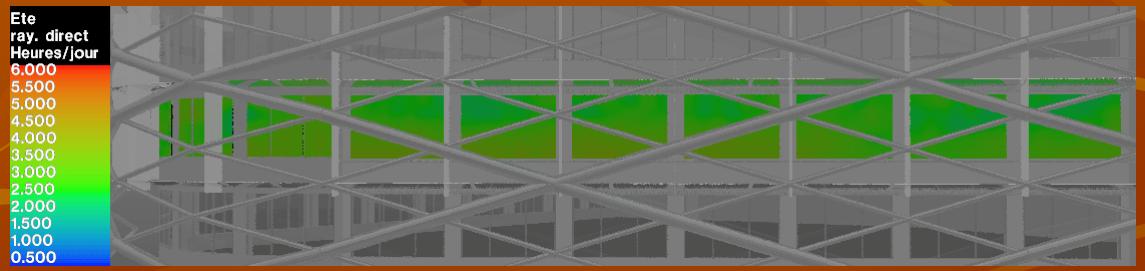
SunExposure



SunExposure results

- Calculated SunExposure for facade with and without sun protections
- Weather: Paris EPW file





Impact of sun protections on the south facade, sun protections decrease sun exposure by approximately 2-3h/day.

- Without protections - direct sunlight approx 5.34 h/day during summer
- With protections – direct sunlight is between 2.5 and 3.5h/day

SunExposure results

- Sun Exposure can be calculated even for facades without any galzing and protection details

Continual or grid false color representation of SunExposure results

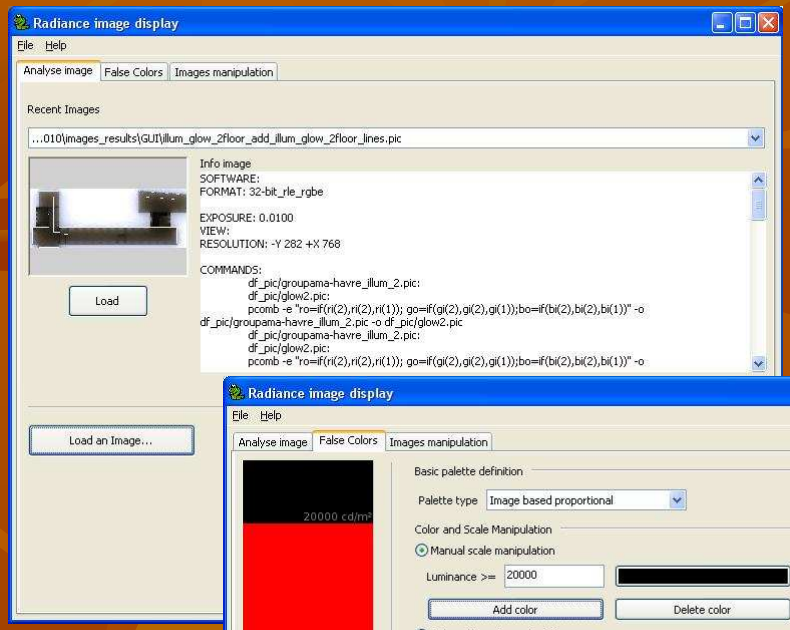
Architectural project: basic preliminary design

- Calculations of building interior daylight ambiance – Daylight Factor and comparison to HEQ labels requirements
- Building outside and inside geometry are defined, position and size of windows and basic materials' characteristics are specified. Materials are defined with their gray reflectance values, and glazing structure and transmittance is defined.
- Calculate DF with adapted dayfact script and analyze image with **RadDisplay**.

RadDisplay

- **RadDisplay** - Radiance image viewing and image analysis with tracing and false color methods.
- For detailed analysis of image pixel values, false coloring is a very powerful tool. It is also a great communication tool for technical images such as Radiance images.
- RadDisplay has advanced interface for false color scales definition, user can set number of colors, precise limits between colors, chose colors for the palette etc.
- If FC palette is adapted for HEQ labels, RadDisplay can be used for estimation of fulfillment of HEQ requirements.

RadDisplay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Analyse image
False Colors
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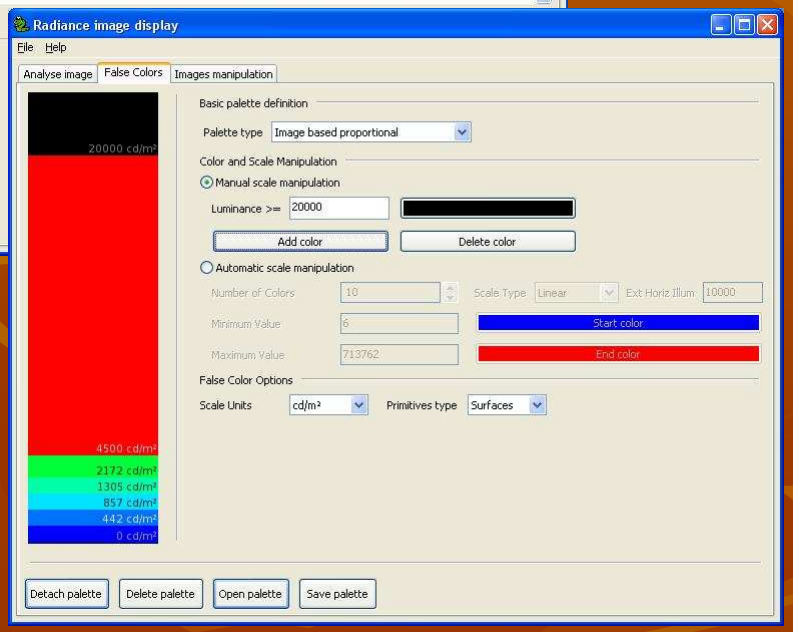
Radiance image display
File Help
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Images manipulation
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Basic palette definition
Palette type
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Color and Scale Manipulation
Manual scale manipulation
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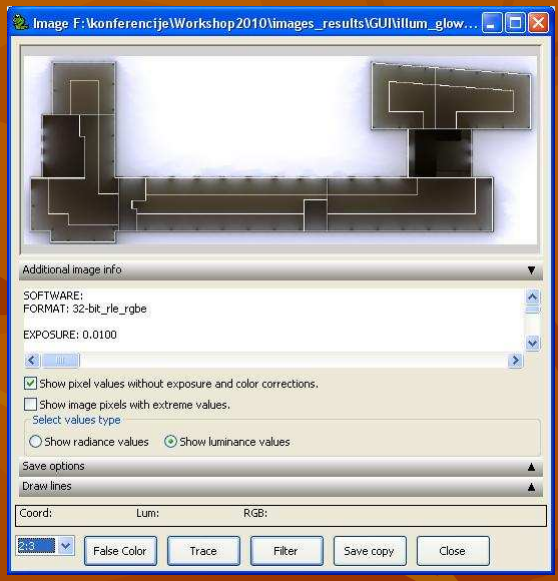
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Coord:
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RGB:
False Color
Trace
Filter
Save copy
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False color illum_glow_2floor_add_illum_glow_2floor_lines.pic
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DF results

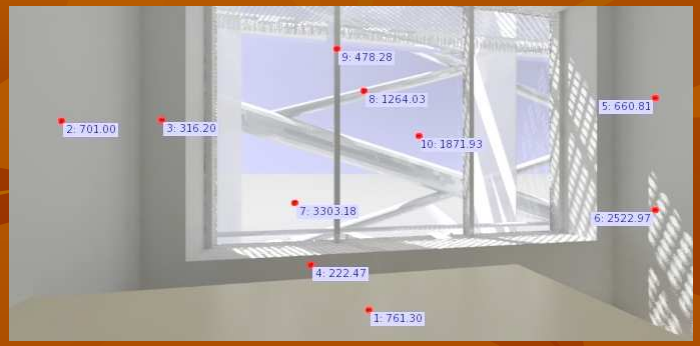
- Metal walking area around the building on each floor below windows, for windows washing and maintenance of metal mesh and sun protections.

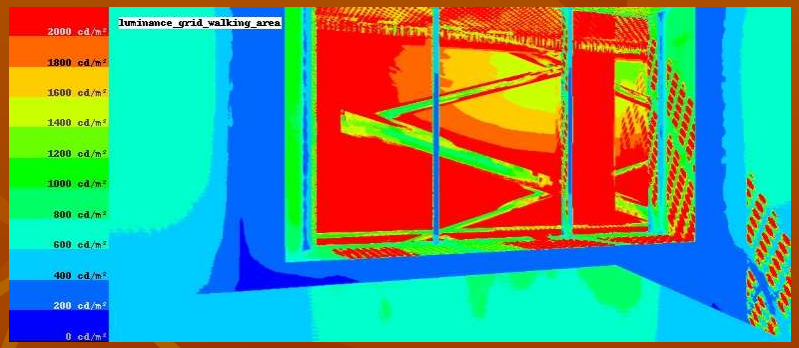
Protection	No walking area	Grid walking area	Reflective walking area
> 1 %	100%	100%	100%
> 1,5 %	100%	100%	100%
> 2 %	84%	76%	74%
> 2,5 %	67%	60%	59%

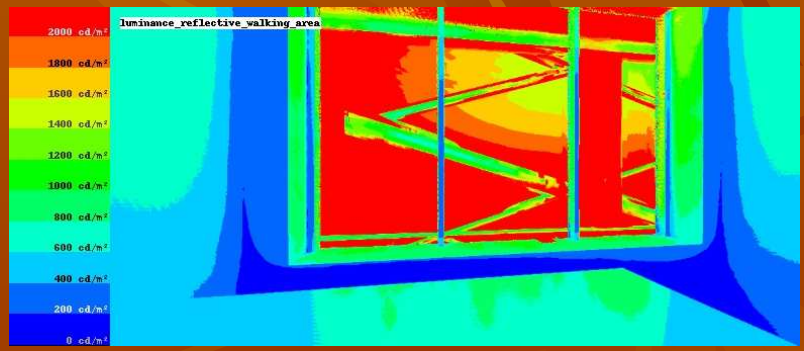
Architectural project: detailed preliminary design

- To achieve comfortable daylight ambiance in some space various quantitative and qualitative performances should be achieved.
- Visual comfort requires that luminance of surfaces within field of vision is acceptable, and that contrasts are within acceptable ranges, to avoid glare occurrence.
- Study internal luminance distribution for south oriented office, for two walking area materials: metal grid material and opaque reflective metal walking area.

Luminance results







Metal grid walking area

Reflective metal walking area

Criteria for comfort/discomfort come from AFE and European Commission

Dynamic daylight calculations

- Dynamic daylight calculations should be performed to obtain info about real building performance over the time, for specified building site and weather conditions.
- These dynamic performances like Daylight Autonomy, Useful Daylight Illuminance and others can be calculated with Radiance with few additional tools and methods.
- Annual illuminance profile and daylight autonomy can give us interesting information about daylighting ambiance and also enable comparison of various project alternatives.
- Calculation methods: Daysim, classic Radiance with rtcontrib and Ward's 3-phase approach, Paclight

Paclight

- **PACIBA** project- develop set of software tools that can calculate various aspects of building energy demands and comfort under the funding of ANR (Agence Nationale de la Recherche France)
- **Paclight**- daylight calculation module developed by De Luminae
- Takes on input building geometry and materials (in Radiance format), climate file (in epw, try, wea or Satel-light format) and reference planes definition, and gives on output annual illuminance profile for specified reference planes.
- For specified reference planes and preferable number of sensor points, Paclight generates rectangular grid or Delaunay triangular mesh of sensor points.
- Annual illuminance profile is calculated with adapted Daysim algorithm, where daylight coefficients are calculated with rtcontrib. Sky luminance distribution model used in Paclight is Perez sky model, while DCs number and position is in accordance with Daysim sky discretization scheme.

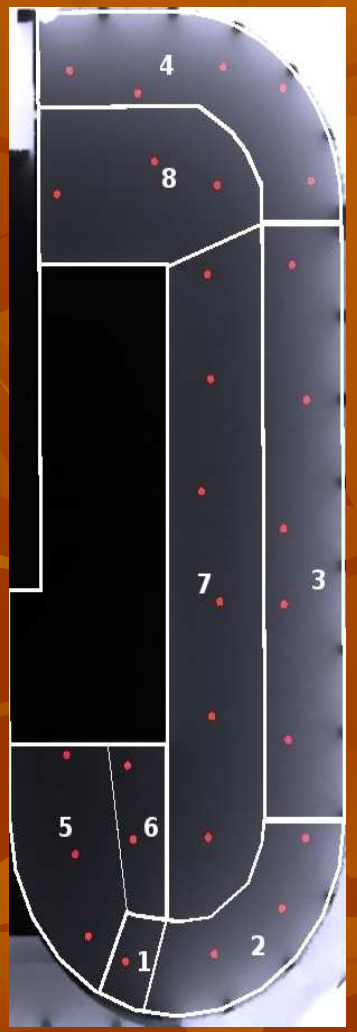
Paclight accuracy

- Accuracy of Paclight in comparison to Daysim and classic Radiance brute force approach has been tested during PACIBA project.
- Paclight and Daysim give illuminance results of similar accuracy, with average error **6 - 9%** in comparison to Radiance brute force calculation.
- If compared to constant illuminance threshold, for daylight autonomy or UDI calculation, both Daysim and Paclight give similar results, where differences to classic Radiance results are from **1.67%** for 1000lux threshold to **7.69%** for 300lux threshold (on a specific example).
- Paclight is adapted for calculation in **parallel threads**, which enable shorter calculation times, without influence on accuracy.
- Accelerations for 4 parallel threads:
  - Linux – 3,5-4 almost linear (parallel threads execute with normal priority)
  - Windows – 1.5-3 (low priority of parallel threads makes calculation slower)

Paclight results

- Calculate and compare DA for two floor materials with reflectance 30% and 10%. Other materials: ceiling 80% reflectance and 70% reflectance.
- Calculation for east building tower, designed as open space offices.
- DA values are calculated for 19th floor, for working hours between 8AM and 18PM, for illuminance threshold value of 500lux.

Zone	DA [%] (floor 30%)	DA [%] (floor 10%)	DDA [%]
1	33.18%	23.79%	39.47%
2	80.91%	80.11%	1.00%
3	72.34%	69.41%	4.22%
4	82.68%	81.31%	1.68%
5	4.93%	1.50%	228.67%
6	16.64%	3.21%	418.38%
7	43.93%	34.01%	29.17%
8	52.41%	40.65%	28.93%



Paclight results

- Influence of floor material on illuminances near the facades is not significant, but deeper in the building it can be rather big.
- Beside obvious recommendation to use brighter floor material, results suggest better organization or electric lighting installation.
- The importance of the savings are impressive for architects.
- Luminaires and switches should be organized in zones: one zone for areas near windows where light will be turned on only in late afternoon hours; one zone for deeper areas - where light will be turned on approx 50% of the time, and third for zones 5 and 6.
- Internal zones are supposed to be used as corridors with light requirements lower than 500lux. For threshold illuminance values of 300lux and floor with 10% reflectance, zones 5 and 6 have DA values 19.2% and 30.41%.

Conclusion

- Daylight ambiance analysis is a process which evolves with the architectural project.
- Daylight performances calculated in various phases of a project design, (should) influence on architects decisions related to building (day)lighting and energy strategy.
- Radiance and additional tools can follow daylight analysis through all phases of architectural project:
  - **RadSunpath** - calculate and visualize sun and shadows paths during the day for the project site
  - **SunExposure**- calculate number of hours when parts of facades are exposed to direct sunlight, for some time period.
  - **RadDisplay** – analyze radiance images and compare to HEQ requirements.
  - **Paclight** - Paciba dynamic daylight calculation module; calculate annual illuminance profile and DA.