

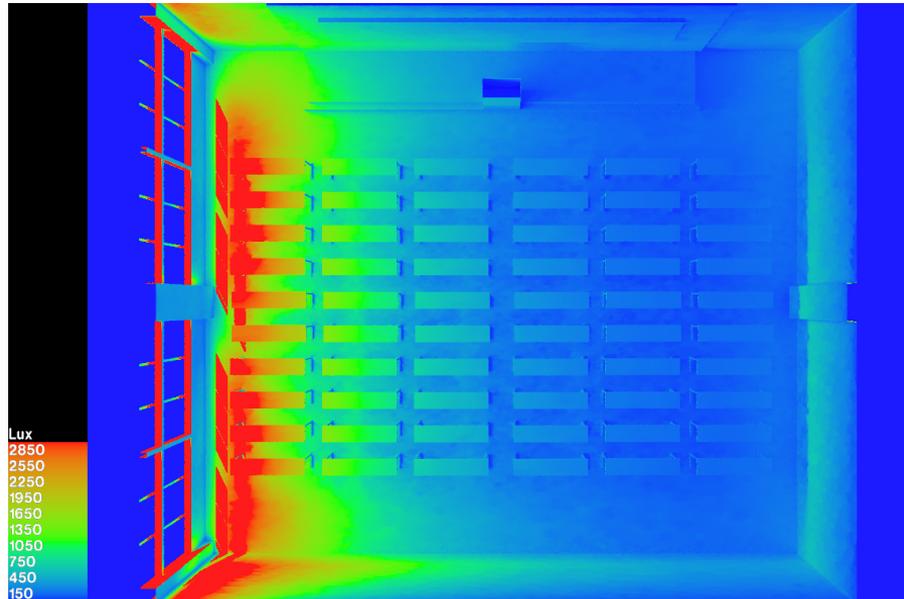
An Expression of Three-Dimensional Distribution of Light in Architecture with Photon Flows

29.08.2016 Radiance Workshop in Padua

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Introduction

- Lighting distribution is usually depicted in two-dimensional expression like horizontal illuminance distribution.

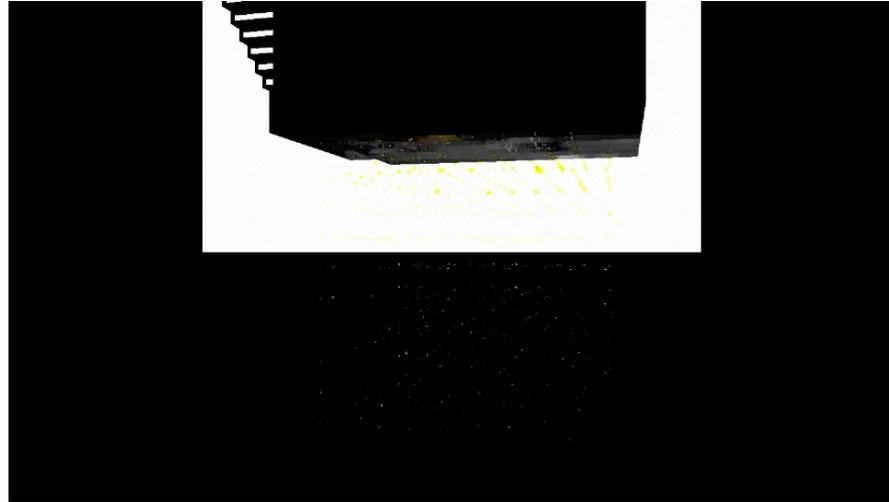


Introduction

- Some architects or lighting designers sometimes express their desire to get useful tools to visualize the light flow when they build a rough sketch of architectural/lighting design.

Introduction

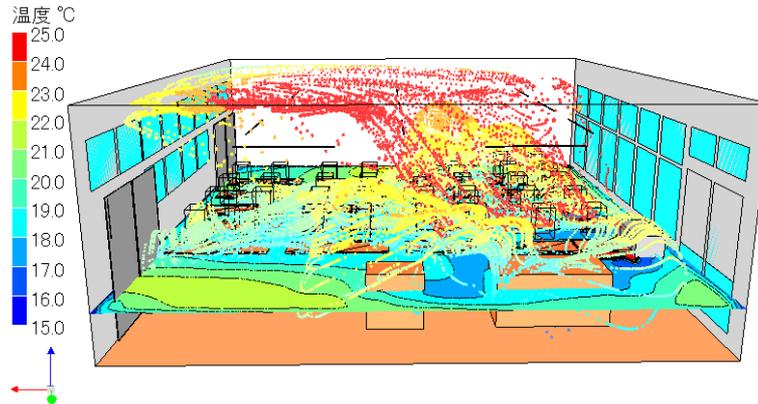
- Scalar illuminance/illuminance vectors are superior way to express lighting in three dimensions, but its visual expression using spheres and arrows cannot always be intuitively recognized.



Introduction

- In air flow/thermal environment simulation, air flow is sometimes depicted by the small spheres in the 3D perspectives.

Steady state (200回)
Time: 10.28944sec



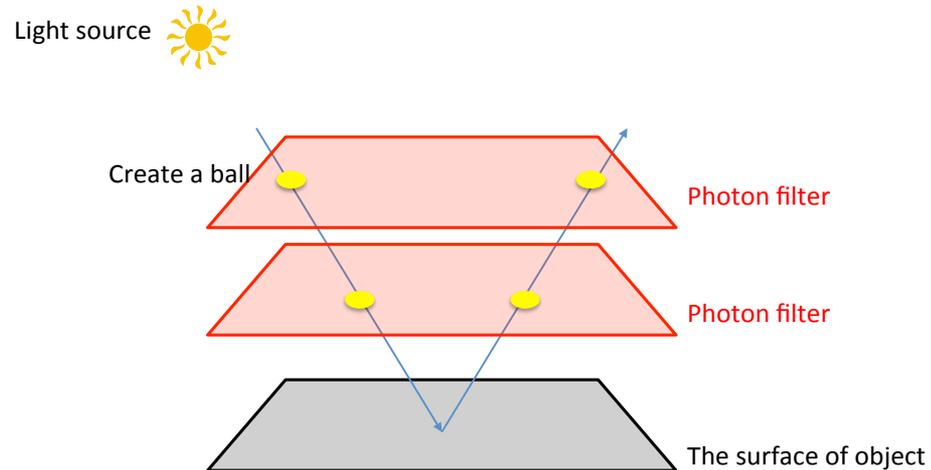
Calculated by Flow Designer

Purposes

- Couldn't we also express light flow in 3D perspectives in the process of BIM?
- Photon mapping algorithm calculates virtual photon flows, so what if we catch them on the virtual surfaces?

Photon Filiter

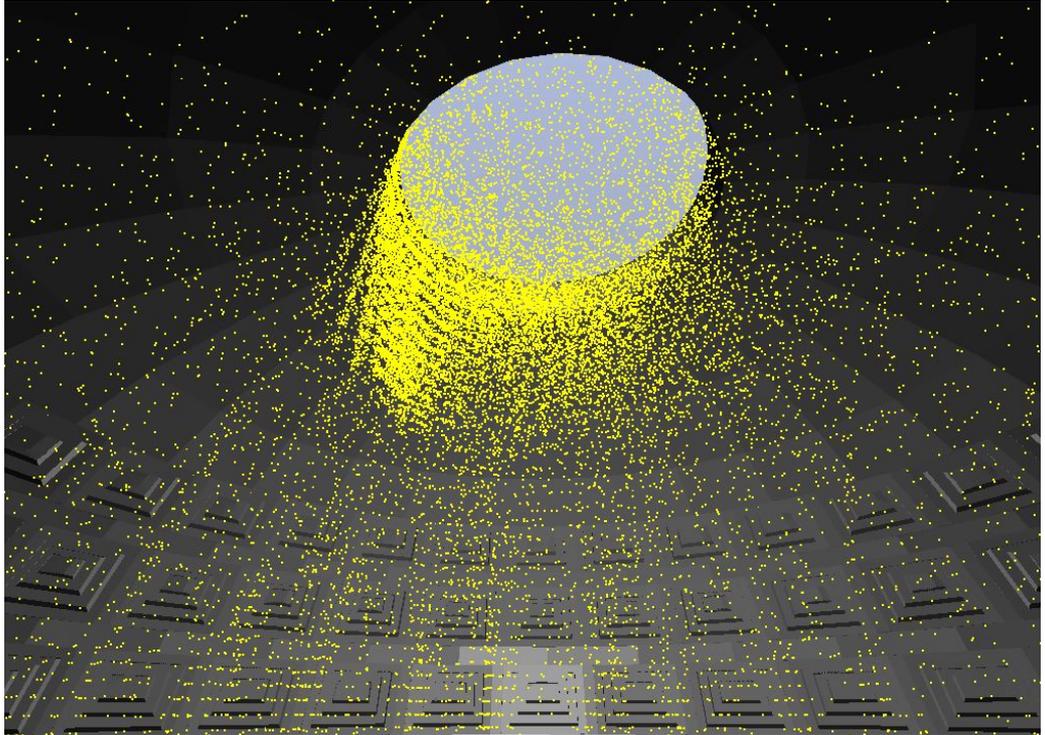
- We put some invisible planes(filters) made of special material in the space, and when a photon hits this material, its position information will be recorded in text files, then the photon will pass this material and move on in the same direction without losing the energy.



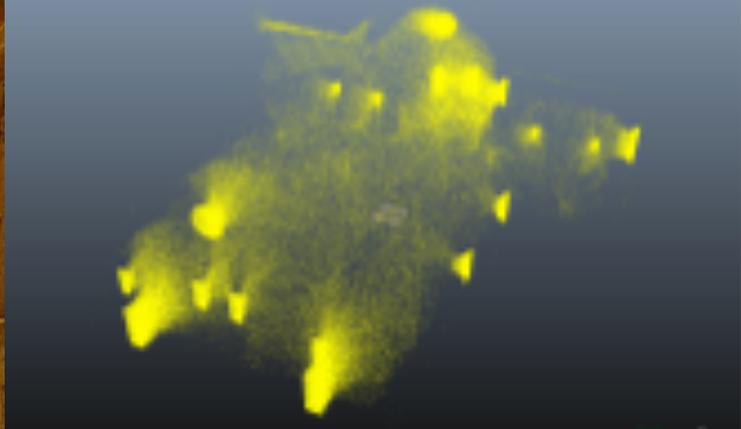
Photon Filiter

- A visible sphere will be created at the collided points. Putting the filter layers in parallel makes it possible to visualize photon flow, that is, the flow of light within a space.
- In the beginning, 3DCG software Maya with rendering plug-in Mental Ray was used. The new material_“Photon Filter” was made by Maya Programming.

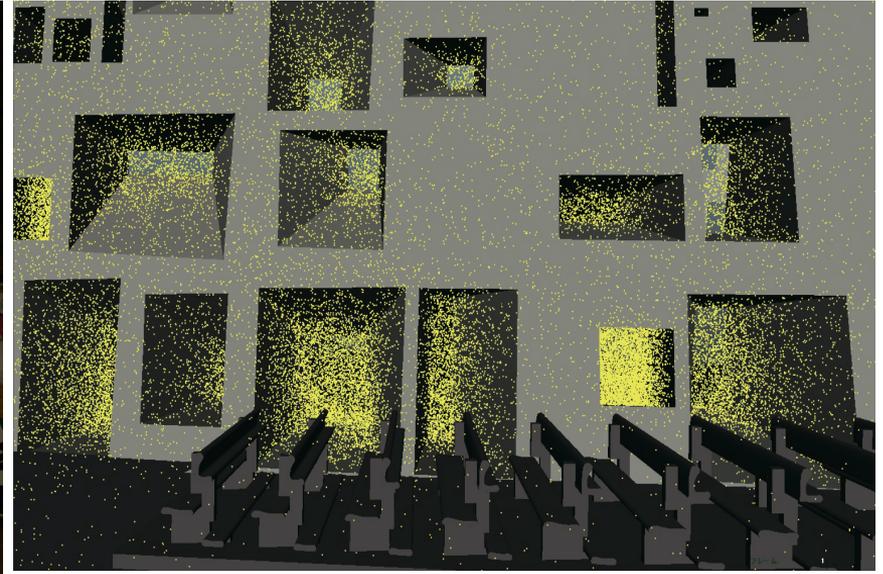
Pantheon



Le Thoronet Abbey

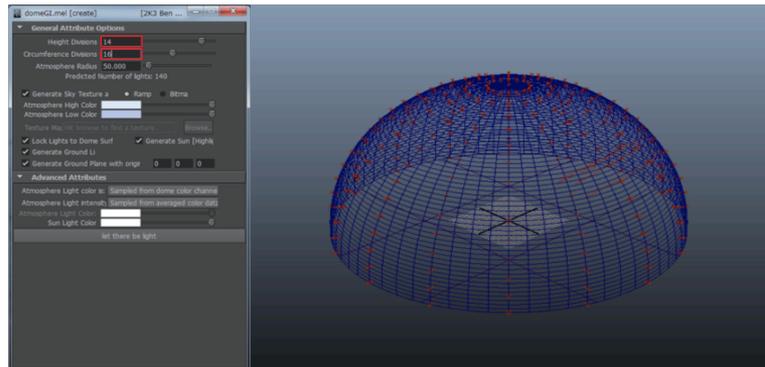


La chapelle Notre-Dame du Haut at Ronchamp



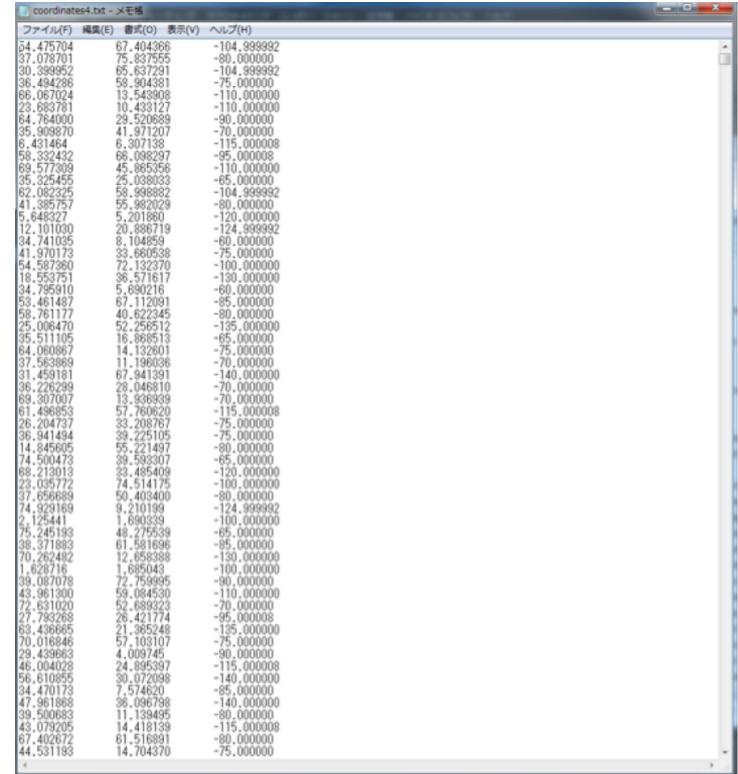
Maya with Mental Ray

- Sun: MentalRay_PhysicalSun
- Sky: domeGI.mel_Virtual Hemisphere Dome
 - Sky is divided to 224 pieces, and luminance is allocated to each piece, in reference to CIE standard skies , and the number of photons emitted from each piece was decided.



Maya with Mental Ray

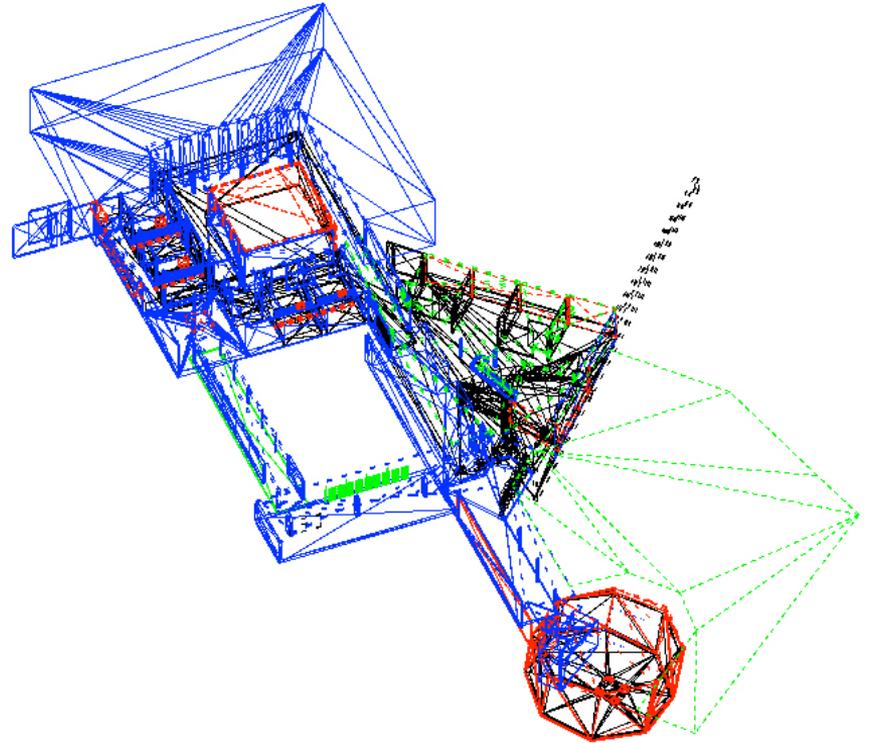
- Collided points' coordinates are outputted to the text file.
- This data can be imported to Rhinoceros, or other modelling programs.



The screenshot shows a text editor window titled "coordinates4.txt - メモ帳". The window contains a list of 44 lines of data, each consisting of three columns of numbers. The first column represents the X-coordinate, the second represents the Y-coordinate, and the third represents the Z-coordinate. The data points are as follows:

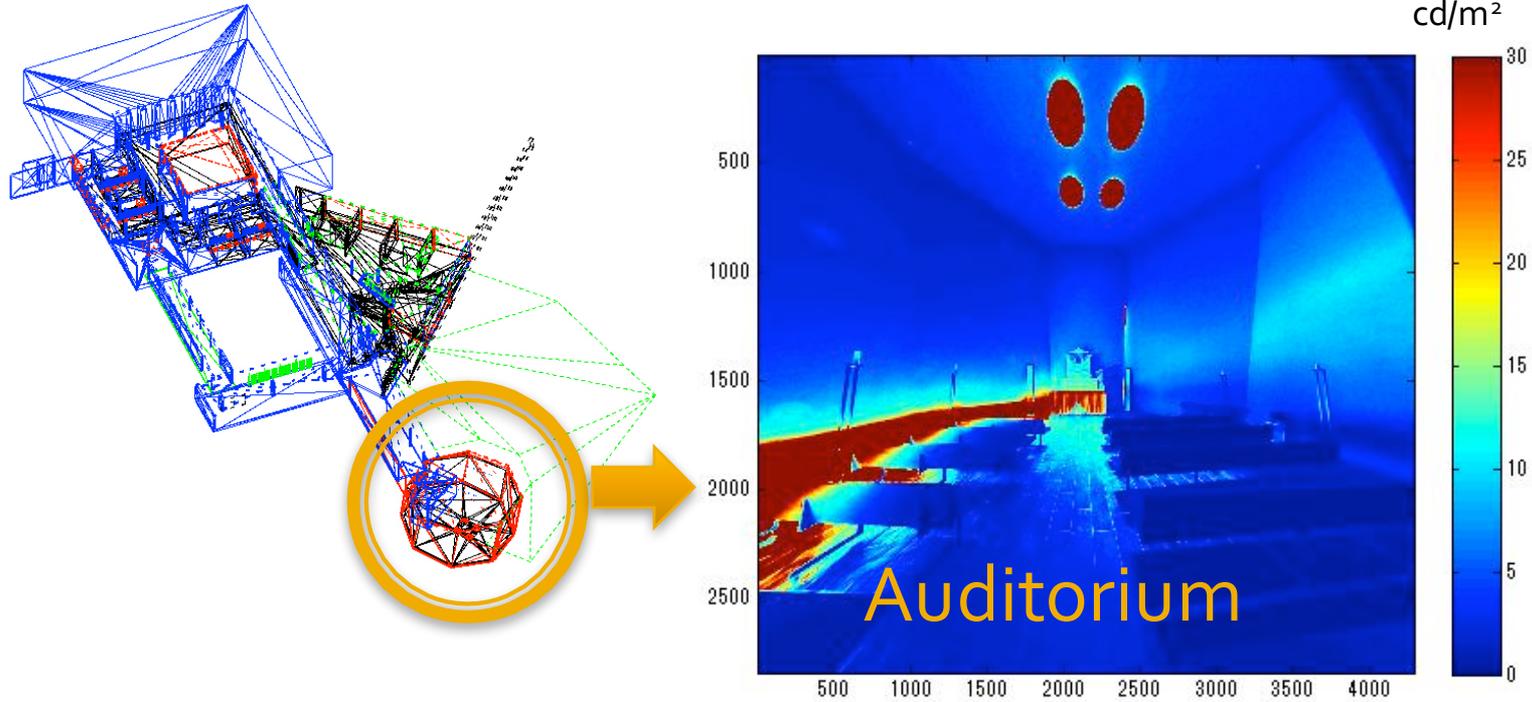
X	Y	Z
34.475704	67.404366	-104.999992
37.078701	75.837555	-80.000000
30.399952	65.637291	-104.999992
36.494296	58.904381	-75.000000
66.067024	13.543808	-110.000000
23.683761	10.433127	-110.000000
64.764000	29.520689	-90.000000
35.969870	41.871207	-70.000000
6.461494	6.307139	-115.000008
58.332432	66.098297	-95.000008
69.577309	45.865356	-110.000000
35.325455	25.038033	-65.000000
62.062325	58.968652	-104.999992
41.385757	55.982029	-80.000000
5.648327	5.201880	-120.000000
12.101030	20.886719	-124.999992
34.741035	3.104859	-60.000000
41.970173	33.860538	-75.000000
54.587360	72.132370	-100.000000
18.553751	36.571617	-130.000000
34.795910	5.690216	-60.000000
53.481487	67.112091	-95.000000
58.761177	40.622345	-80.000000
25.006470	52.256512	-135.000000
35.511105	16.866513	-65.000000
64.060967	14.132901	-75.000000
37.563869	11.196036	-70.000000
31.459181	67.841391	-140.000000
36.225299	28.048810	-70.000000
69.307007	13.836939	-70.000000
61.496853	57.760620	-115.000008
26.204737	33.208767	-75.000000
36.941494	39.225105	-75.000000
14.849395	65.221491	-80.000000
74.500473	39.593307	-65.000000
68.213013	33.485409	-120.000000
23.035772	74.514175	-100.000000
57.656999	50.403400	-90.000000
74.929169	9.210199	-124.999992
2.125441	1.690339	-100.000000
75.245193	48.275539	-65.000000
28.571893	61.591696	-95.000000
70.262482	12.658388	-130.000000
1.628716	1.685043	-100.000000
39.087078	72.759995	-90.000000
43.961300	59.094530	-110.000000
72.631020	52.689323	-70.000000
27.793268	26.421774	-95.000008
63.436665	21.365248	-135.000000
70.016346	57.103107	-75.000000
29.439663	4.009745	-90.000000
46.004028	24.895397	-115.000008
56.610855	30.072098	-140.000000
34.470173	7.574620	-85.000000
47.361868	36.096798	-140.000000
39.500683	11.139495	-80.000000
43.079205	14.418139	-115.000008
67.402672	67.518891	-80.000000
44.531165	14.704370	-75.000000

Kaze-no-oka Crematorium



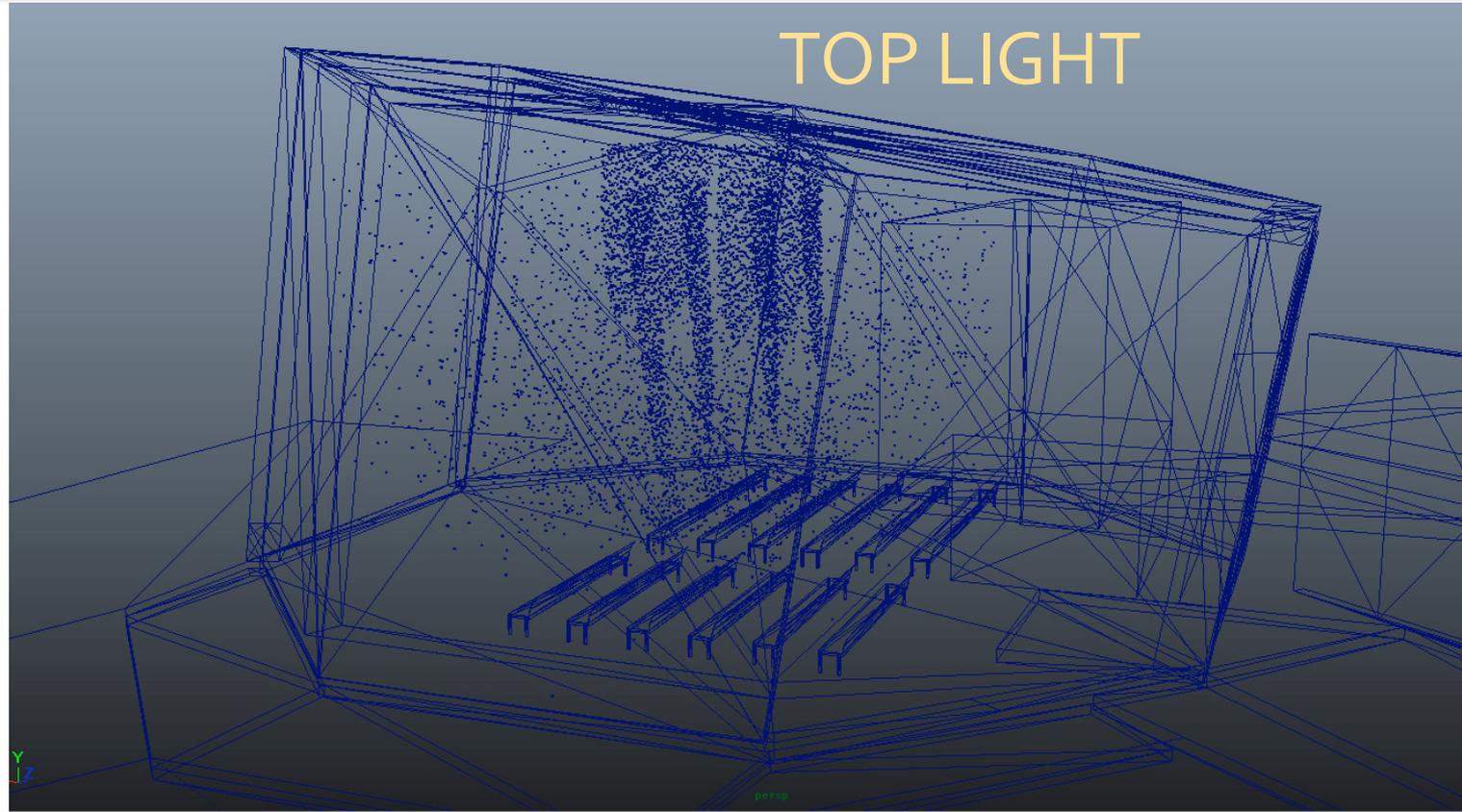
Designed by Humihiko Maki in 1997

Kaze-no-oka Crematorium

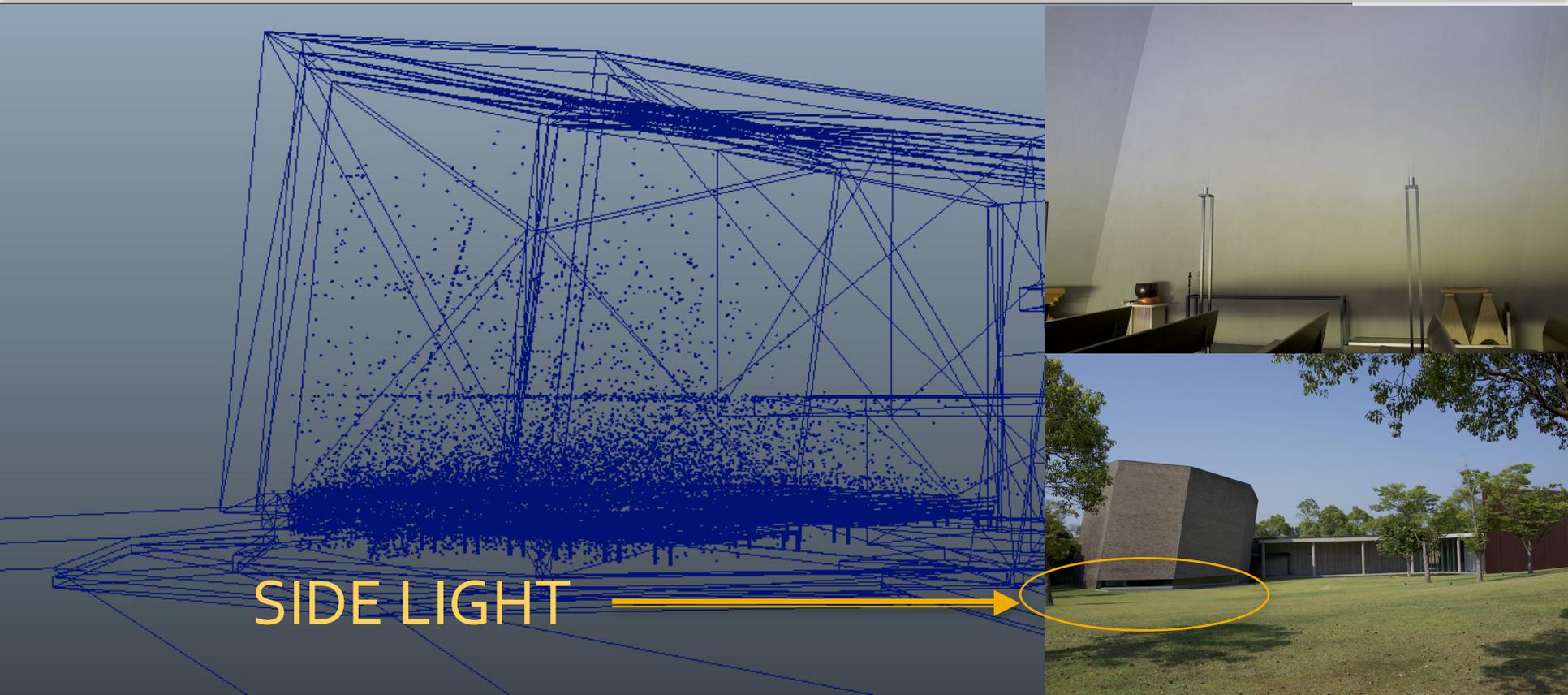


Its auditorium has two openings: top lights and lower side light

Kaze-no-oka Crematorium



Kaze-no-oka Crematorium

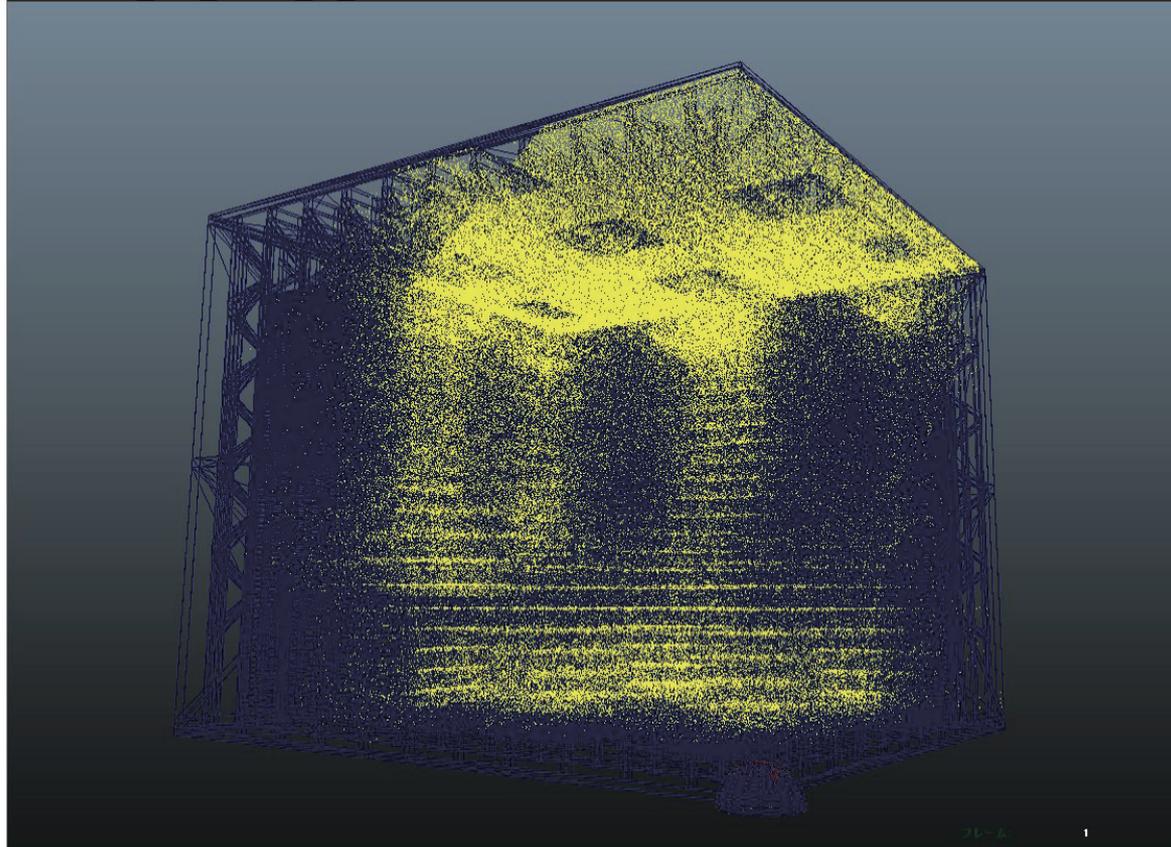


Sunpu Church



Designed by TAIEA NISHIZAWA in 2008

Sunpu Church

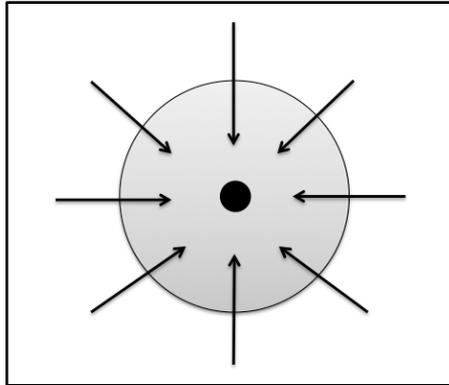


What exactly can be inferred from Photon Flow?

- There is a risk of misleading designers and architects into a wrong interpretation of light environment, because, strictly speaking, we could not infer the appearances of the buildings from the photon flow.
- Luminance distribution is necessary for understanding correct appearances.

Scalar illuminance

- Theoretically density of photons - number per unit volume - will equate with scalar illuminance?



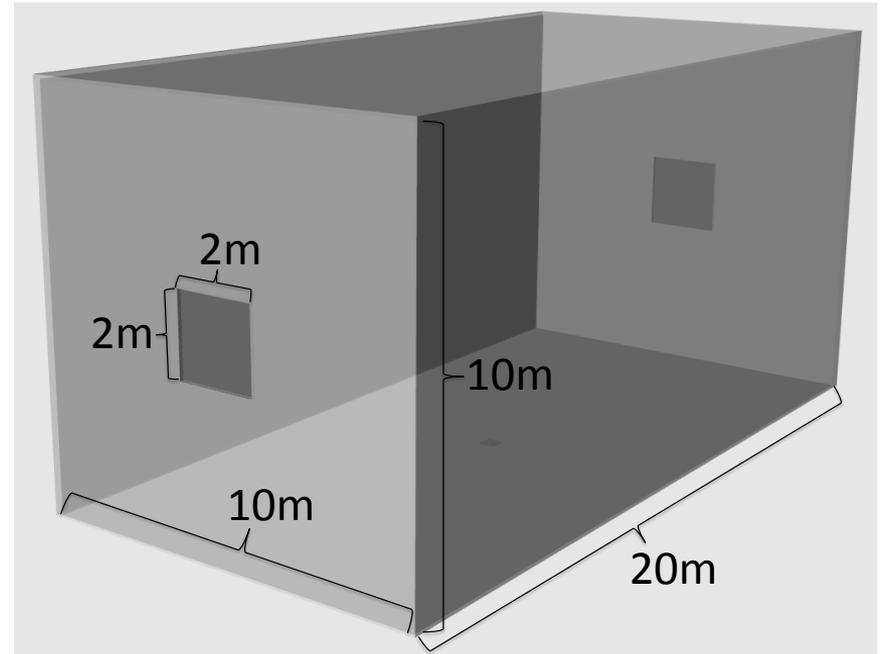
Scalar Illuminance
=the mean illuminance over
the surface of a sphere

Scalar illuminance and Density of Photons

- We verified this assumption by calculating scalar illuminance and the density of photons in a simple rectangular space using the latest Radiance.

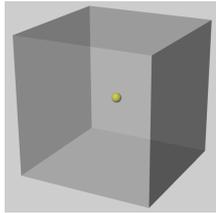
Scalar illuminance and Density of Photons

- A simple rectangular box 10m wide, 20m long and 10m in height
- Two openings of 2m square

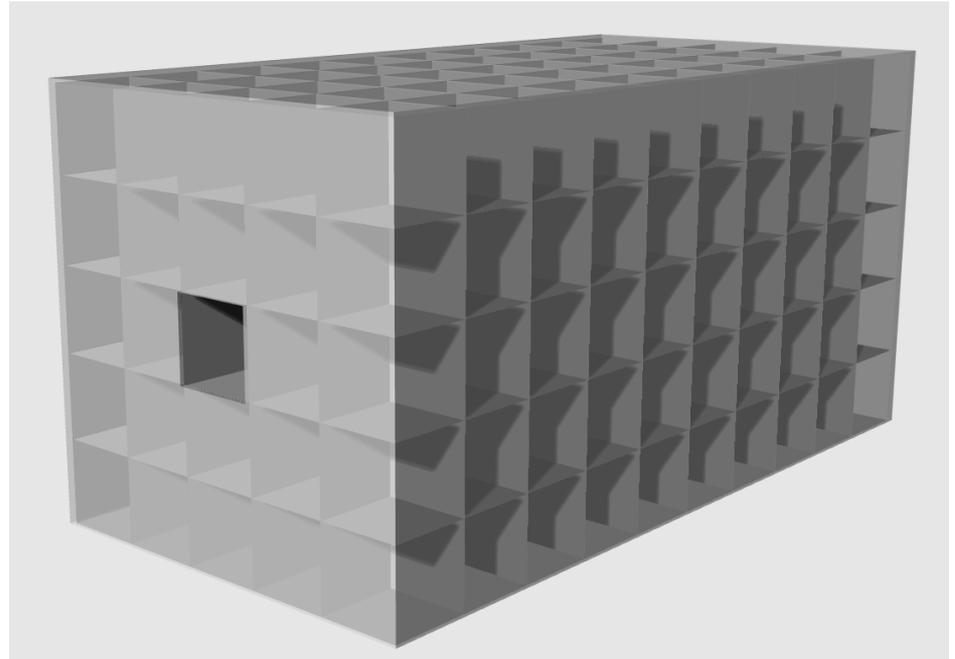


Scalar illuminance and Density of Photons

- Divided into 250 cubes of $2\text{m} \times 2\text{m} \times 2\text{m}$



The scalar illuminance of the center of each cube was calculated and the number of photons in each cube was counted.



Scalar illuminance and Density of Photons

① $E_{(x)} = E_{(x+)} - E_{(x-)}$ Vector component of each coordinate axis

② $|E| = \sqrt{(E_{(x)}^2 + E_{(y)}^2 + E_{(z)}^2)}$ Composition of vectors

③ $\sim E_{(x)} = \frac{E_{(x+)} + E_{(x-)} - |E_{(x)}|}{2}$ Symmetric component of each coordinate axis

④ $\sim E = \frac{\sim E_{(x)} + \sim E_{(y)} + \sim E_{(z)}}{3}$ The average of symmetric components

⑤ $E_{sr} = \sim E + \frac{|E|}{4}$ Scalar Illuminance : ②+④

※ E_{sr} : Scalar Illuminance

In reference to Lighting by Design by Dr. Cuttle

Scalar illuminance and Density of Photons

- Photon Filter in Radiance
...in a tentative way!

```
void trans photonfilter
0
0
7 1 1 1 0 0 0.99999 1
```

$$\begin{aligned} \text{specular transmittance} &= (1 - \text{spec}) * \text{colour} * \text{trans} * \\ \text{tspec} &= (1 - 0) * 1 * 0.99999 * 1 \\ &= 0.99999 \end{aligned}$$

Scalar illuminance and Density of Photons

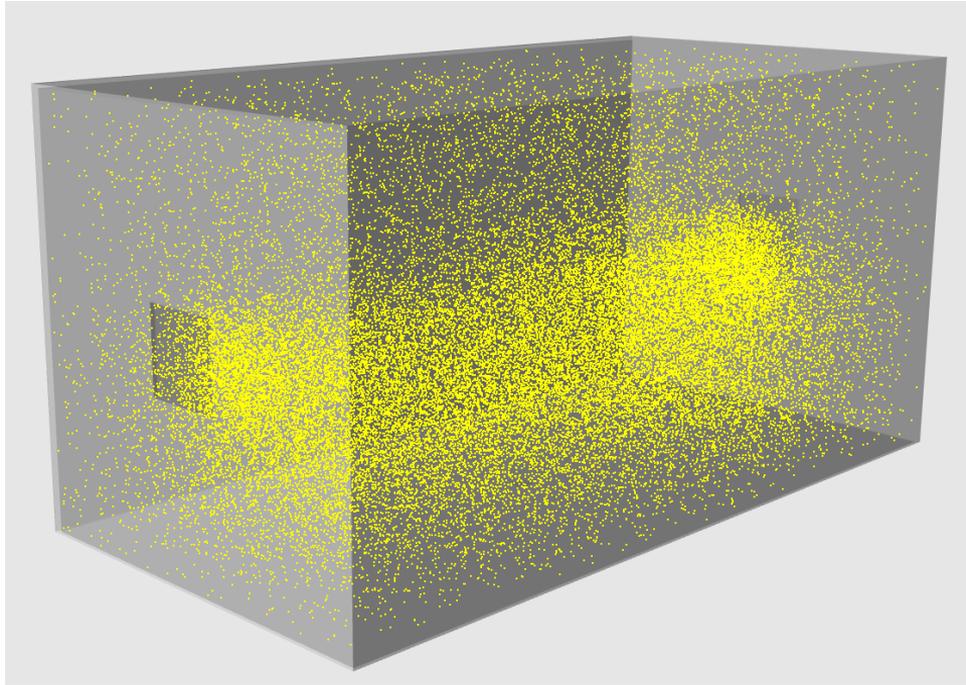
- `mkpmap -apg try.pmap 30000 try.oct`
- `pmapdump -n 30000 try.pmap > photontry.rad`
- Extract the xyz data of each collided points



Visualize photon flows in Rhinoceros

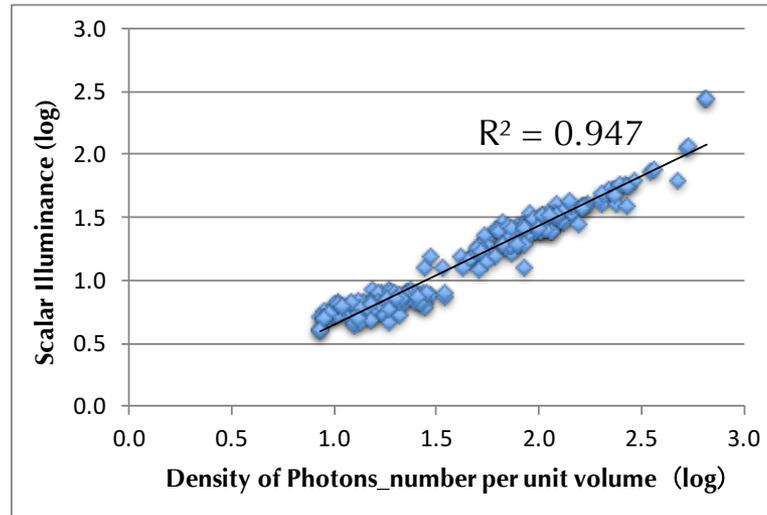
Scalar illuminance and Density of Photons

Visualize photon flows in Rhinoceros



Scalar illuminance and Density of Photons

The correlation coefficient indicates a strong positive correlation between them.



Absolute values of light intensity should be reflected on photon densities, though...in future works...

NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

Other recent samples...calculated by Radiance

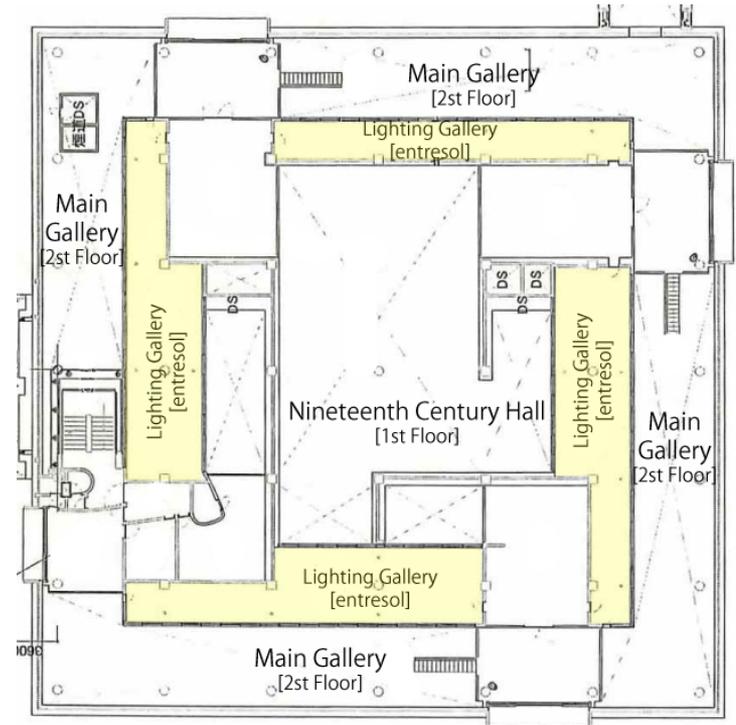
National Museum of Western Arts in Tokyo was originally designed by French Architect, Le Corbusier, and has just been registered as the World Heritage with his other works this summer.

An investigating committee for restoration was organized in Architectural Institute of Japan in 2009.

The purpose of our study was to investigate the possibility to restore the clerestory windows to original form for the preservation of authenticity, within the scope of conservation requirements of museum's collections.

NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

The planar configuration is square, and at the center of the building there is a Nineteenth Century Hall which has a double-high structure.



NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

This hall has a triangular cone skylight which brings natural light from the northern sky.



19 century hall

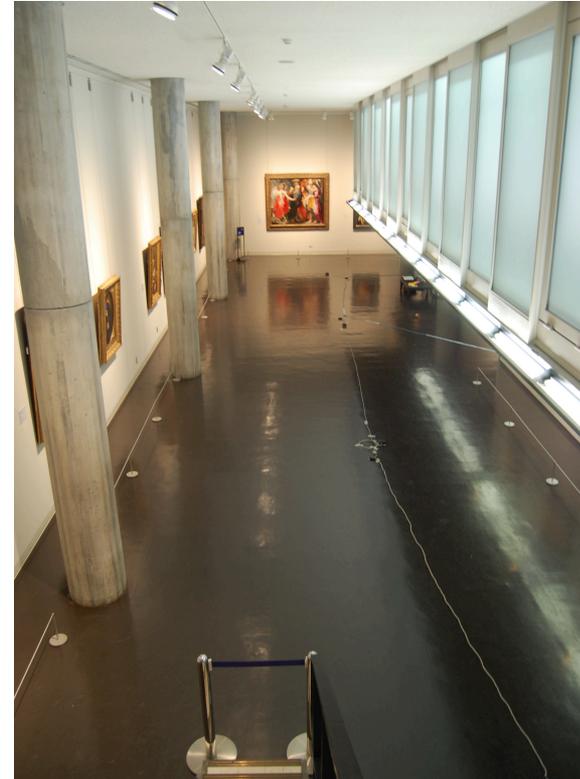
NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

19 century hall



NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

A main gallery on the second floor is approached by a ramp in the Nineteenth Century Hall. This gallery encircles the Hall and there is an entresol - lighting gallery - that wraps around the Hall at half the height of the second floor.



NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

In original design natural light entered from the high side light placed on the entresol floor and fills the main gallery on the second floor and the Nineteenth Century Hall.



Now its glazings have been painted with the intention of excluding daylight completely and fluorescent lamps are now used instead of natural light.

NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

Top Lights:

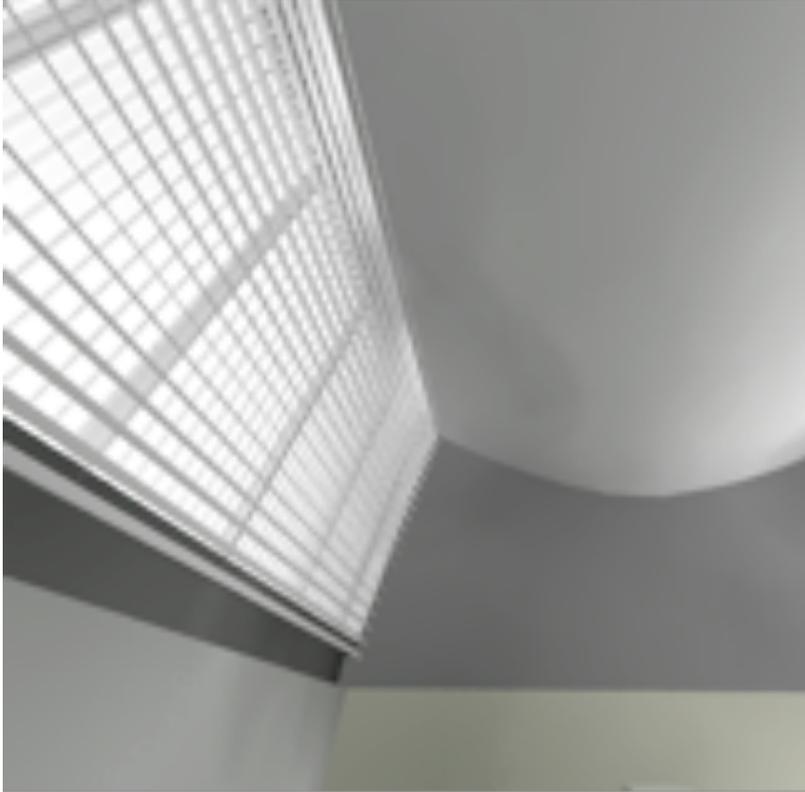


NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

Lighting Gallery : now



NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO



The main problems of the original spaces are strong sunlight and reflective glare which is caused by the location of the Lighting Gallery.



One of the proposals for the renovation is the reintroduction of daylight by using blinds.

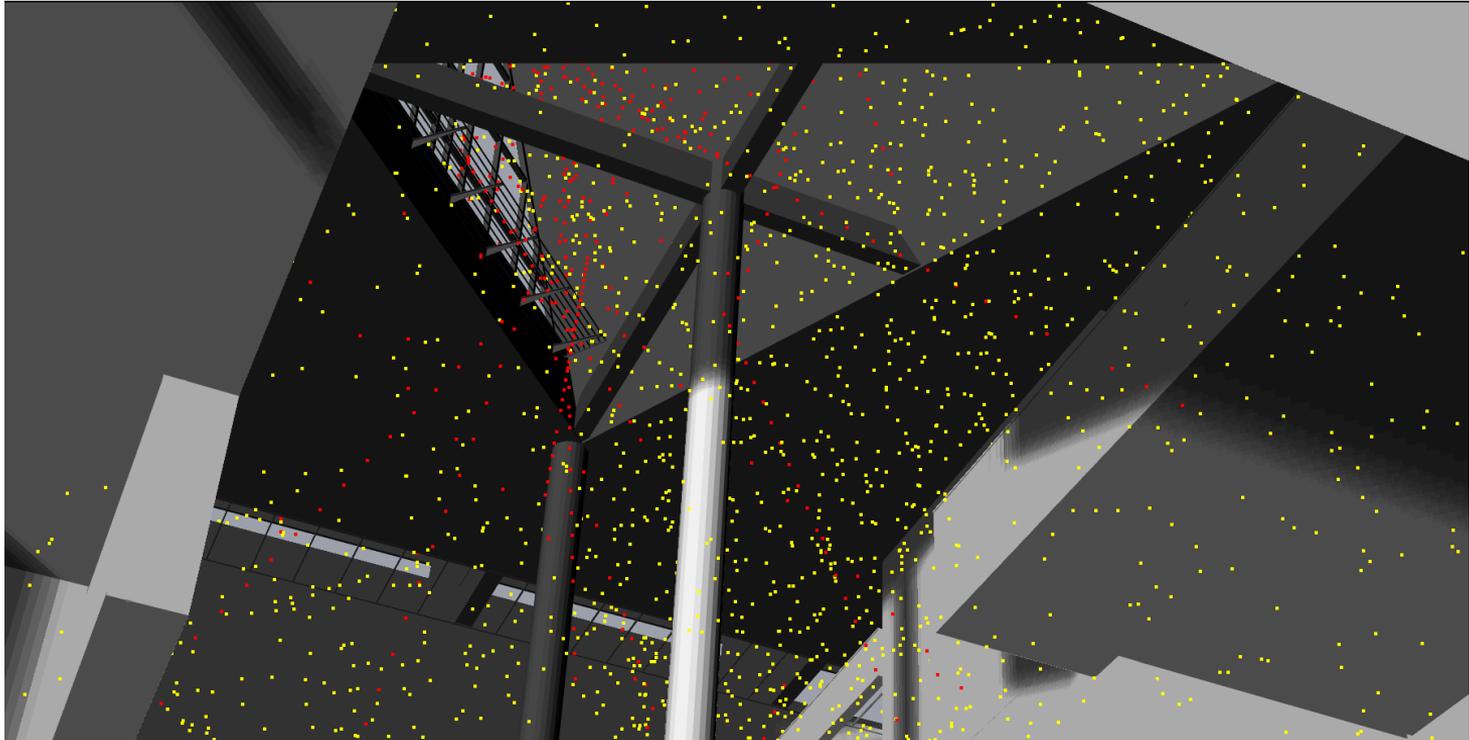


Annual daylighting environments were calculated by Radiance with Typical Annual Weather Data (TWD9302/L) in Tokyo area , to verify the effect of these blind systems.

NATIONAL MUSEUM OF WESTERN ARTS IN TOKYO

RED: Triangular Cone Skylight

YELLOW: Lighting Gallery



Future Works

We would like to do an interview survey whether architects use it efficiently for their preliminary design of buildings.

Quantitative analysis will be necessary.

We could try an animation of photon flow.

Thank you for your attention.