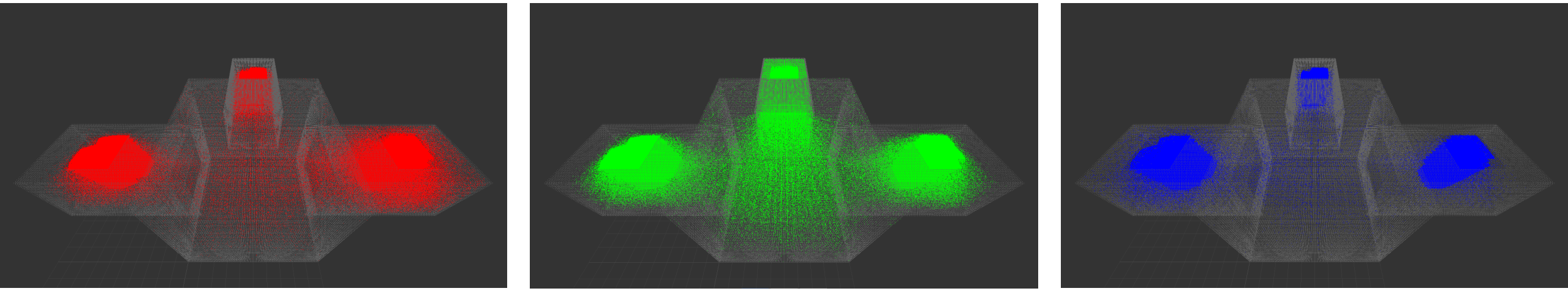

A three-dimensional expression of light flow in colour using photon mapping

2018 INTERNATIONAL RADIANCE WORKSHOP
LOUGHBOROUGH,UK
TUSEDAY 4th SEPTEMBER

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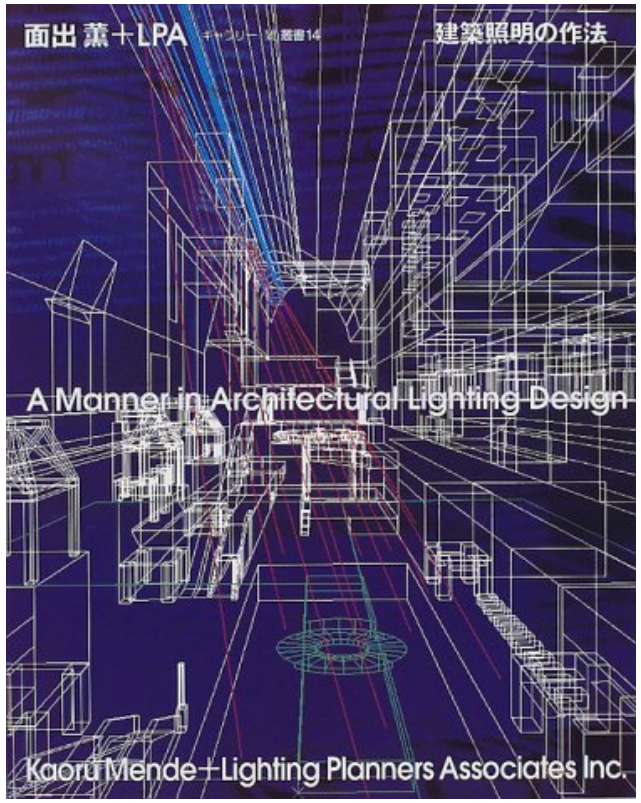
Motivation



When I meet good architecture all around the world, there is always a good light there. Sometimes, as soon as I step into architecture, I feel confused as to "What is this mysterious comfort attributed to ?". At that time, vague light particles should be present there. Architectural lighting design a task of thinking how to create a comfortable light environment like this.

(Quotes from "Kaoru Mende + LPA architectural lighting method")

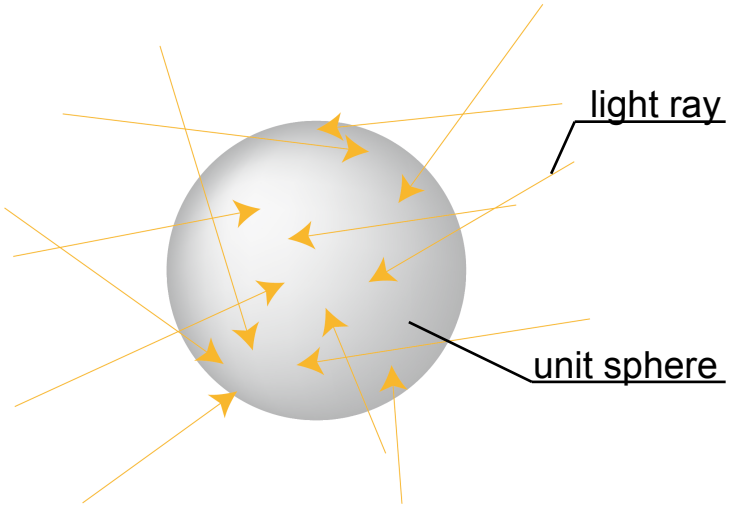
I would like to create the way to express this feeling that the designer is looking for.

The History of Three Dimensional Expression of Li

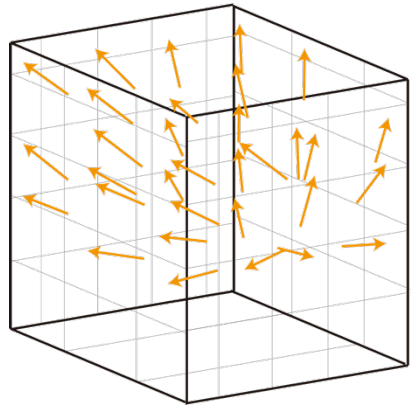
In 1939,
"THE LIGHT FIELD" --by A. Gershun

□ Propose an expression method of distributed light in space.

In this paper, the concepts of light field, scalar illuminance, and light vector were born.



Scalar illuminance



Light vector

The History of Three Dimensional Expression of Li

In recent years, expression of light field has been drawing attention to create a human centric environment.

In 2016,
"The Global Structure of the Visual Light Field and its Relation to the Physical Light Field" --by T. Kartashova

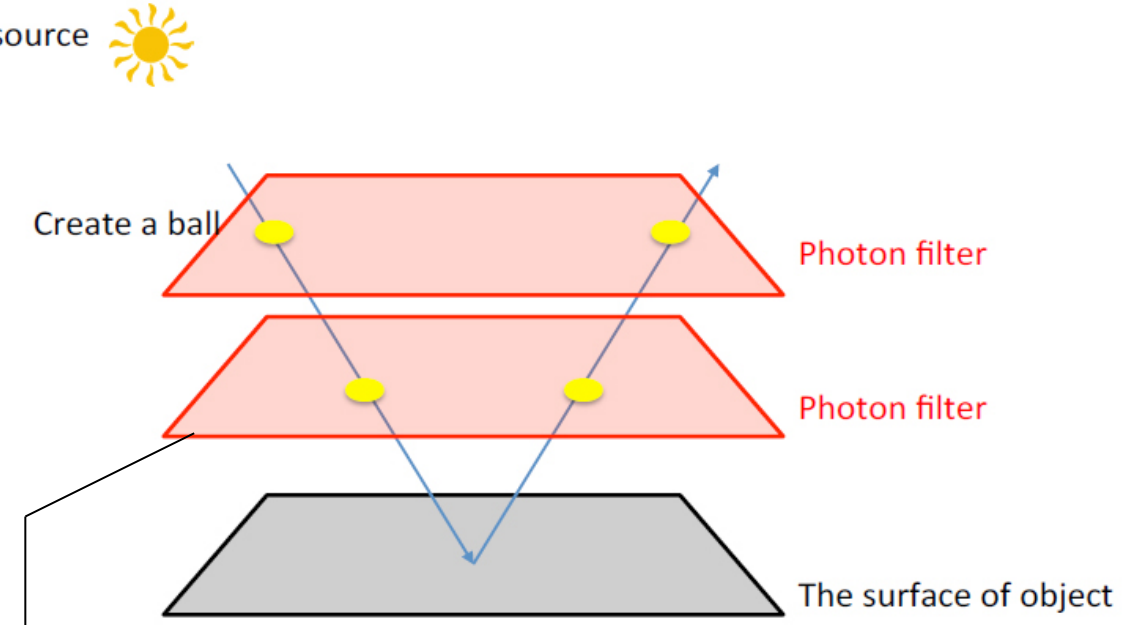
□ Confirmed that the physical light field and the visual light field are slightly different but similar.

The visual light field : Field of light perceived by people

Many expressive methods have been considered to describe the human-centric light environment.

The previous report in 2016 Radiance workshop

We put some invisible filter made of trans material in the architecture model on the grid, and when a photon hits this filter, its position information will be recorded. We used Radaince5 to make photon .

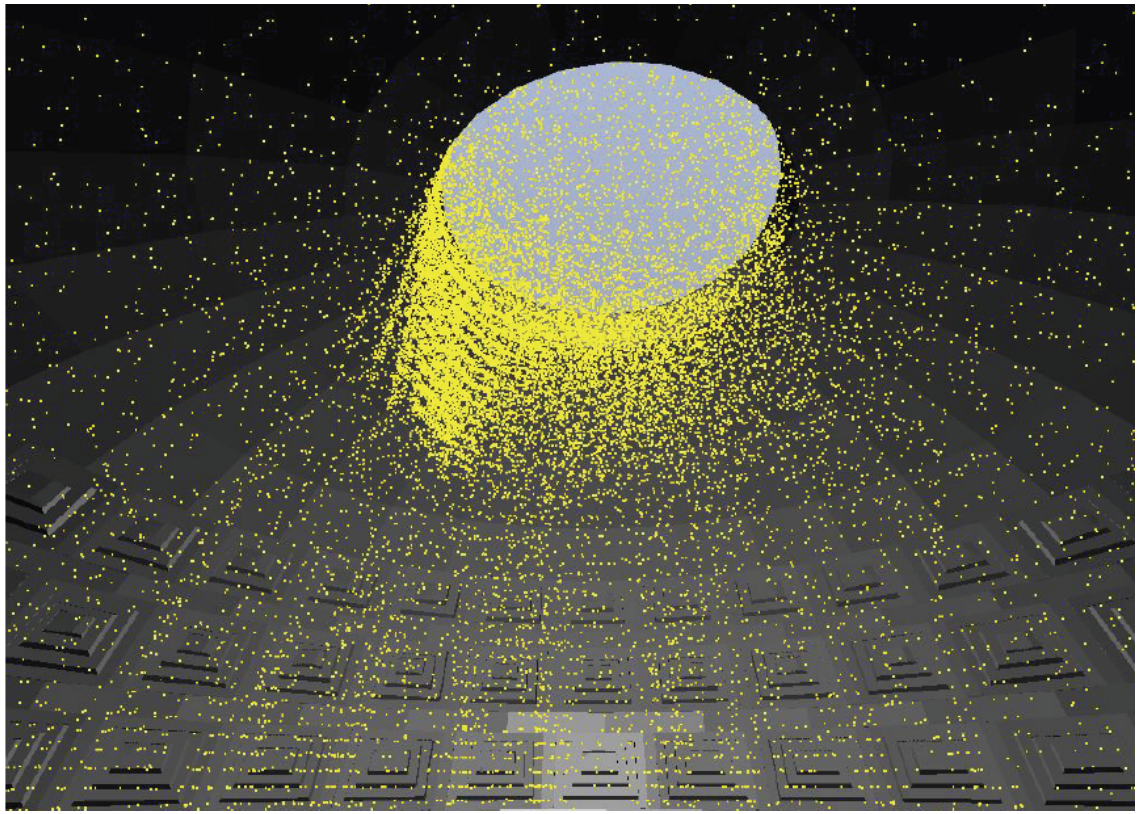



```
void trans photonfilter
0
0
7 1 1 1 0 0 0.99999 1
```

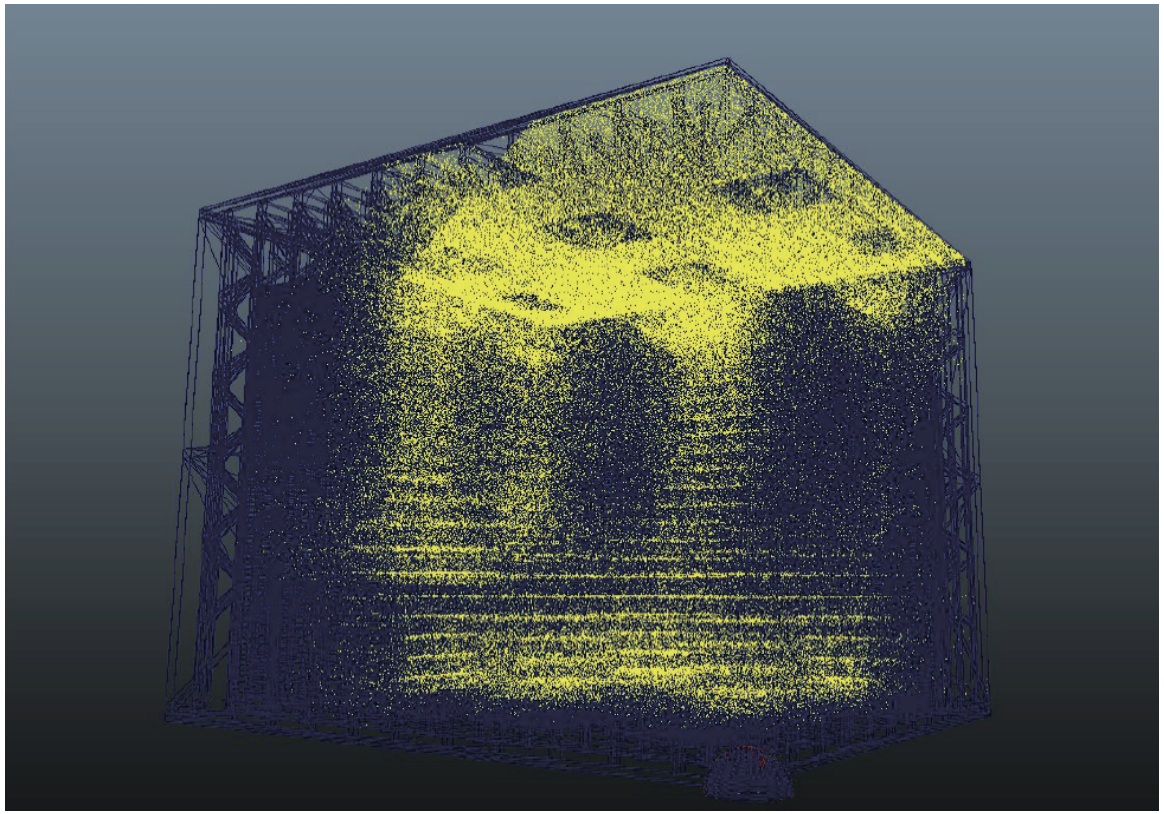
We can succeeded the expression light like…

The previous report in 2016 Radiance workshop

Pantheon in Rome

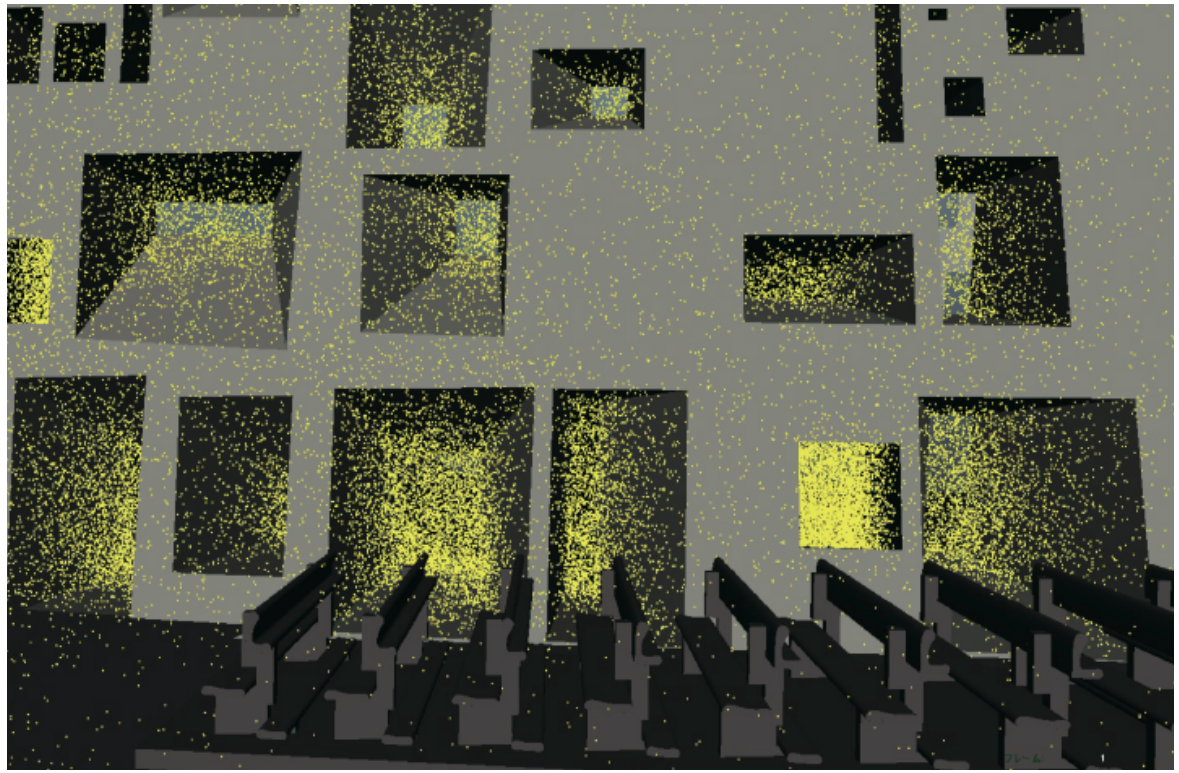


Sunpu church in Japan

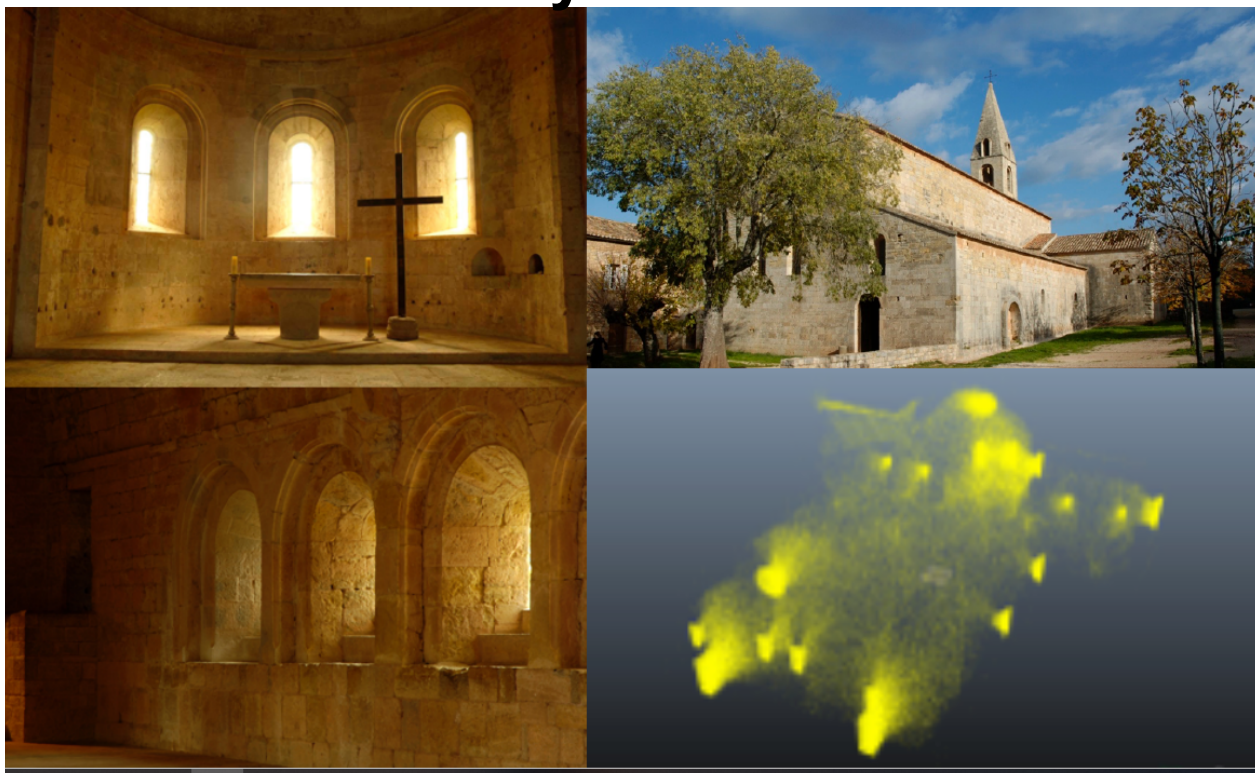


The previous report in 2016 Radiance workshop

Notre Dame du haut in France

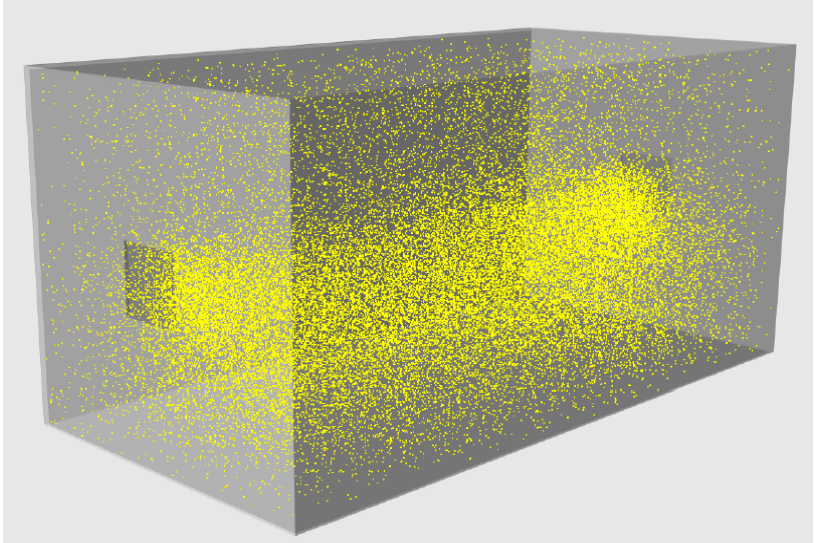


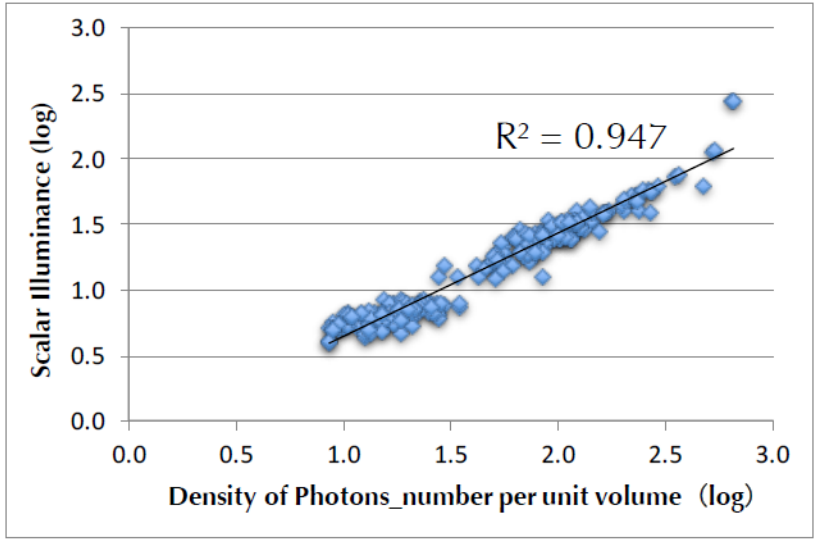
Le Thoronet abbey in France



The previous report in 2016 Radiance workshop

Moreover, we confirmed the relationship between the density of photons and the scalar illuminance. They have a positive correlation with scalar illuminance, **but we could not calculate the absolute value of scalar illuminance from the density of photon at arbitrary points.**



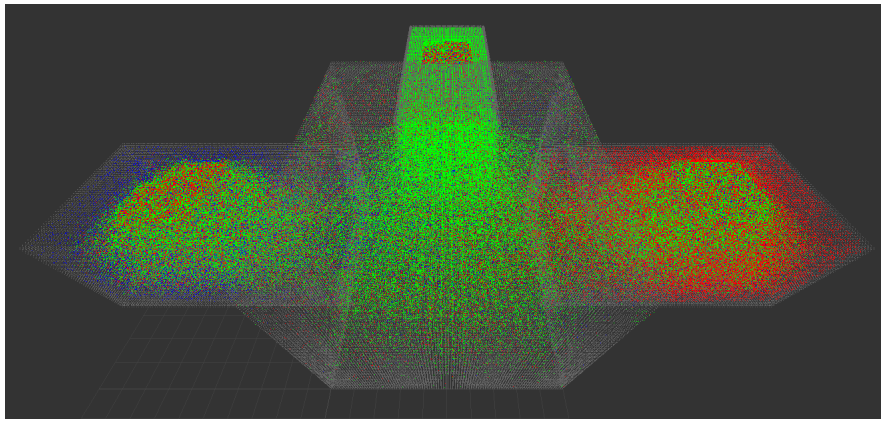


In this report

In this report we will present two topics.

1. We linked the photon distribution to the absolute value of scalar illuminance.

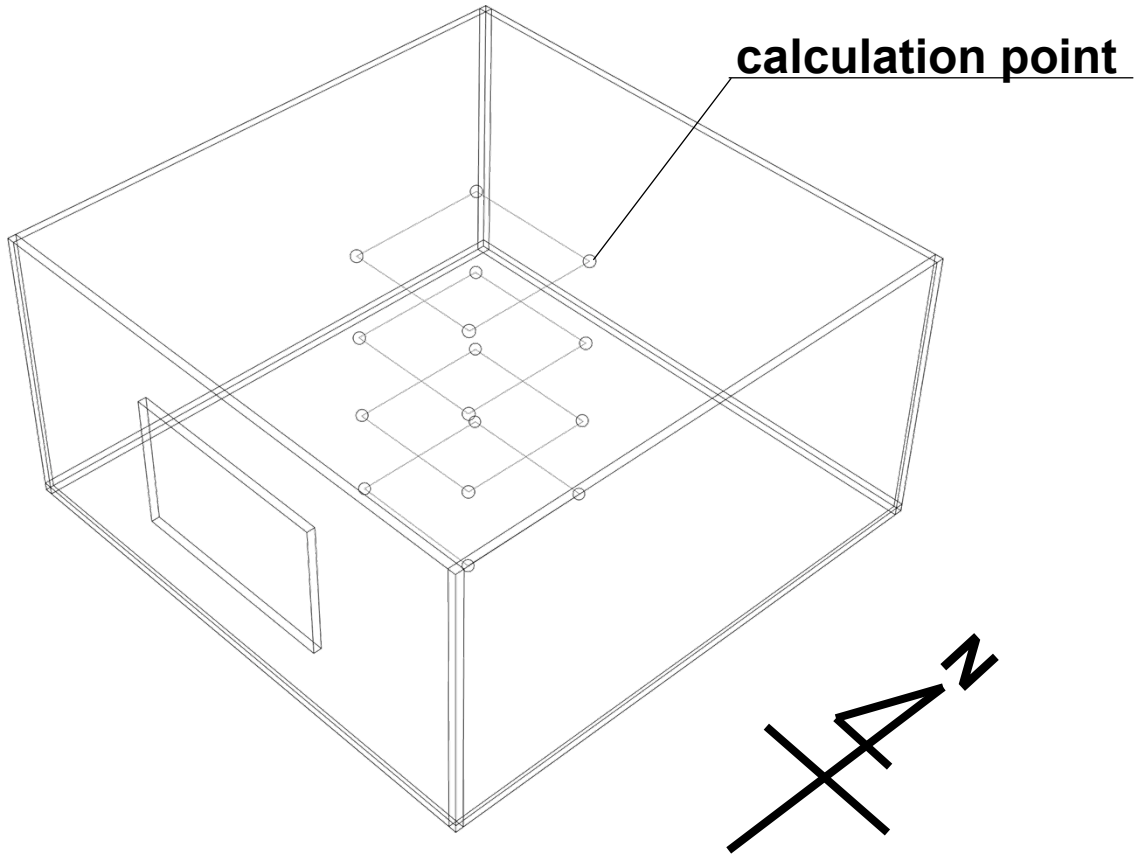
2. We make a new method to depict the photon flow in RGB colour separately.



Photon distribution and the absolute value

<Method>

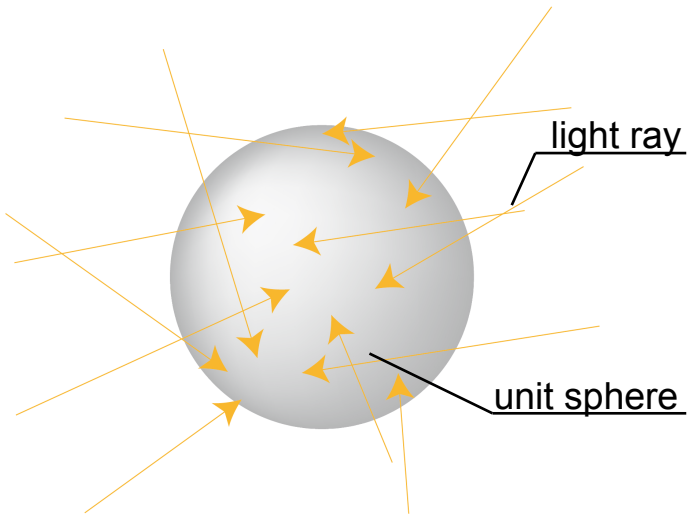
To confirm the relation between photon distribution and absolute value, we compared the scalar illuminance value obtained from cubic illumination and number of photons at the same points in a simple room.



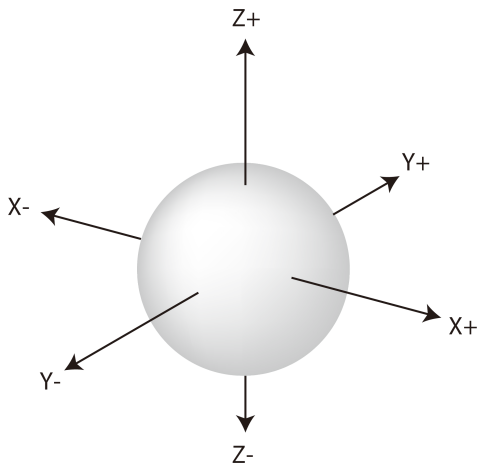
Photon distribution and the absolute value

<From cubic illumination>

Scalar illuminance is an illuminance over the surface of a sphere. This value can be calculated by using cubic illumination and 5 formulae below.



Scalar illuminance



Cubic illuminance

① $\mathbf{E(x)} = E_{(x+)} - E_{(x-)}$ Vector component of each coordinate axi

② $|\mathbf{E}| = \sqrt{E_{(x)}{}^2 + E_y{}^2 + E_z{}^2}$ Component of vectors

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

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

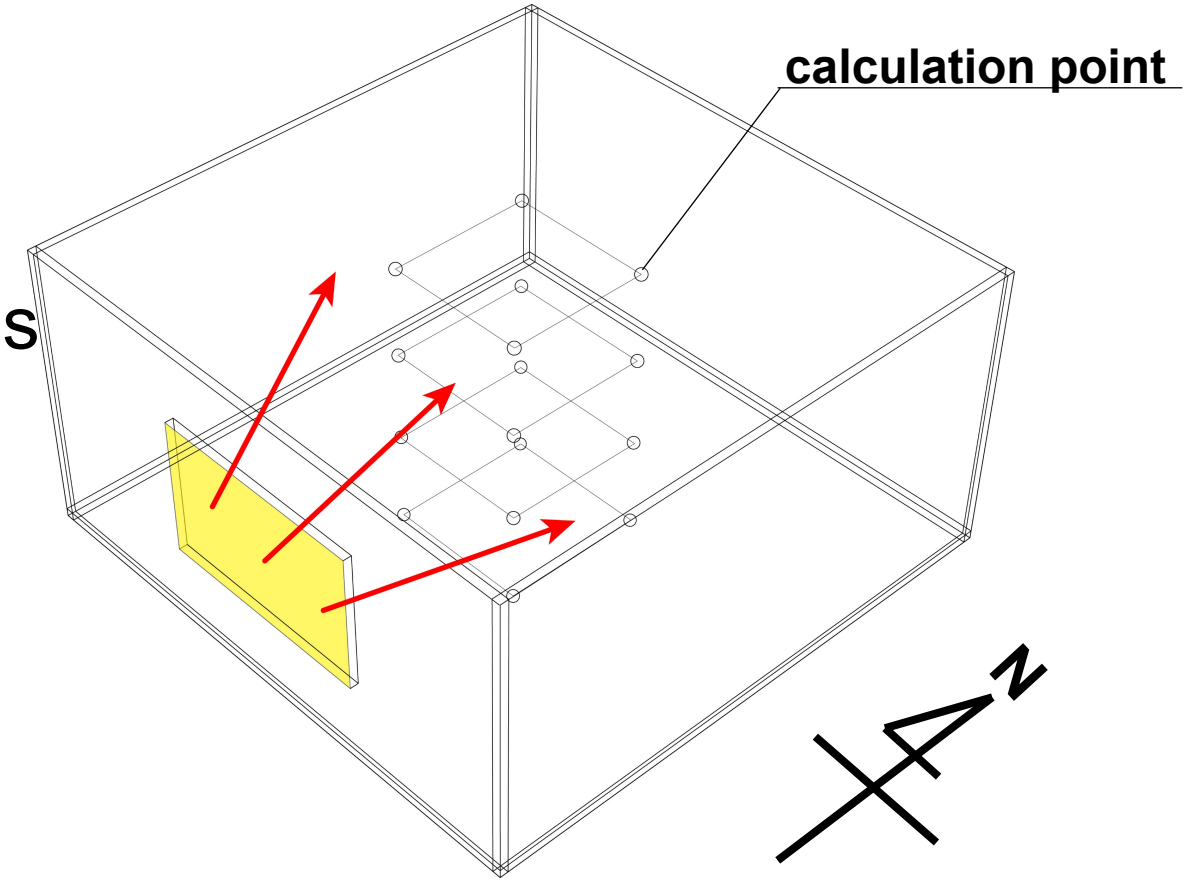
⑤ $E_{sr} = \sim E + \frac{|E|}{4}$ Scalar illuminance

In reference to “Lighting by Design” by C Cuttle

Photon distribution and the absolute value

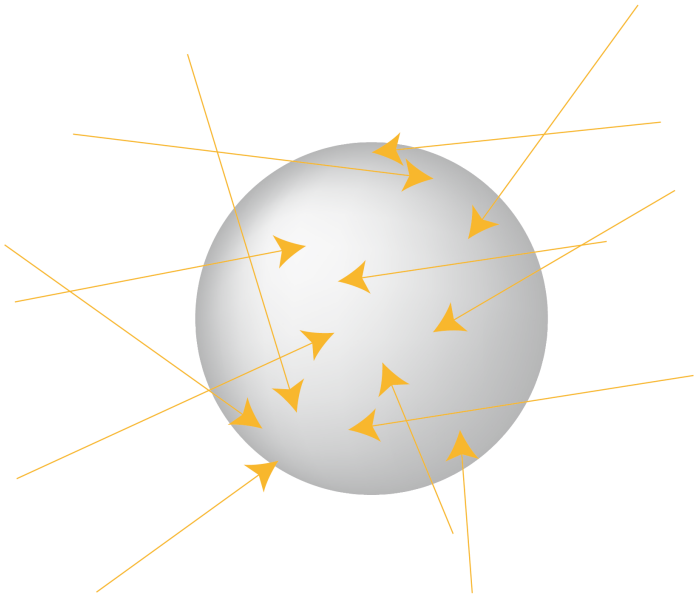
<From photons>

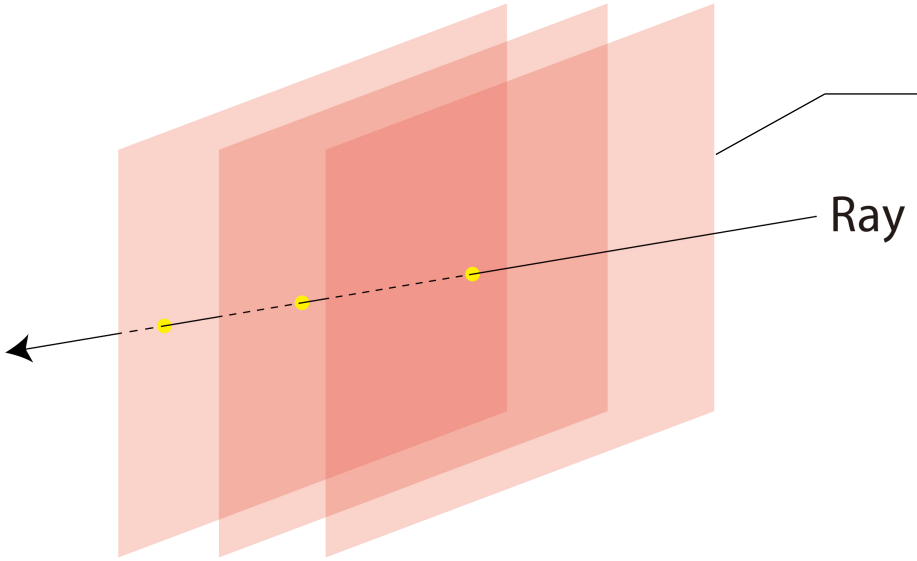
1. Set the photon port
2. Emit photons from photon port to the room
3. Count the number of photons on the sphere



Photon distribution and the absolute value

In order to count the number of photons on the sphere, we make a virtual sphere using *antimatter* material. After emitting photons into the space using photon port, only photons on the sphere are taken out.





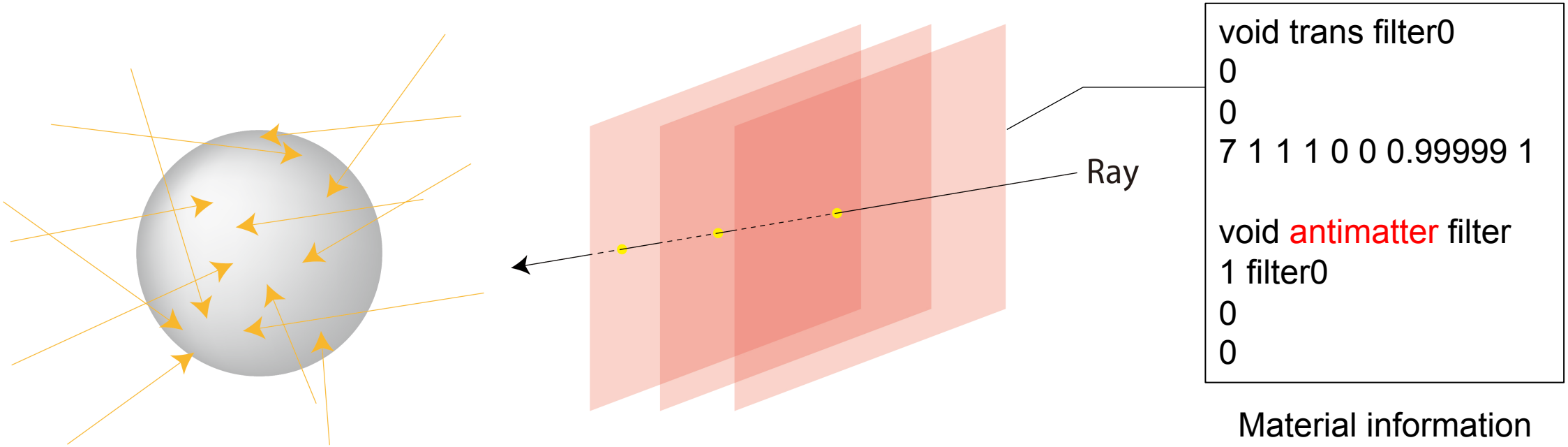

```
void trans filter0
0
0
7 1 1 1 0 0 0.99999 1

void antimatter filter
1 filter0
0
0
```

Material information

Photon distribution and the absolute value

Most of the light rays intersect twice with spherical surfaces, but since the antimatter material records only photons that incident from the front side, it never counts photons in duplicate.



Material information

Photon distribution and the absolute value

$$E = N \times W/A \times L$$

E : Scalar illuminance

N : Number of photons

W : Each photon's energy(refer to header information)

A : Surface area of virtual sphere

L : Luminous efficacy(=179)

```
nodars036156:desktop yosizawa$ getinfo test1.gpm
test1.gpm:
        #?RADIANCE
        mkpmap -apg photon/test1.gpm 10M -aps filter -t 1
        NumPhotons      = 9928571
        AvgFlux         = [3.30e+02, 3.30e+02, 3.30e+02]
        Bbox            = [-150.000, -150.000, -150.000]
        CoG             = [5042.258, 3801.823, 2317.495]
        MaxDist^2       = 26357358.000
        FORMAT=Radiance_Global_kdT_Photon_Map
        VERSION=3.0k
```

mkpmap header information

The energy is calculated by assigning this RGB value into the following equation.

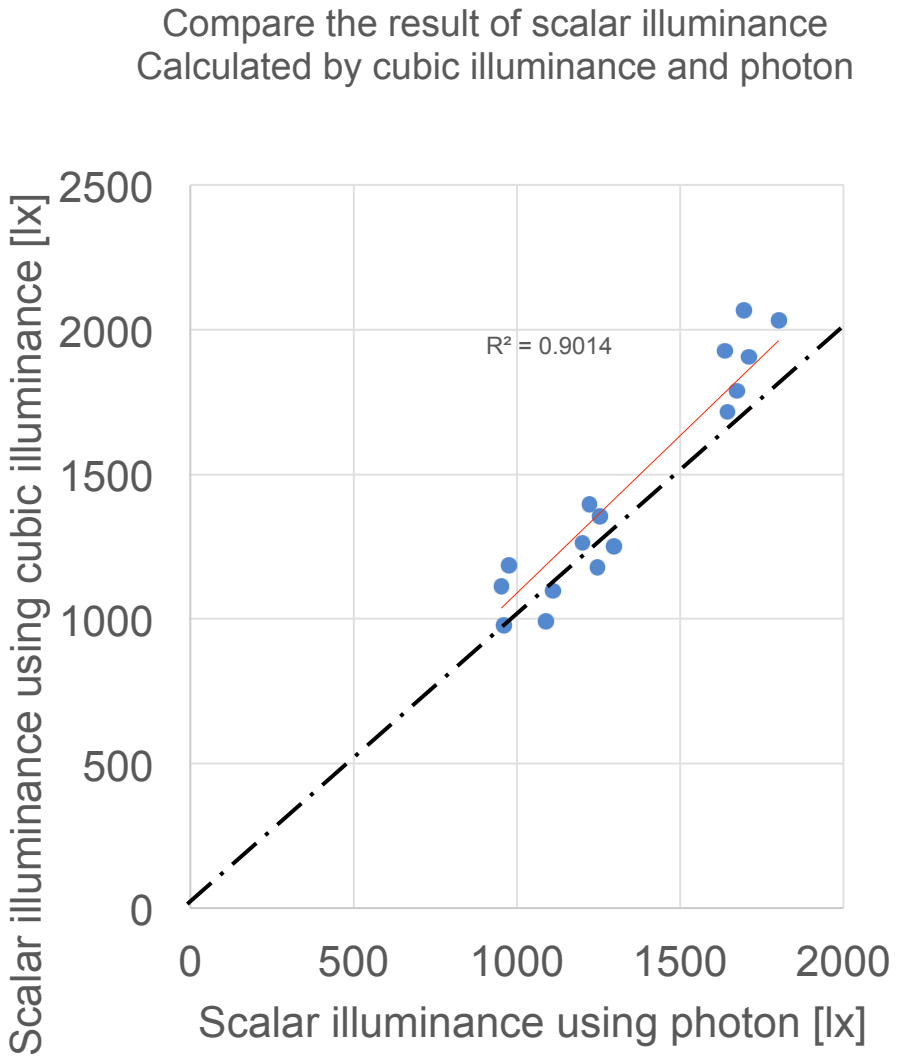
W = R×0.265 + G× 0.67 + B× 0.065

Photon distribution and the absolute value

The right graph shows the scalar illuminance calculated by the cubic illuminance and the number of photons.

We confirmed that the photon distribution and the absolute value are linked.

We can estimate the absolute intensity of light environment from the appearance of photon density.



Depict photon flow in RGB colour separately

<Background>

For human perception, not only the intensity of light but also the colour of light should be an important aspect.

<Aim>

Making it possible to depict the photon flow in RGB colour.

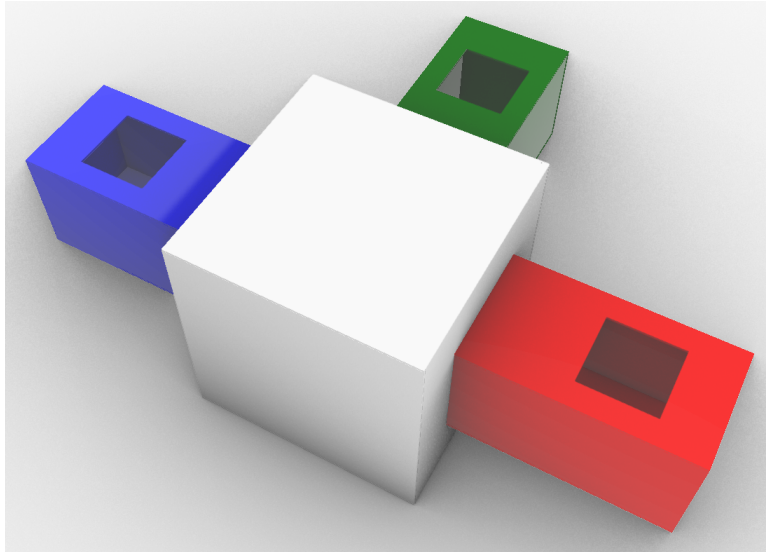
Photon flow in RGB colour

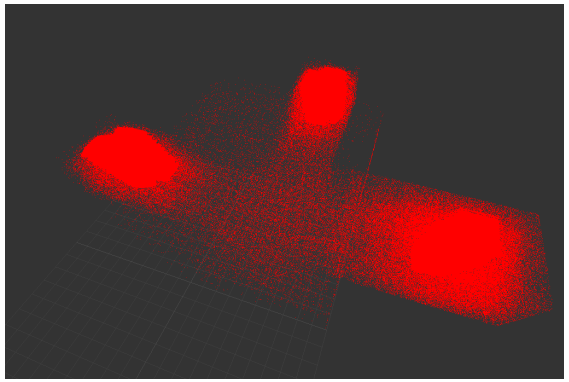
<method>

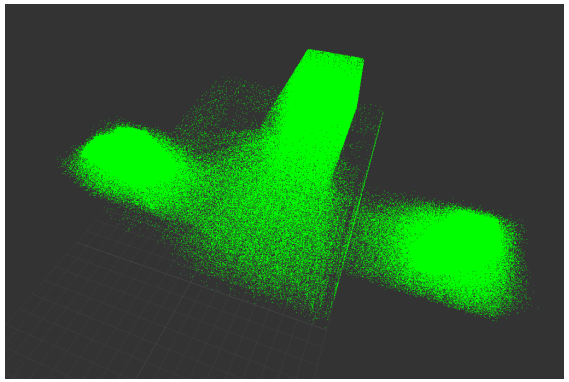
Materials of the analysis space and light source are set separately for RGB, and RGB photon are acquired by using photon filter which antimatter material is applied.

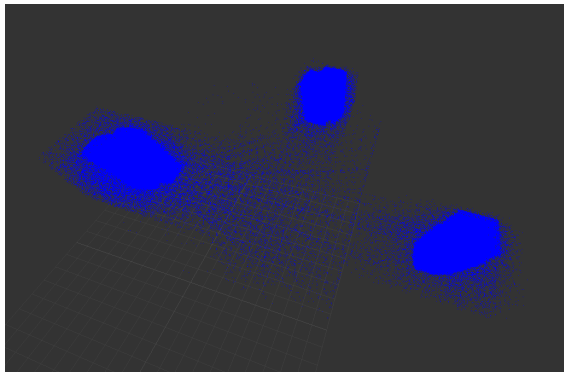
In order to approximate human perception, the ratio of the emission amount of RGB photon is R:G:B=0.265:0.67:0.065.

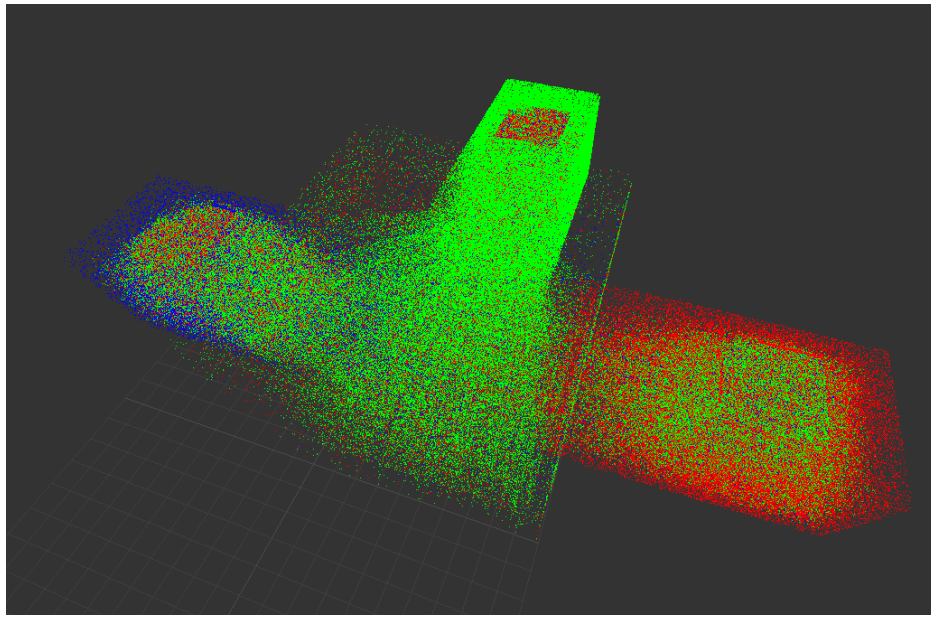
Photon flow in RGB colour











Analysis at Villa Müller

Credits and Data

Architecture title : Villa Müller
Architecture type : Private House
Location : Prague, Czech Republic
Design : 1928 - 1929
Construction : 1929 - 1930
Architect: Adolf Loos

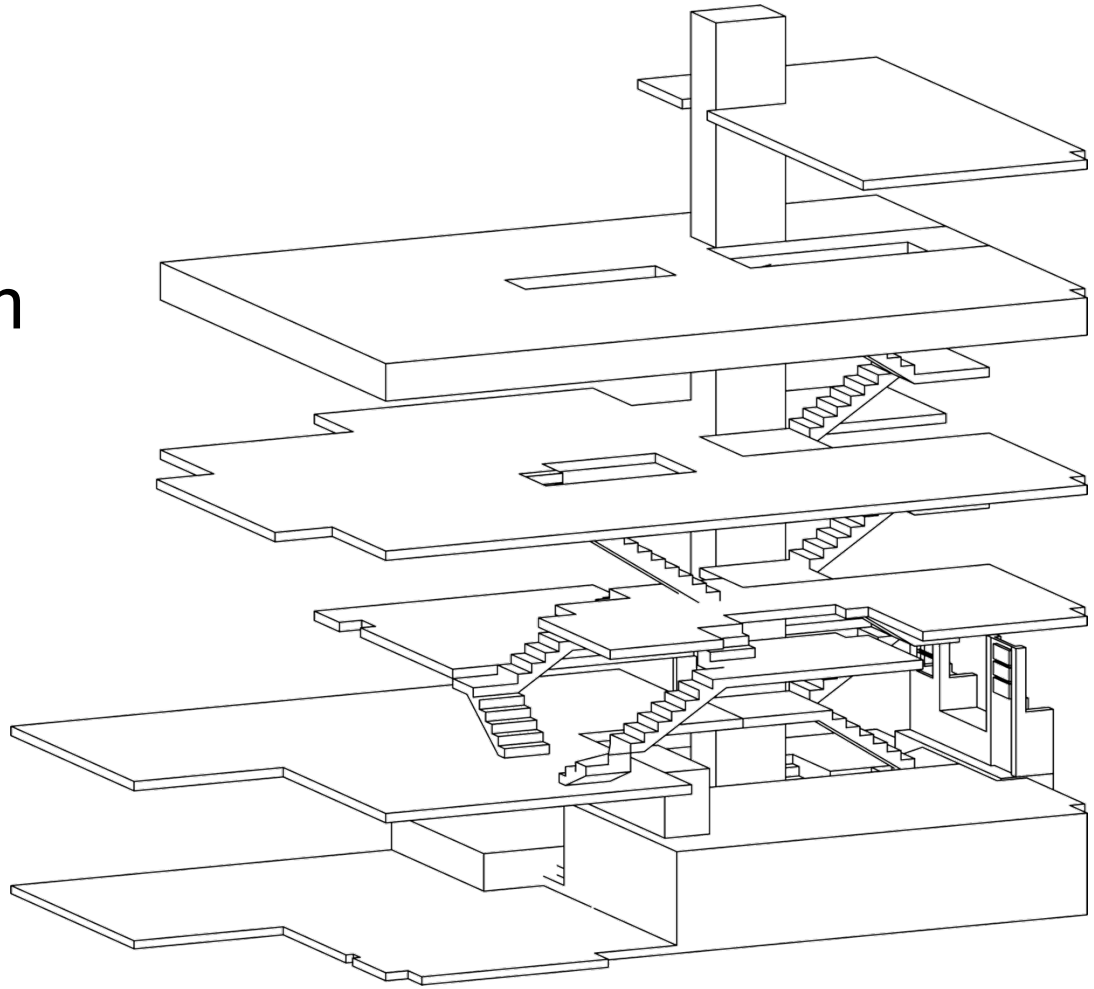
Analysis at Villa Müller

Characteristics

1. Raumplan

   “Raumplan” is to think of the room layout of houses as a three-dimensional figure, instead of as floor plans in a conventional way.

- Rooms are continuously connected.



Villa muller circulation

Analysis at Villa Müller

Characteristics

2. Material

   Characteristic materials and colors are used for each room.

□ Characteristic interior decoration is given for each room.

Children's room

Men's dressing room

Main hall

Entrance

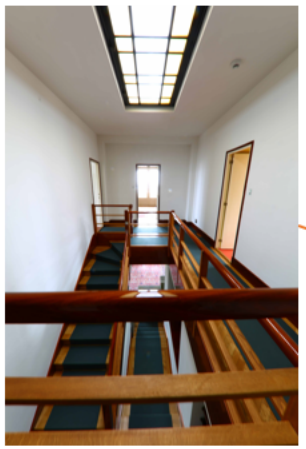
Analysis at Villa Müller

Main bedroom

Bathroom

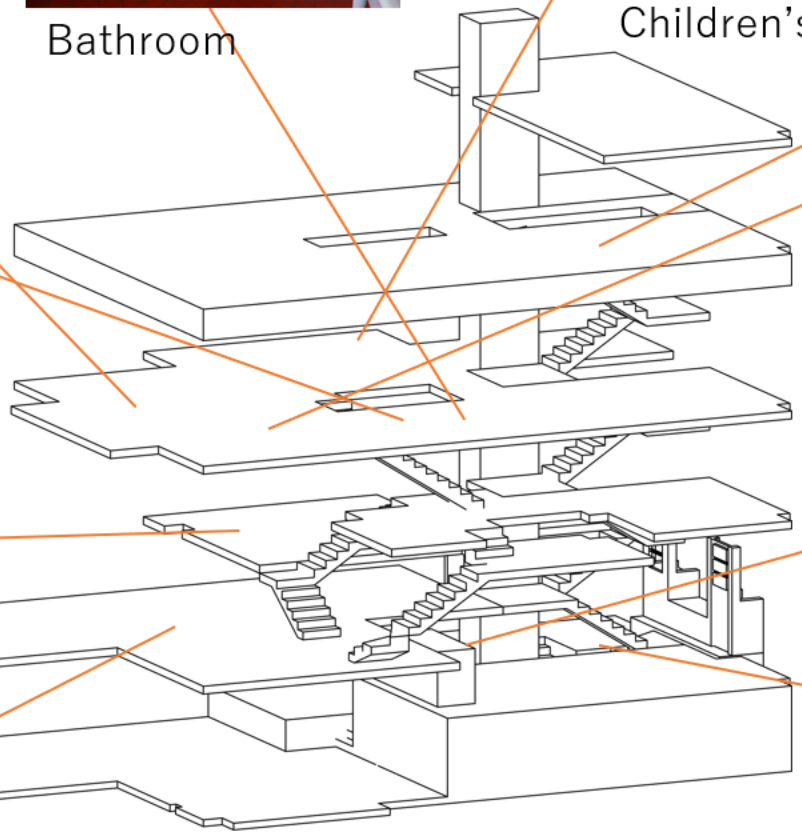
Children's room

Summer breakfast room



Staircase

Men's dressing room



Entrance hall

Dining room

Main hall

Entrance

Analysis at Villa Müller

<Purpose>

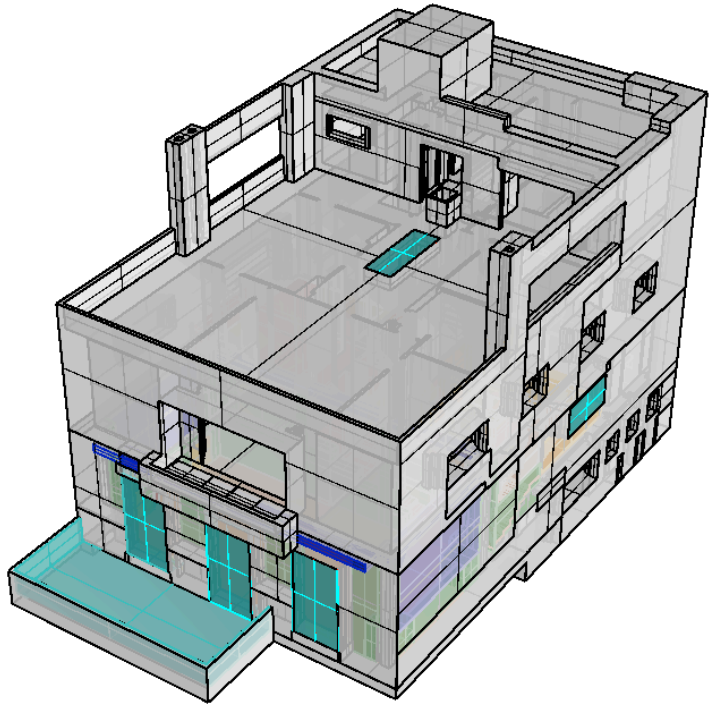
1．Can we depict light flow and distribution in complex space using our new method?

2．Confirm whether this method using Photon filter is effective for description of light in space.

➡Compare the impression of the analysis result using photon filter with the impression when actually visiting.

Analysis at Villa Müller

<Method>
Make the model in Rhinoceros
↓
Convert the model into radiance format
↓
Apply the material (We prepare 4 types of material data, one of them has all RGB values, and others have only R, G, B value respectively.)
↓
Emit photons using *mkpmap*



Rhinoceros model

Analysis at Villa Müller

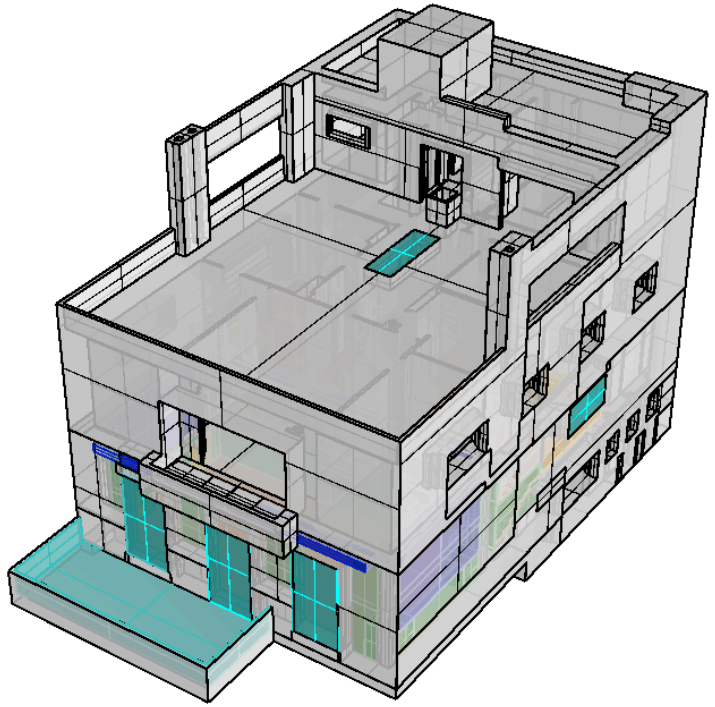
<Method>

↓

Get photon's coordinate using *pmapdump*

↓

Enter coordinate data in Autodesk's Recap



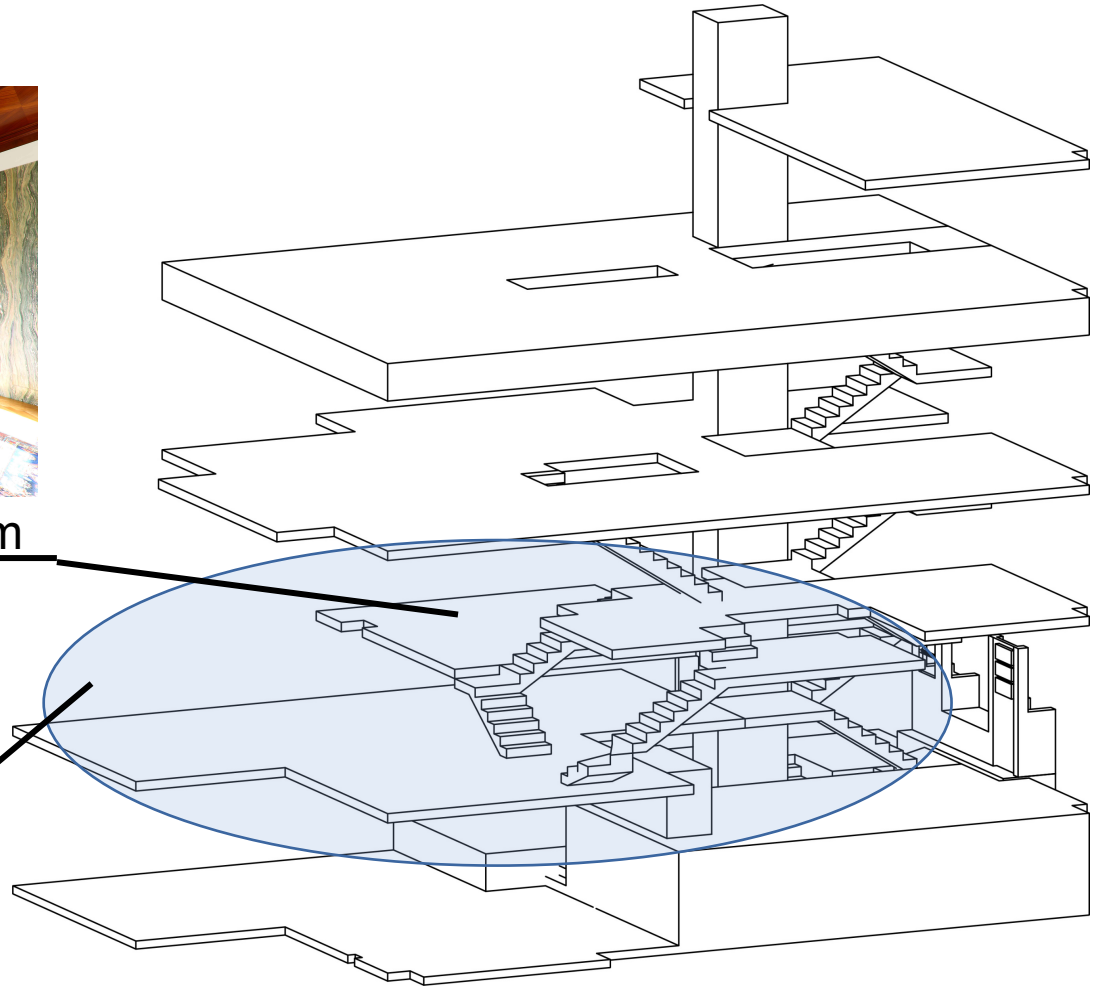
Rhinoceros model

Analysis at Villa Müller

Analysis space

Dining rooom

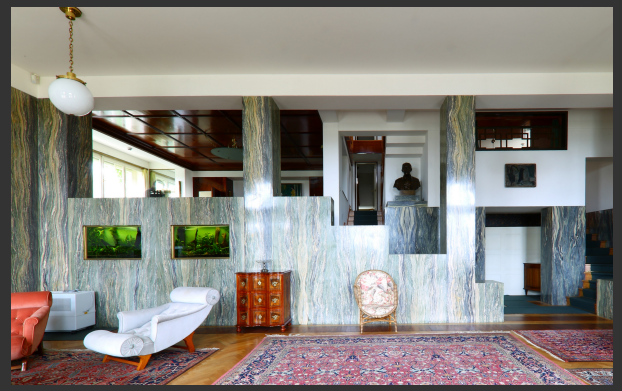
Main hall



Window

Dining room

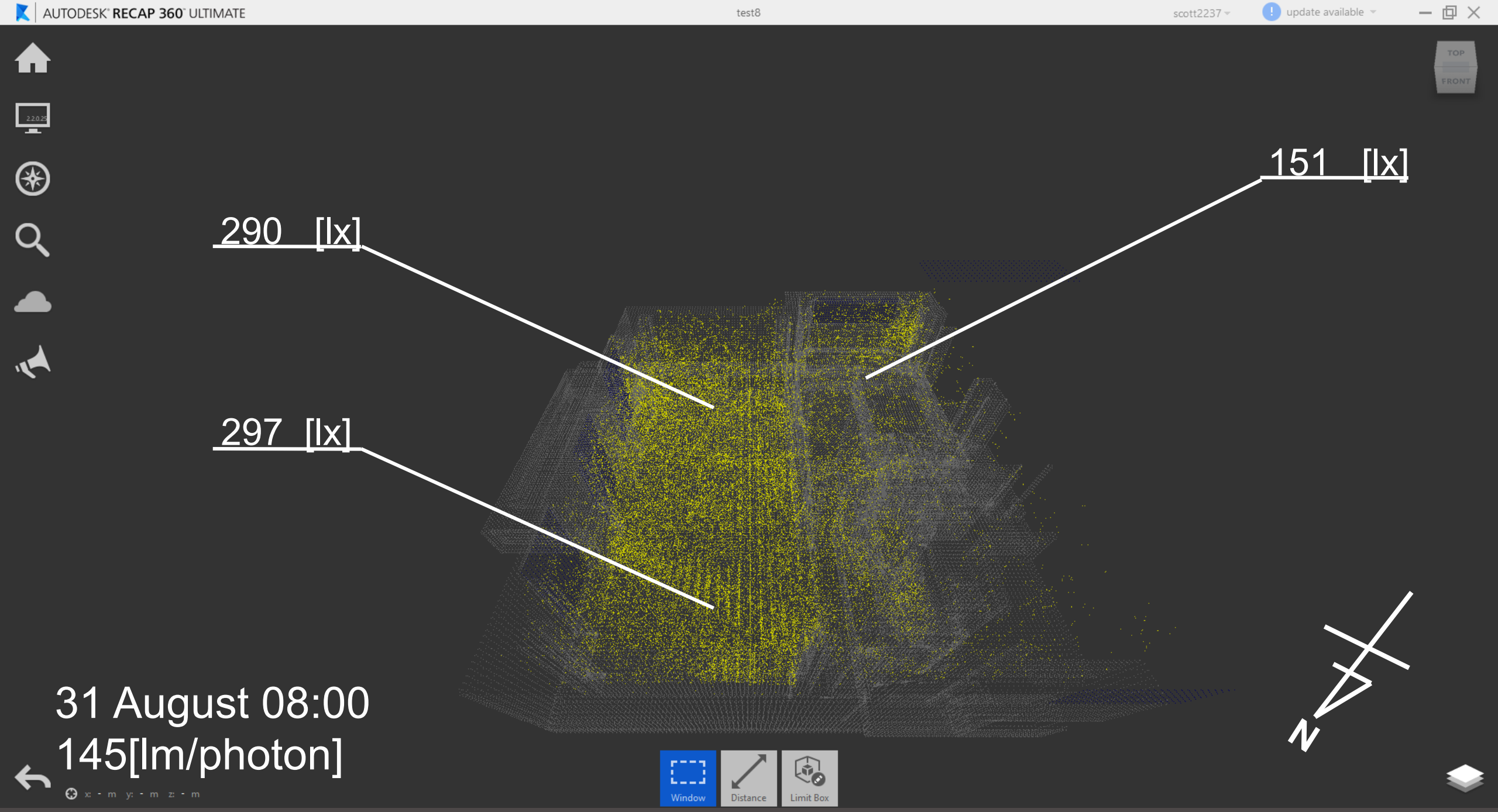
Main hall

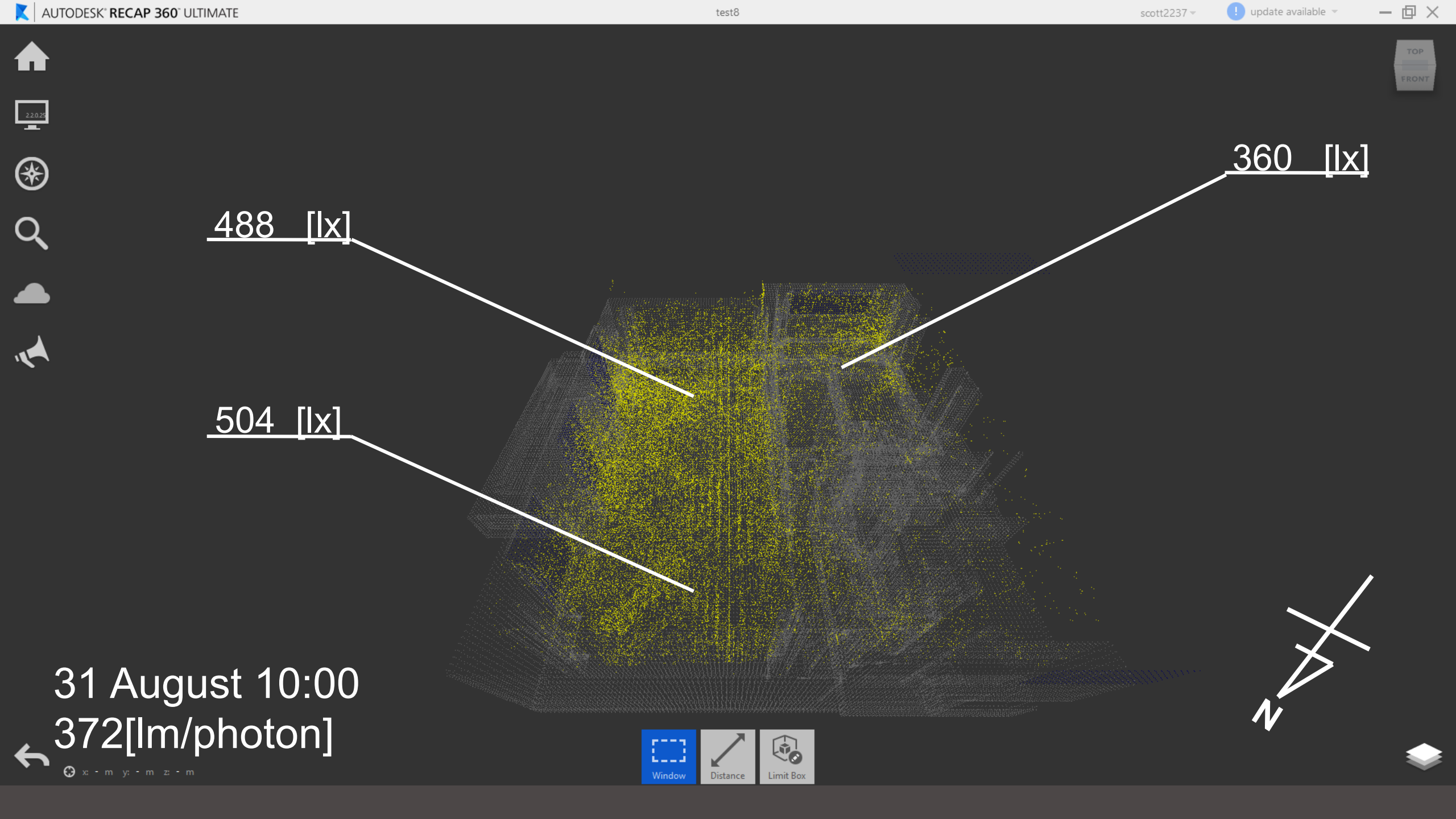


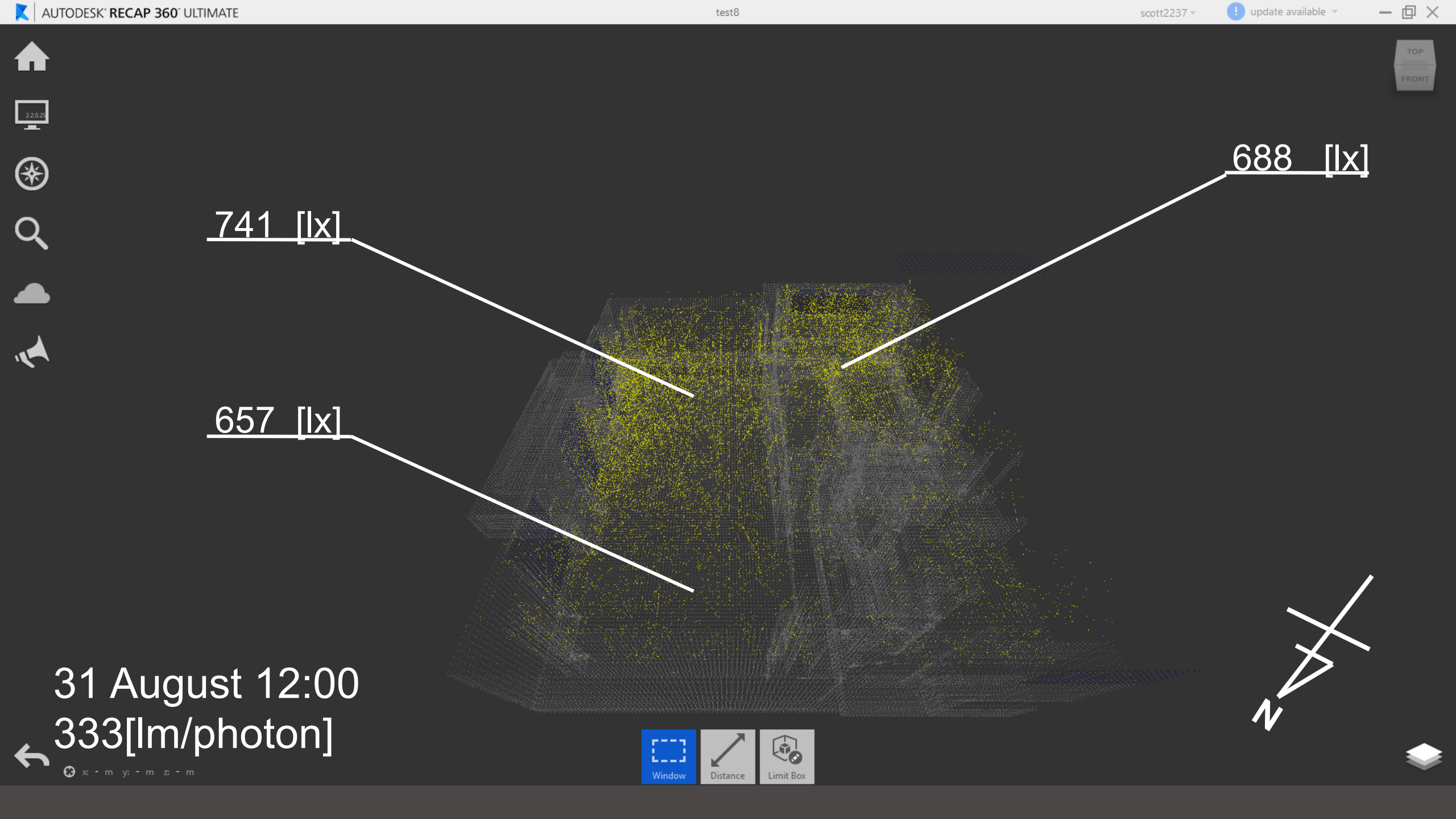
N

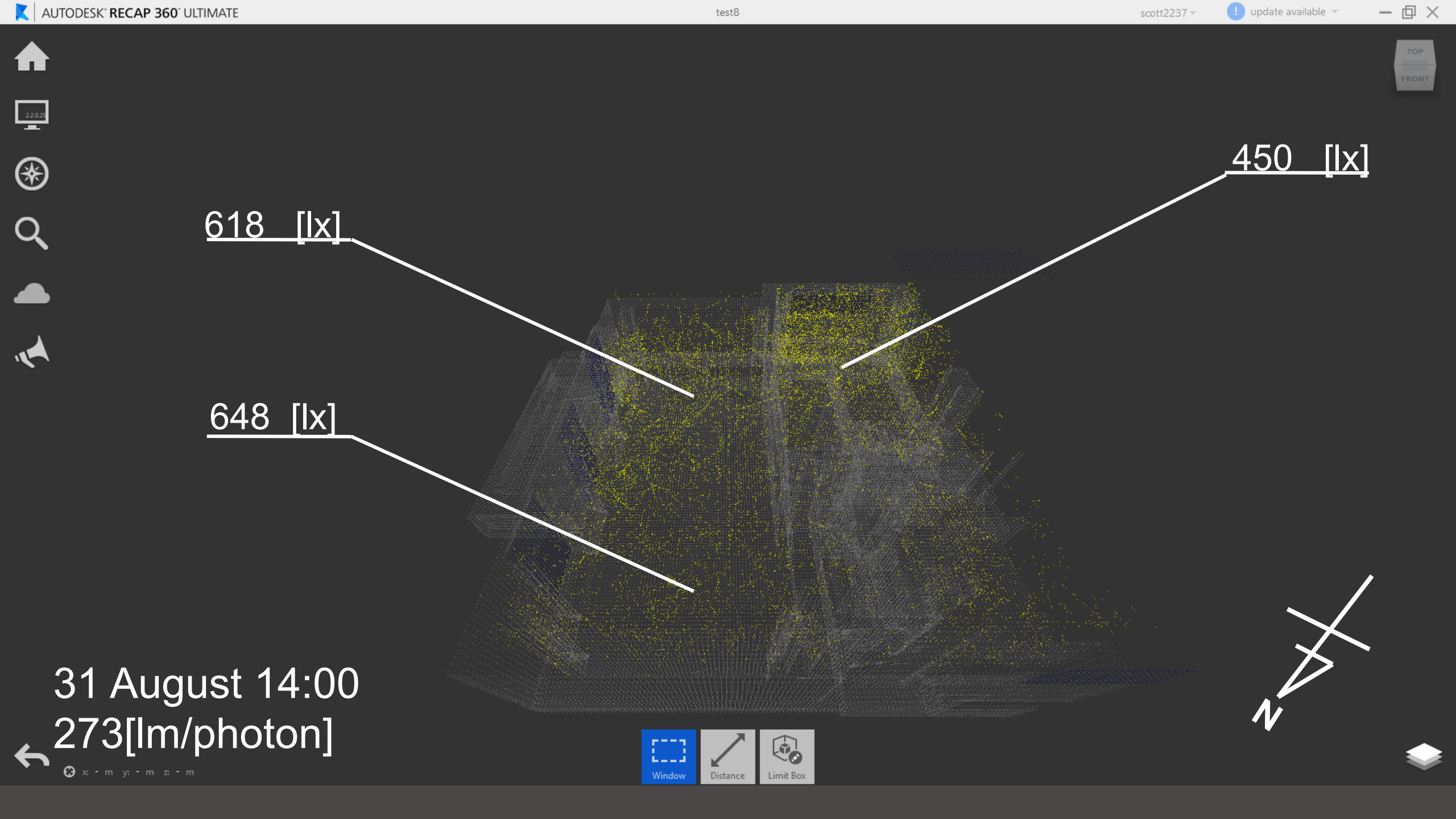
Window
Distance
Limit Box

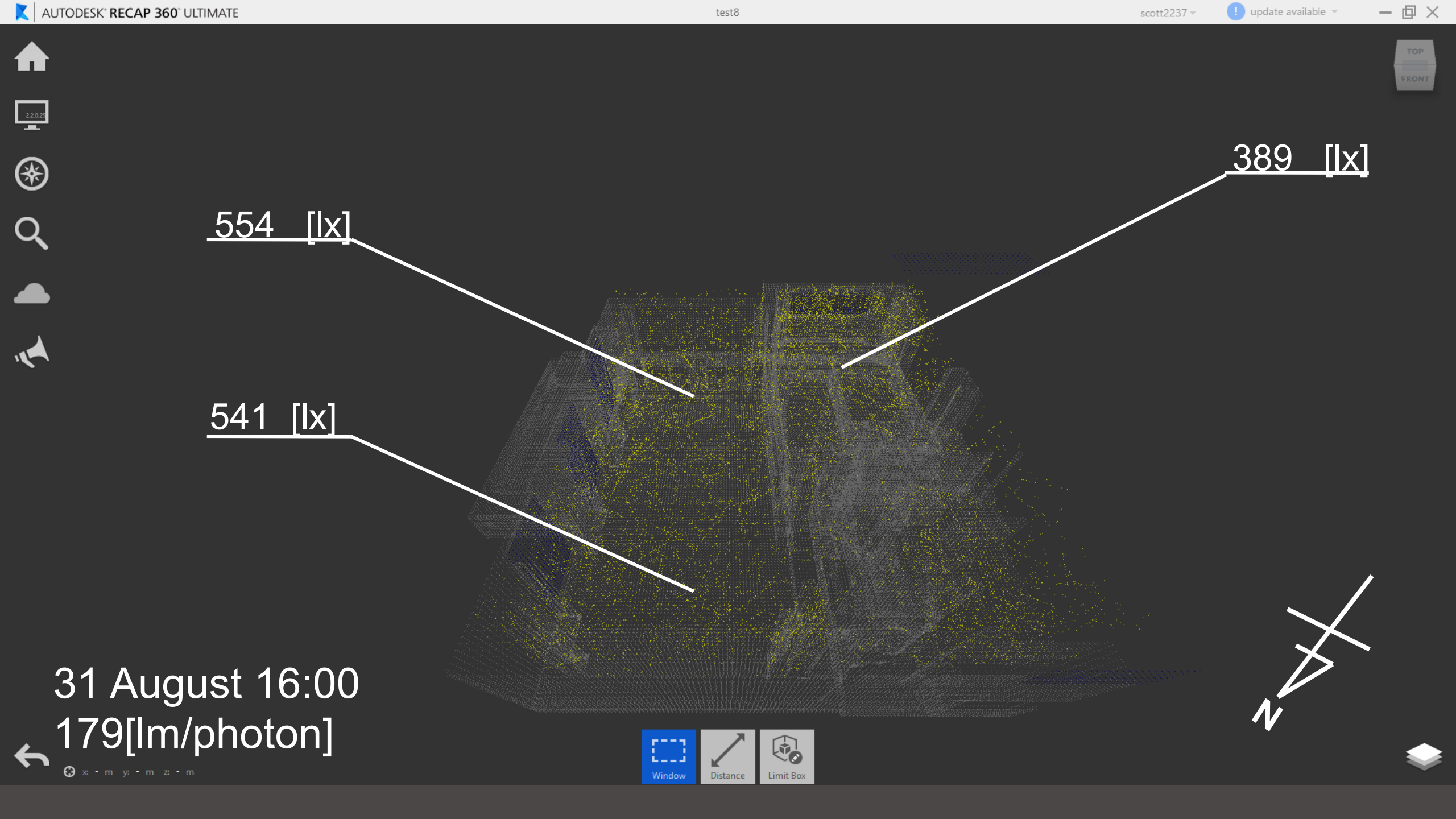
x: - m y: - m z: - m

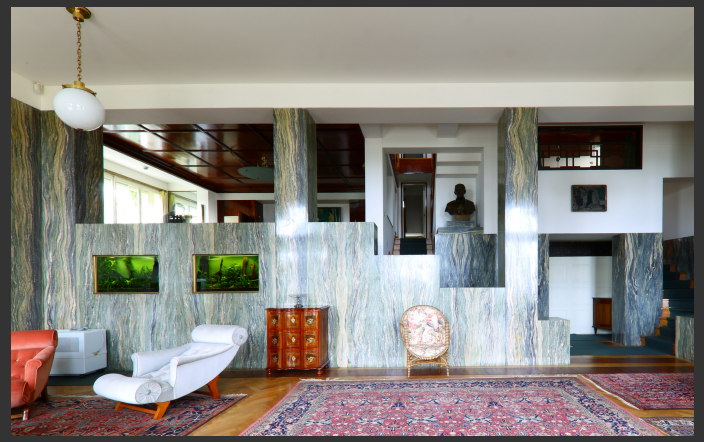

151 [lx]
290 [lx]
297 [lx]
31 August 08:00
145[lm/photon]
x: - m y: - m z: - m
Window
Distance
Limit Box
TOP
FRONT
N


360 [lx]
488 [lx]
504 [lx]
TOP
FRONT
N
31 August 10:00
372[lm/photon]
x: - m y: - m z: - m
Window
Distance
Limit Box


TOP
FRONT
688 [lx]
741 [lx]
657 [lx]
N
31 August 12:00
333[lm/photon]
x: - m y: - m z: - m
Window
Distance
Limit Box

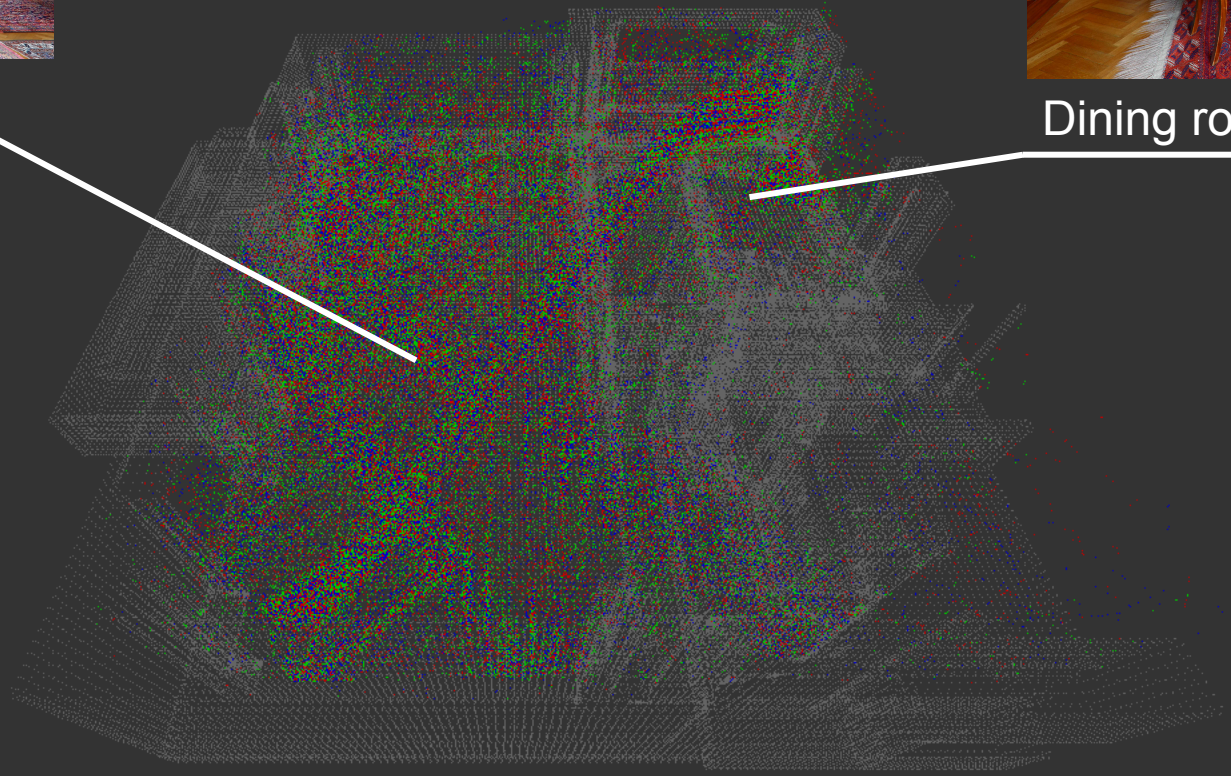

618 [lx]
450 [lx]
648 [lx]
31 August 14:00
273[lm/photon]
Window
Distance
Limit Box
N


TOP
FRONT
389 [lx]
554 [lx]
541 [lx]
N
31 August 16:00
179[lm/photon]
x: - m y: - m z: - m
Window
Distance
Limit Box

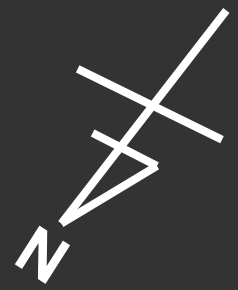


Main room

Dining room

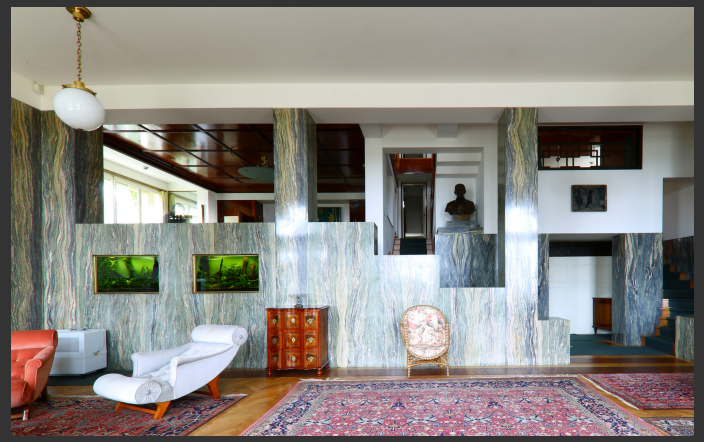


31 August 10:00



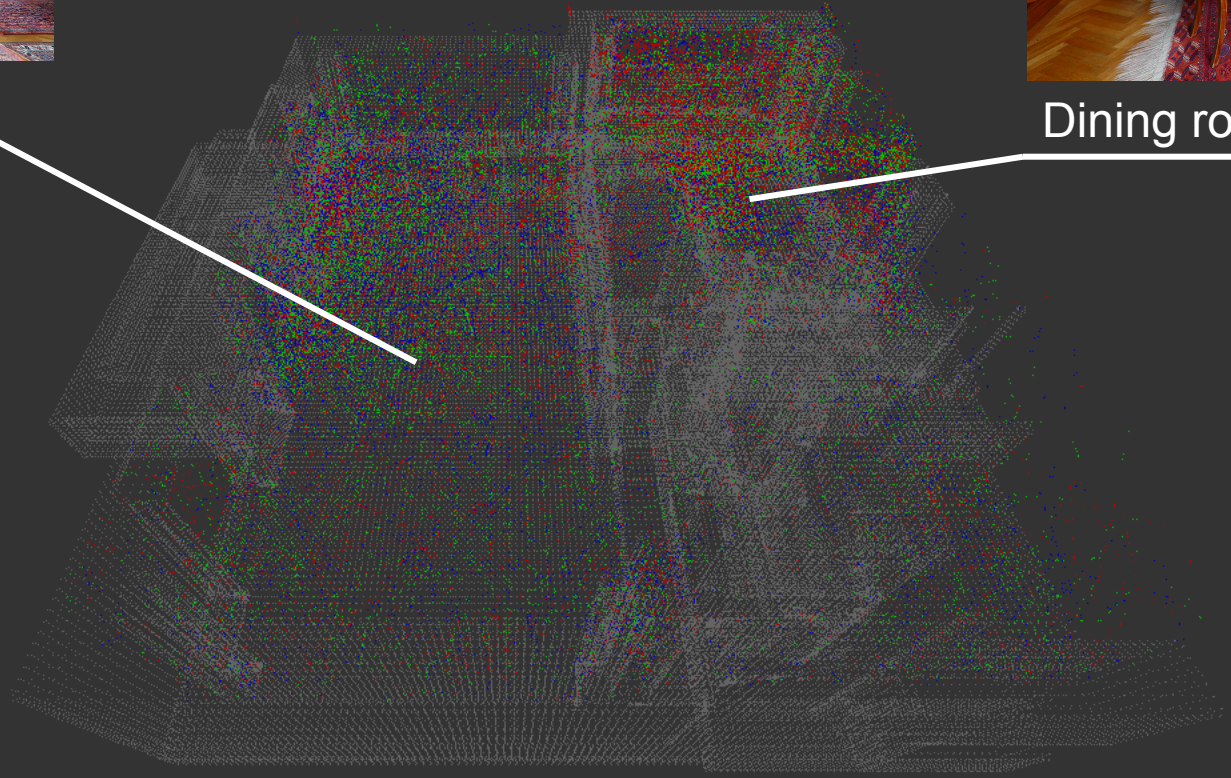
Window Distance Limit Box

x: - m y: - m z: - m

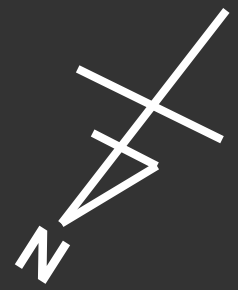


Main room

Dining room



31 August 12:00



Window
Distance
Limit Box

x: - m y: - m z: - m

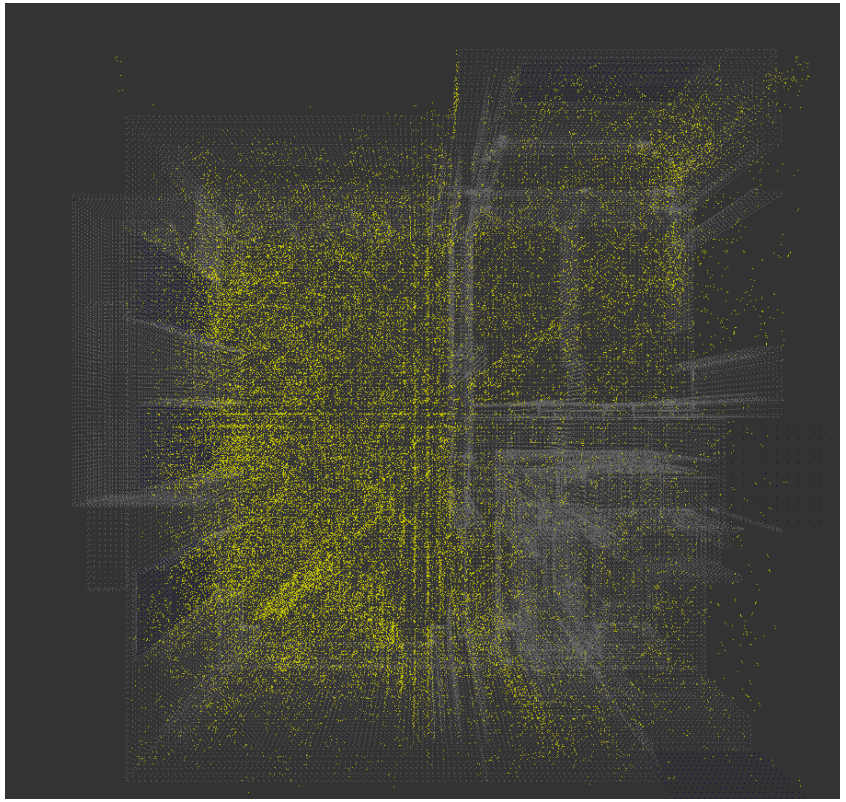
31 August 11:00

Conclusion

<Advantage of this method>

It became possible to depict the flow and density of light in three-dimensionally way.

In addition, we can estimate the absolute intensity of light environment from the appearance of photon density.

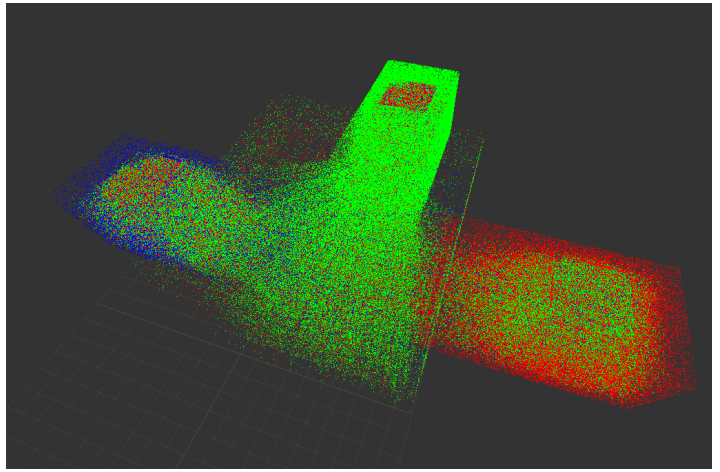


Conclusion

<Advantage of this method>

This technique using photons can read light flow, light density and physical values. This means that this method could have some advantages to estimate the lighting environment.

Furthermore, it became possible to express the light colour distribution using photons in a space.
These characteristics will help to describe the human-centric light environment.



Future works

I would like to confirm whether the light environment expressed by photons is related to human perception through some subjective experiments in near future.

Thank you for your attention.