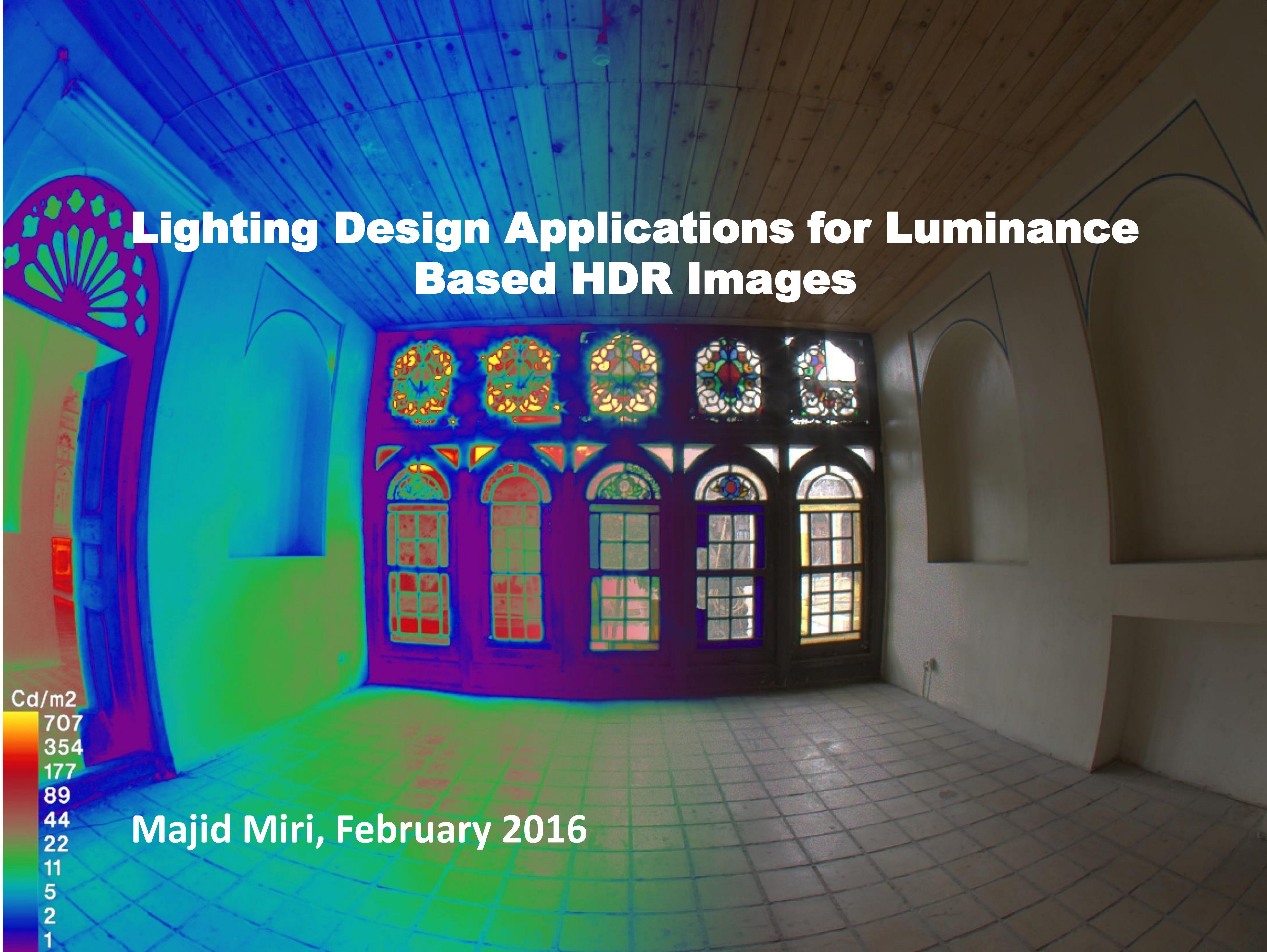
Lighting Design Applications for Luminance Based HDR Images



Majid Miri, February 2016

Human visual system

The human visual system is **able** to **adapt** to lighting conditions that vary **by nearly 10 orders of magnitude**.

Within a scene, the human visual system functions over a range of around **5 orders of magnitude** simultaneously.

Limitation in technology

While typical cathode ray tube **(CRT) disp**lays are able to reproduce around **2 orders of magnitude** of intensity variation.

Although LCDs tend to be somewhat brighter than CRT displays, their brightness is not orders of magnitude larger.

Limitation in Technology

Due to limitation inherent most digital image sensors, almost all regular cameras cannot capture the full dynamic range of scene in a single exposure.

Limitation in Technology

If we had a digital sensor that could record the full dynamic range in a single shot. In fact, such sensors are being actively developed, and some are even being marketed, but only a few integrated solutions are commercially available.

Civetta 360˚ digital imaging

SpheroCam HDR

1. High Dynamic Range (HDR) images

Since all regular cameras have limitations in that they cannot capture a large dynamic range of luminance in a realistic scene,

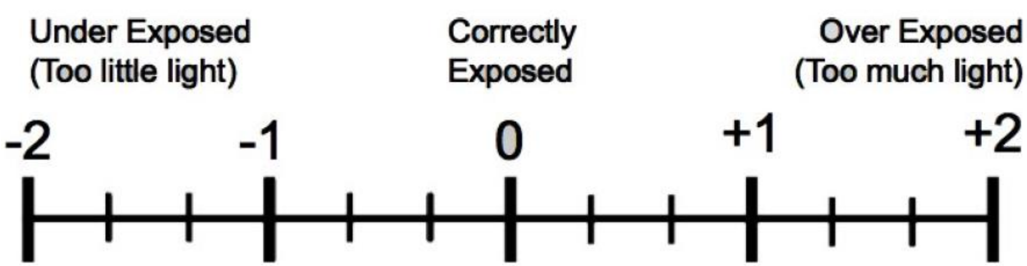
or

1. High Dynamic Range (HDR) images

Since all regular cameras have limitations in that they cannot capture a large dynamic range of luminance in a realistic scene, we need to assemble a sequence of LDR (low dynamic range) photos taken by them to create a HDR (high dynamic range) image which includes the whole range.

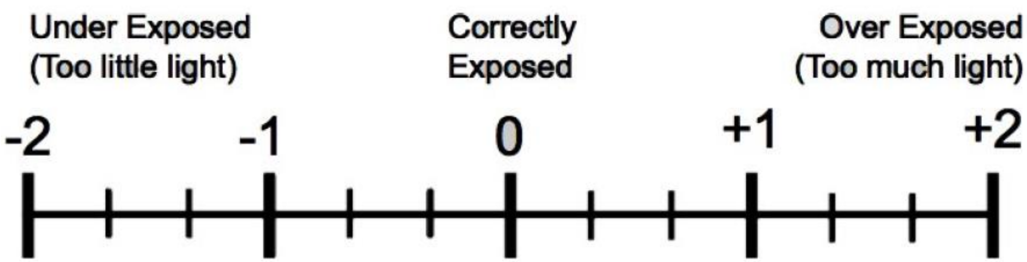
1. High Dynamic Range (HDR) images

Thus by taking multiple exposures, each image in the exposure will have different pixels properly exposed and other pixels under- or overexposed. However, each pixels will be properly exposed in one or more images in the sequence.



1. High Dynamic Range (HDR) images

This may be achieved by photographing a static scene multiple times where for each frame the **exposure value** is varied. This leads to a sequence of images, which may be combined into single HDR image.



1. High Dynamic Range (HDR) images

Bracketing:

In short, bracketing is taking the same photo more than once using different settings for different exposures.

There are different ways to adjust the camera settings to manipulate exposure. One is to change the **aperture**, another is the **shutter speed** and the third is **ISO**, while keeping the other two the same.

Usually between 2.8 to 22

Usually between 30” to 1/8000”

Usually between 24 to 6400

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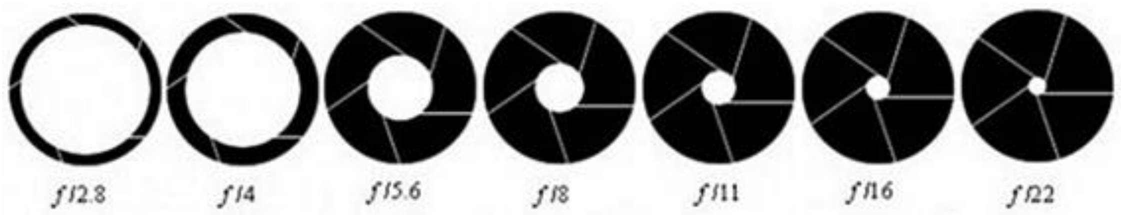
Aperture (F-number): Controls the amount of light reaching the image sensor. In combination with variation of shutter speed, the aperture size will regulate the image sensor's degree of exposure to light.



The smaller F Stop number the larger the opening and the greater the amount of light entering the camera.

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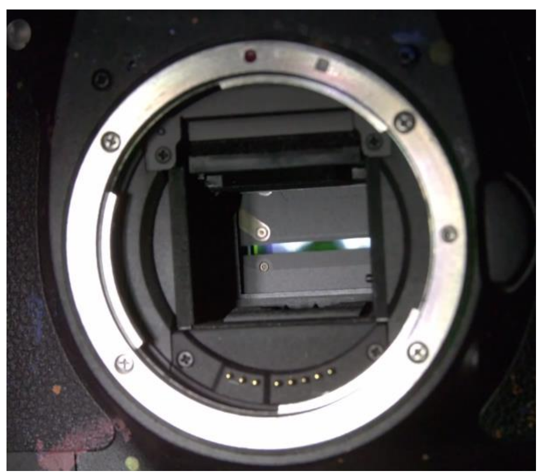
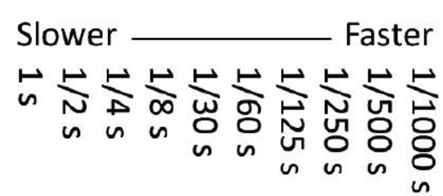


Usually between 30” to 1/8000”

Shutter Speed (Exposure Time):
The effective length of time a shutter is open or duration of light reaching the image sensor. The longer the shutter is open the more light reaches the image sensor.



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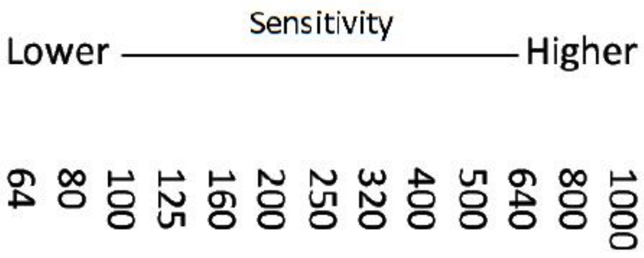
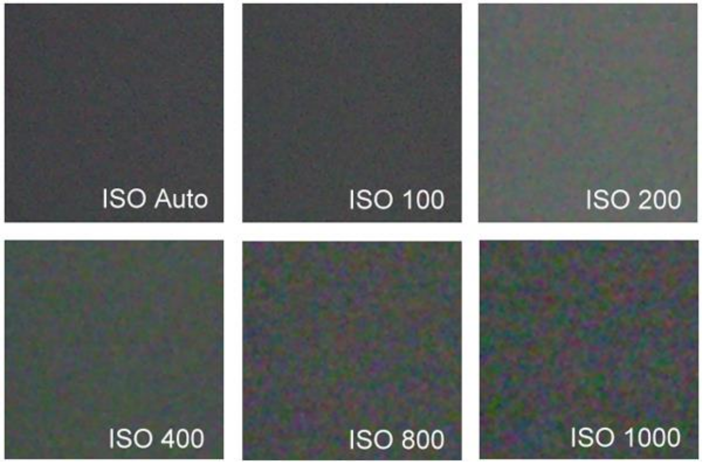
ISO (Film Speed): is a measurement of a digital camera's imaging sensor's sensitivity.





Usually between 24 to 6400

1. High Dynamic Range (HDR) images

In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

Exposure Value (EV) denotes all combinations of a camera's shutter speed and relative aperture that give the same exposure.

EV = $log_2 \frac{N^2}{t}$ where *N* is relative aperture, *t* is the exposure time in seconds

1. High Dynamic Range (HDR) images

In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

For creating a luminance based HDR image:

Bracketing:

- Tripod: Bracketing usually requires the subject matter to remain still between shots, and the camera should also be placed on a tripod.

1. High Dynamic Range (HDR) images

In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

For creating a luminance based HDR image:

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- In Digital Camera use Manual Settings

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At least 3 images with different exposure values

Enable RAW file saving (ex. CR2, CRW, NEF, DNG, etc.)

Apperture: Use F8 or F11

ISO: 100

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In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

For creating a luminance based HDR image:

Bracketing:

- Tripod
- In Digital Camera use Manual Settings
  - **At least 3** images with different exposure values
  - Enable **RAW** file saving
  - Apperture: Use **F8** or F11
  - ISO: **100**
- Luminance meter (for calibrating cameras and lenses)

1. High Dynamic Range (HDR) images

In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

HDR Tools:

- Based on photos taken by DSLR cameras

TechnoTeam Bildverarbeitung GmbH

Photosphere

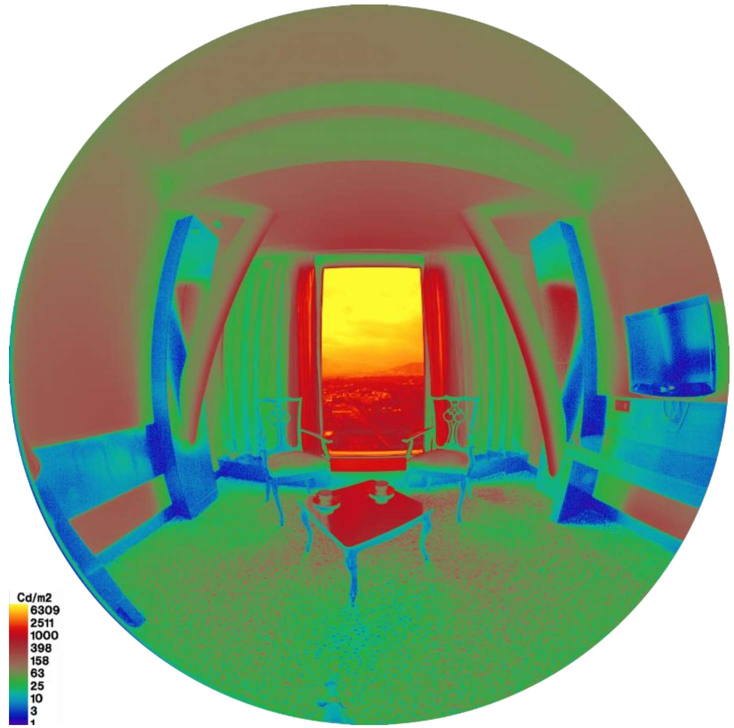
AFTAB

- By computer simulation software

Radiance

DIALux evo

RELUX light simulation tools



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In a photo realistic HDR image, each pixel corresponds to a realistic luminance value.

HDR Tools:

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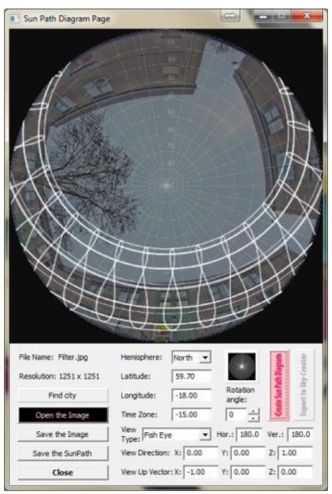
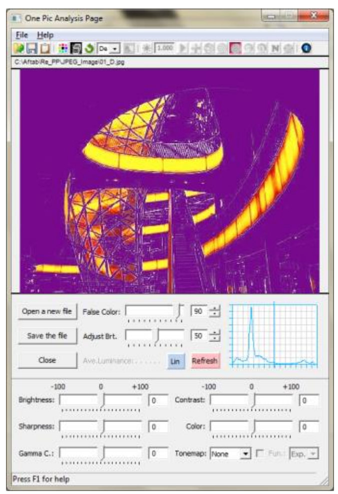
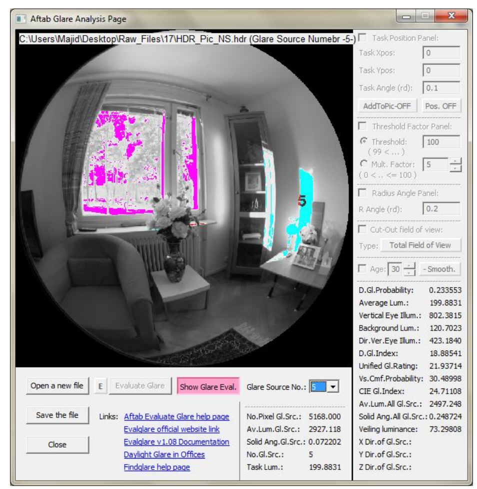
Camera Calibration, Creating HDR, Evaluating HDR, Glare Evaluation,
Sun-path Diagram generator

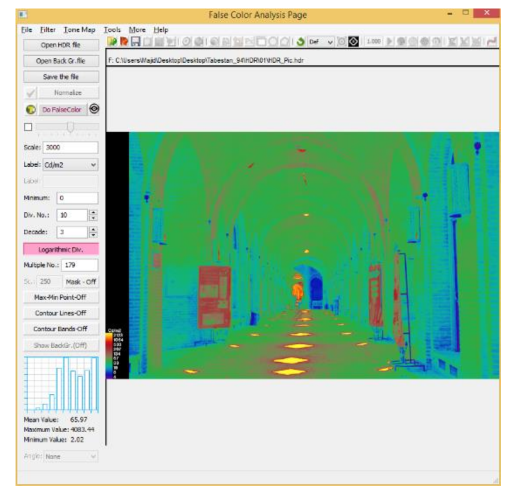
AFTAB

Written in Python with some commands scripted in C++
With the help of some Radiance commands, evalglare, and dcraw









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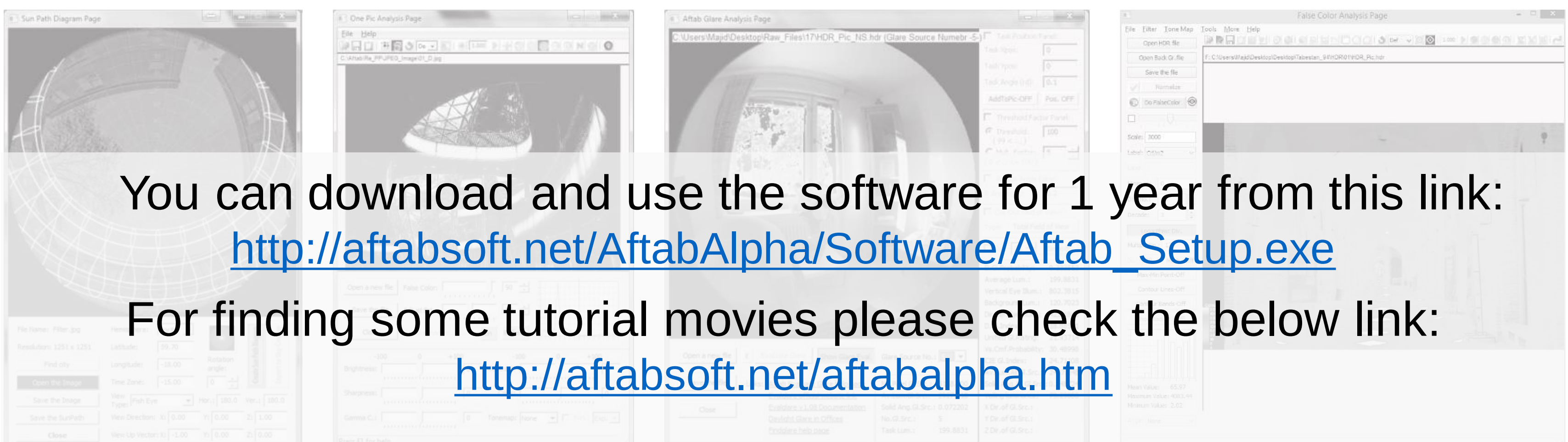


You can download and use the software for 1 year from this link:
http://aftabsoft.net/AftabAlpha/Software/Aftab_Setup.exe

For finding some tutorial movies please check the below link:
http://aftabsoft.net/aftabalpha.htm

2. Main lighting design purposes

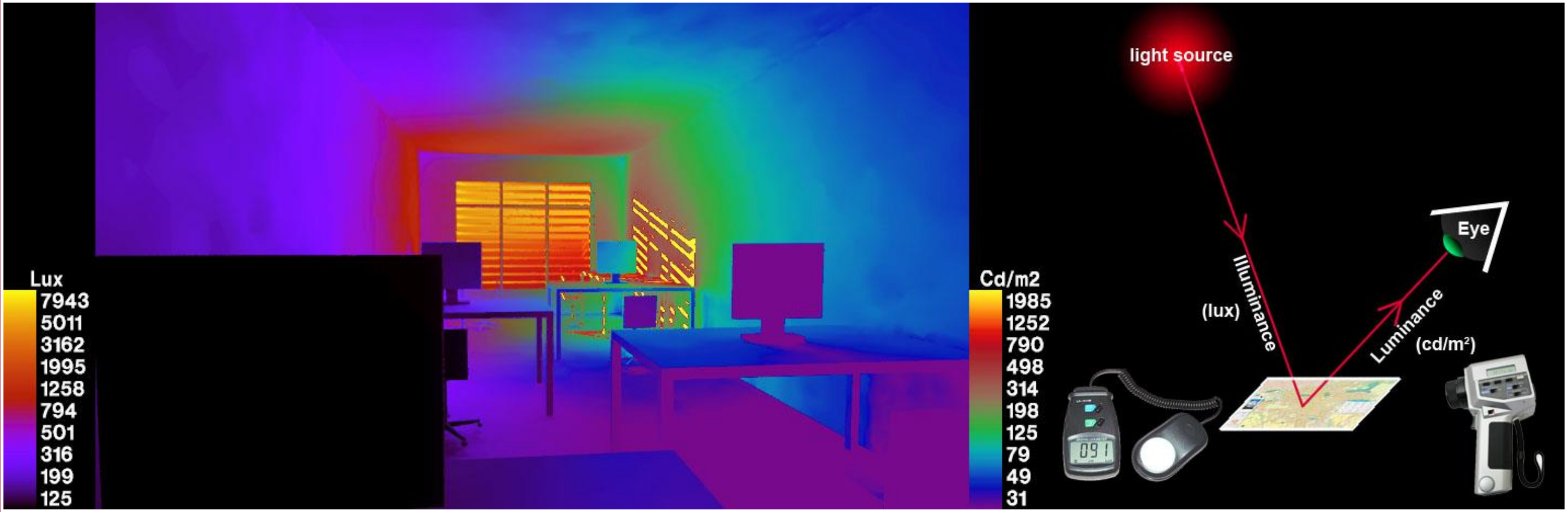
- Visibility → Quantity
- Appearance → Quality

THE LIGHTING HANDBOOK, 10TH EDITION

EUROPEAN STANDARD

3. Lighting measurements

- Visibility → **Quantity** (illuminance or **luminance**)
- Appearance → Quality



Most of the lighting standards use illuminance and **not** luminance.

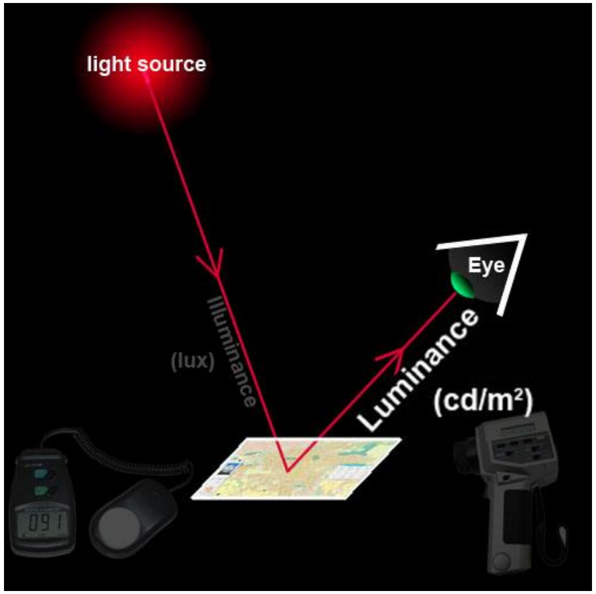
4. Luminance characteristics

- Visibility → **Quantity**
- Appearance → Quality

Luminance values are more directly related to what we see.

It is more relevant when considering the **visibility** and **indirectly** the **appearance** of the space.

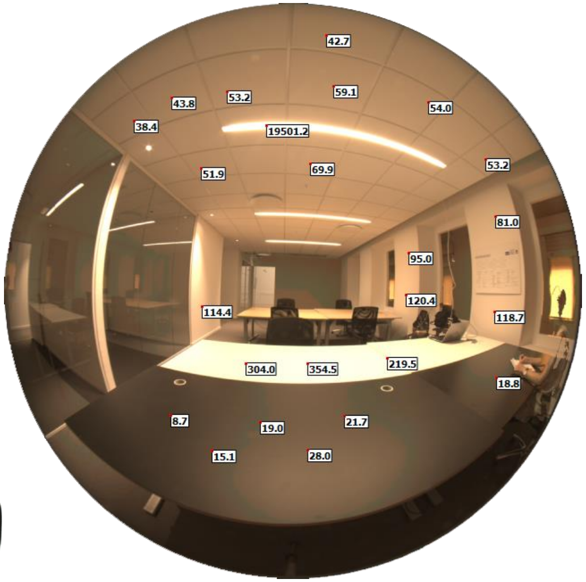
It is view independent.



5. Luminance measurement methods

- Visibility → **Quantity**
- Appearance → Quality

Using a luminance meter, it is not easy to measure the luminance value of each point in a realistic space.



5. Luminance measurement methods

- Visibility → **Quantity**

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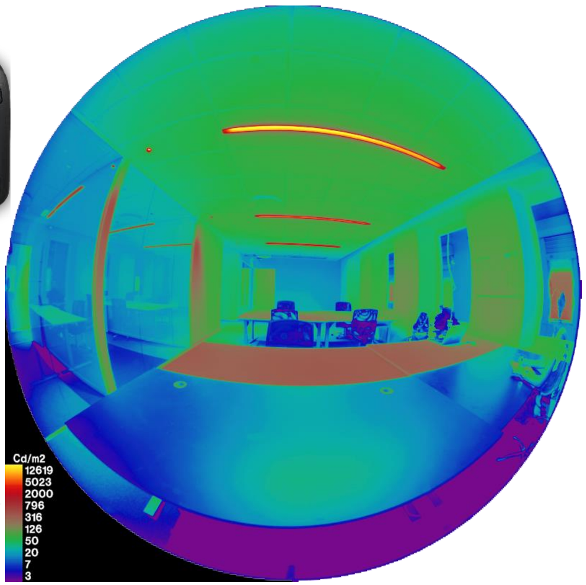
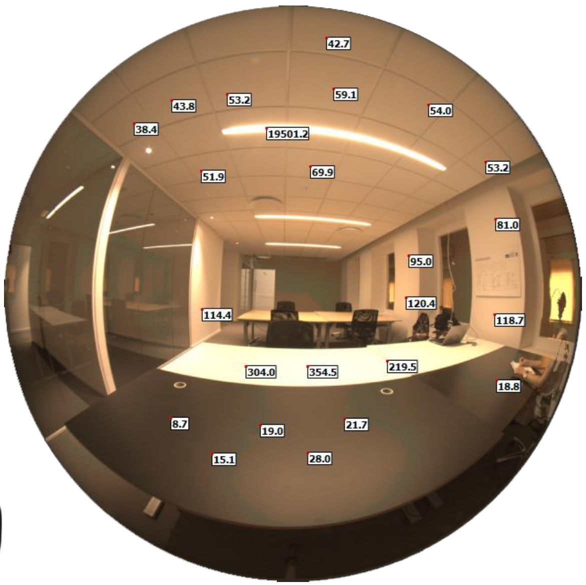
Using a luminance meter, it is not easy to measure the luminance value of each point in a realistic space. So, the photo realistic HDR photography technique is the answer.

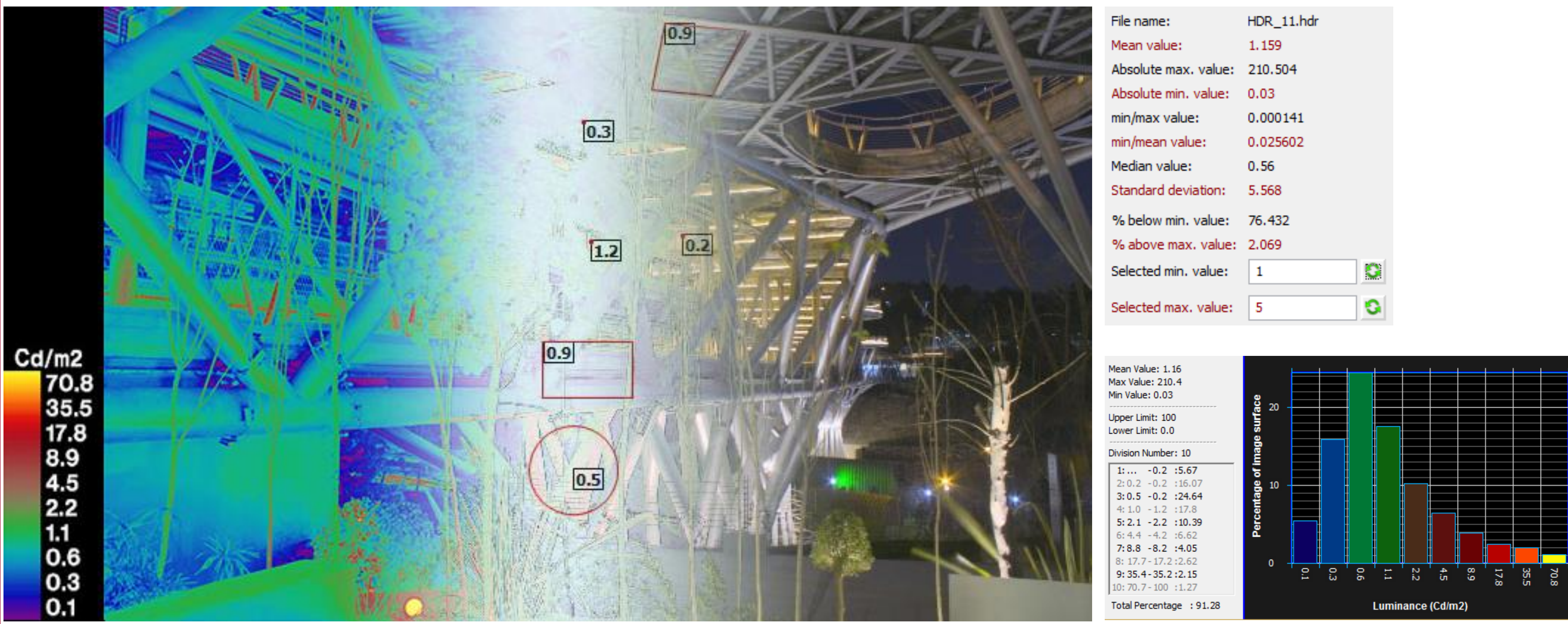



6. (Per Pixel Data) lighting analysis

Using per-pixel luminance data of a photo realistic HDR image to quantify or even qualify the lighting conditions of a space.

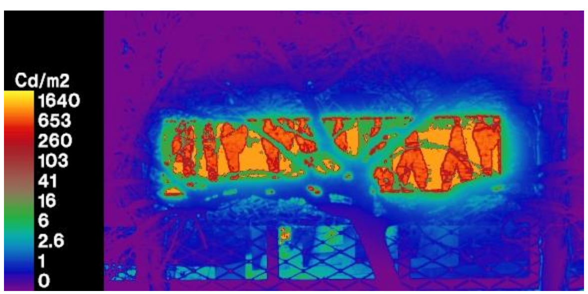
- To quantify or even - To qualify



6. (Per Pixel Data) lighting analysis

i. Single image analysis

The whole image, a region or regions of interests like visual field of view.

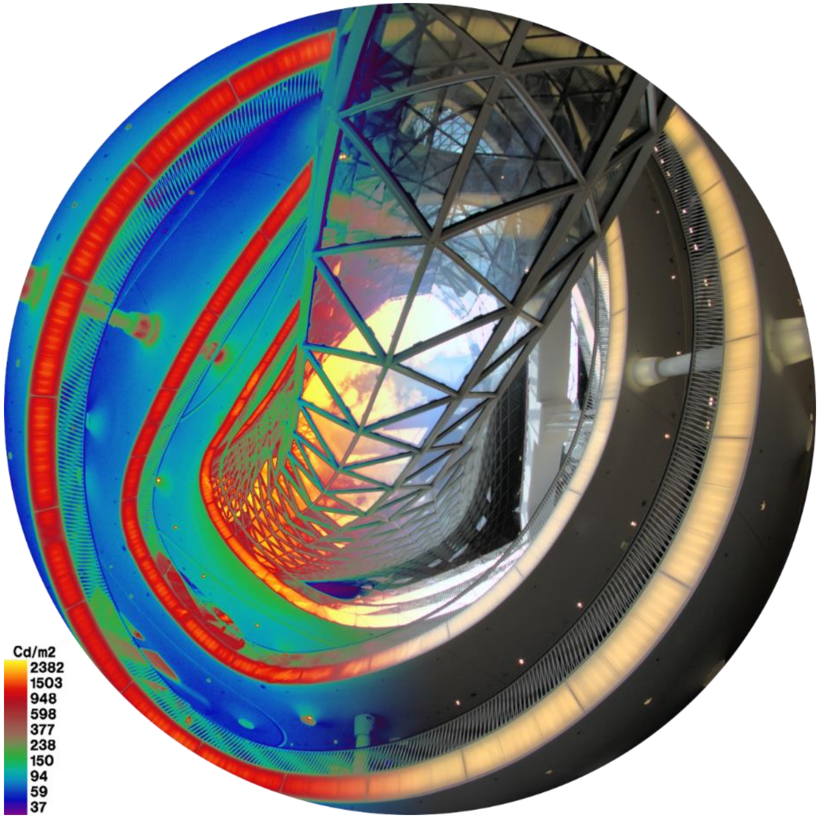


6. (Per Pixel Data) lighting analysis

i. Single image analysis

a. Numerical analysis

- Visually
- Mathematically/statistically
- Luminance to brightness conversion



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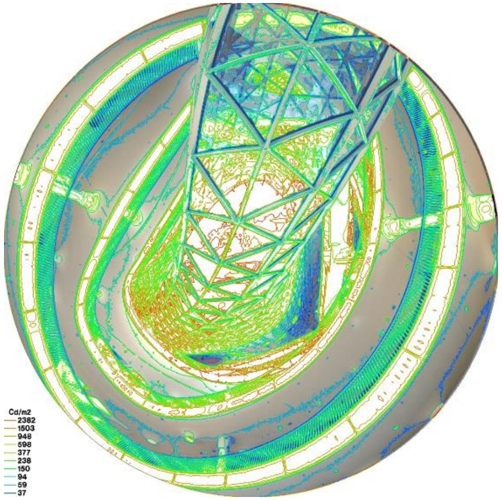
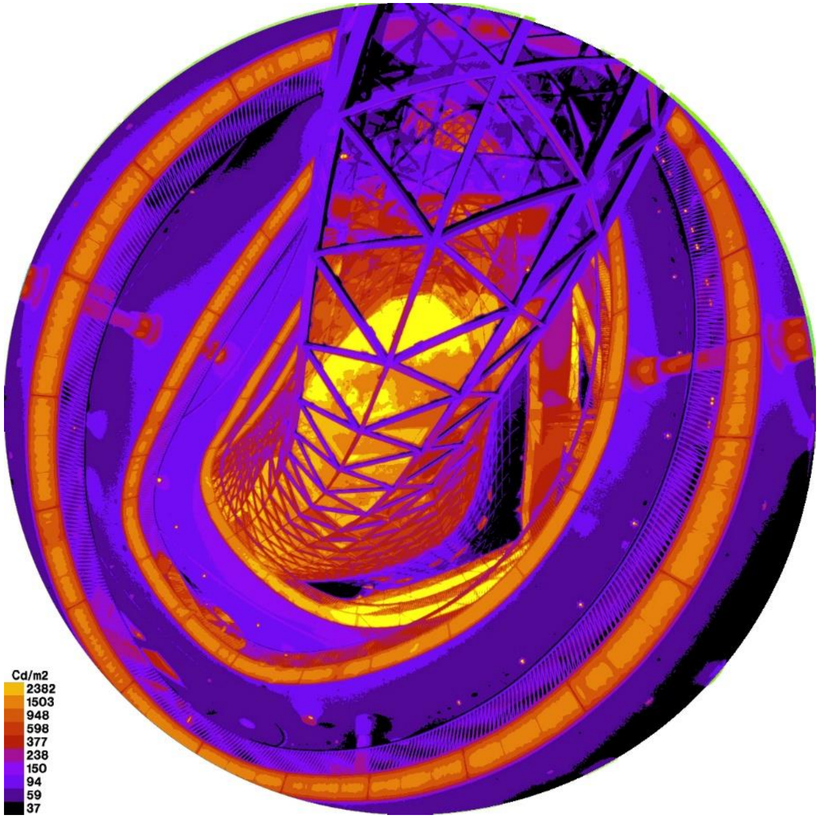




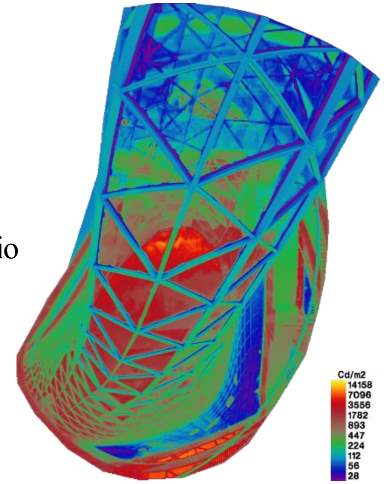
6. (Per Pixel Data) lighting analysis

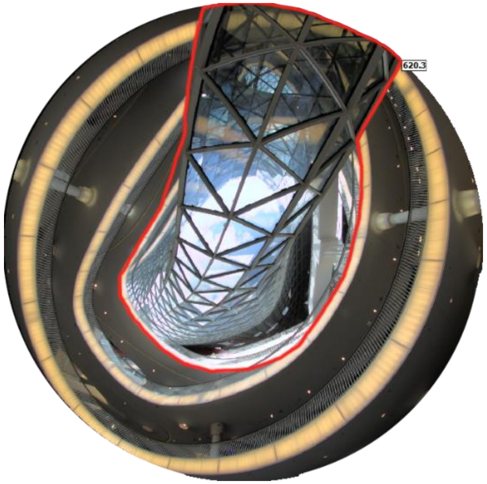
i. Single image analysis

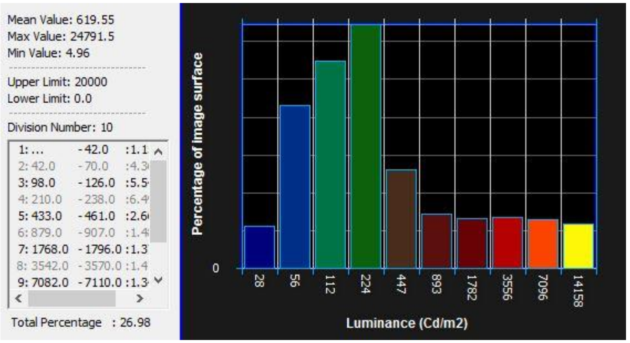
a) Numerical analysis

- Visually
- **Mathematically/statistically**
  - **The whole or part of a scene**
  - Task to background luminance ratio
- Luminance to brightness conversion

File name:	HDR_Pic_72.hdr
Mean value:	436.768
Absolute max. value:	24791.5
Absolute min. value:	4.962
min/max value:	0.0002
min/mean value:	0.01136
Median value:	109.566
Standard deviation:	745.951
% below min. value:	84.004
% above max. value:	0.522
Selected min. value:	1000
Selected max. value:	5000
☑ Exclude black pixels	







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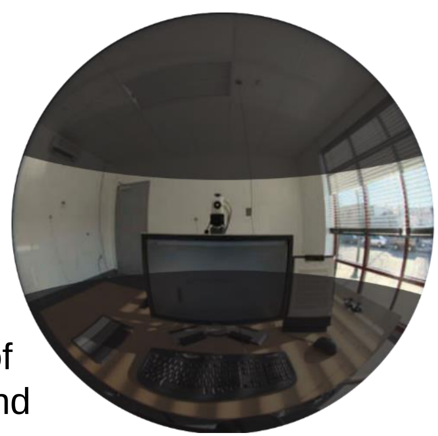
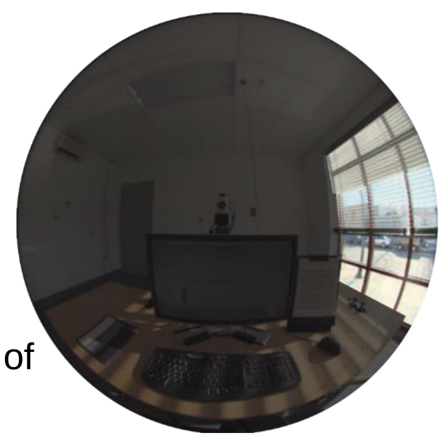
Wymelenberg KVD and Inanici M (2015) proposed a few new luminance based design metrics for predicting human visual comfort in offices with daylight. Two of them are as follows:



Mean luminance of 40˚ horizontal band



Standard deviation of window luminance

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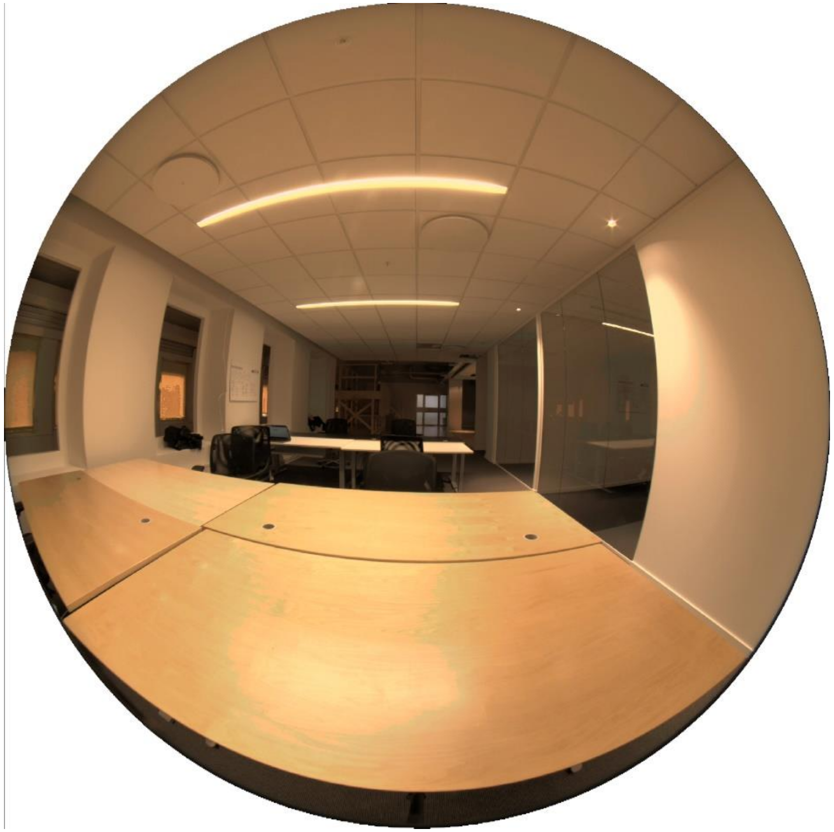

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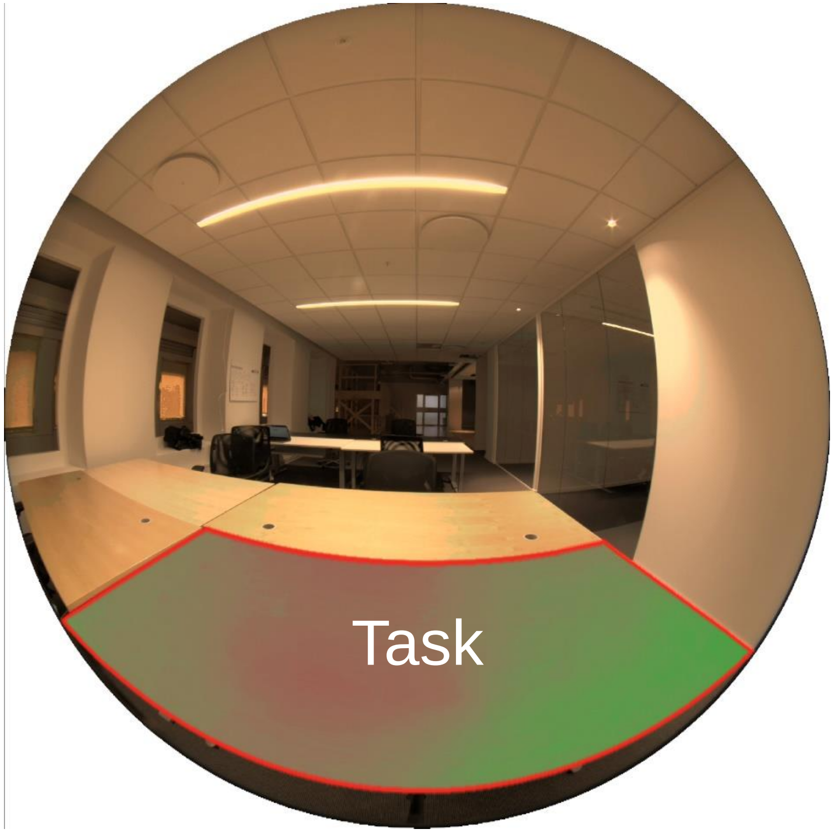

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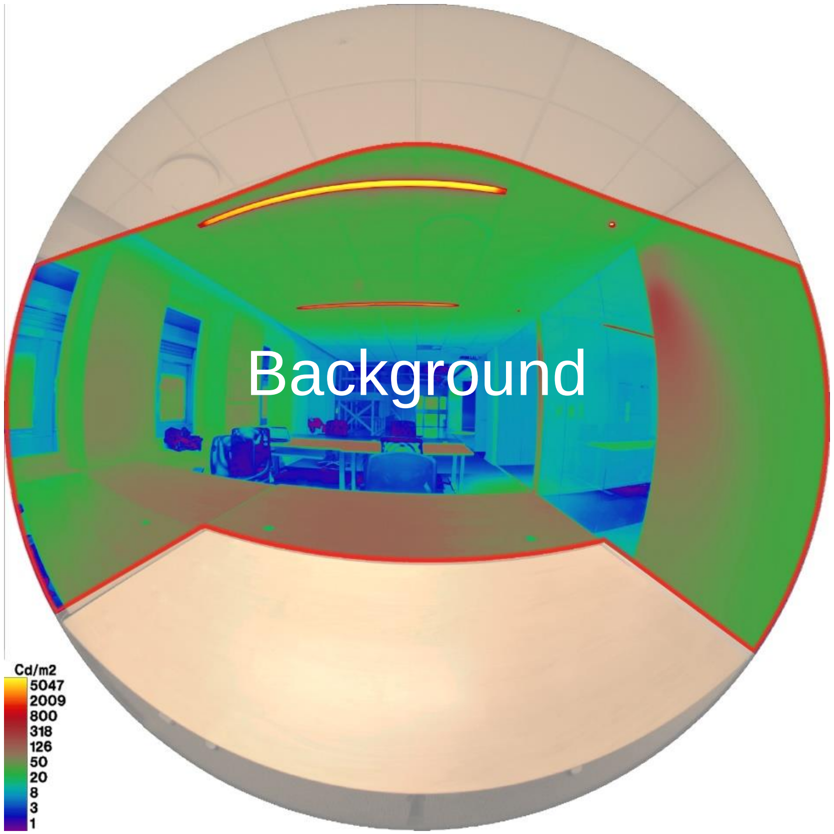

Cut-Out field of view to ”total field of view” according to Guth, 1958, done by Evalglare

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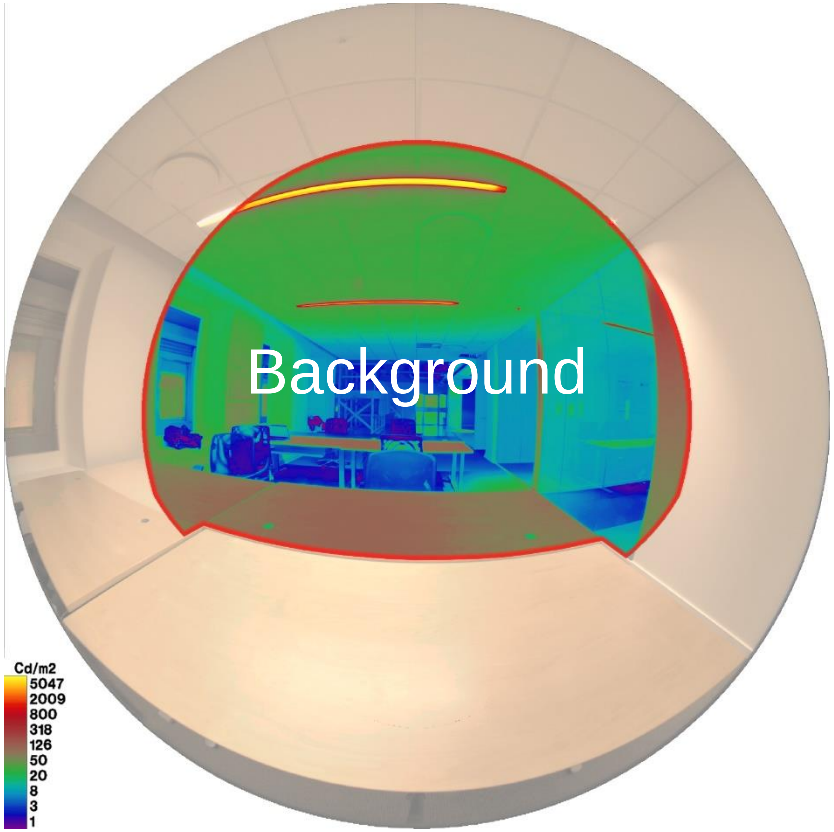

Cut-Out field of view to ”field of view seen by both eyes” according to Guth, 1958, done by Evalglare

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6. (Per Pixel Data) lighting analysis

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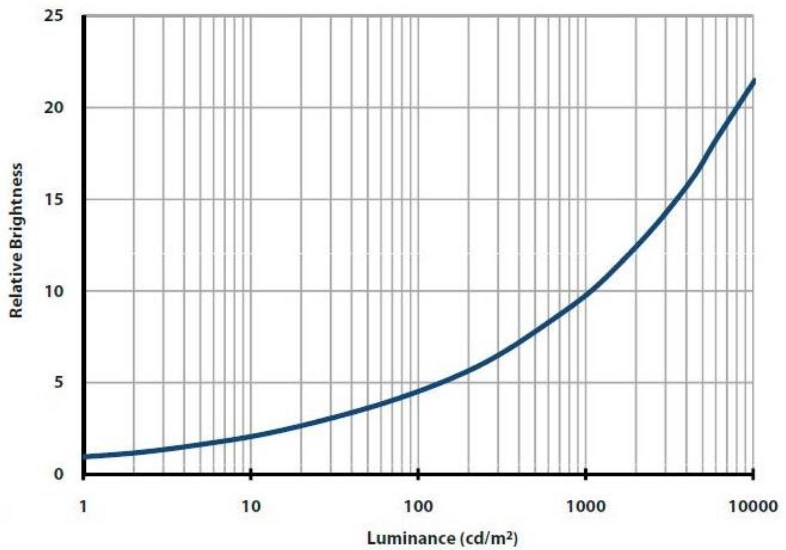

A luminance-brightness power relationship based on an exponent of 1/3 (DiLaura, Houser, Mistrick, et. al. 2011, p. 4.10)

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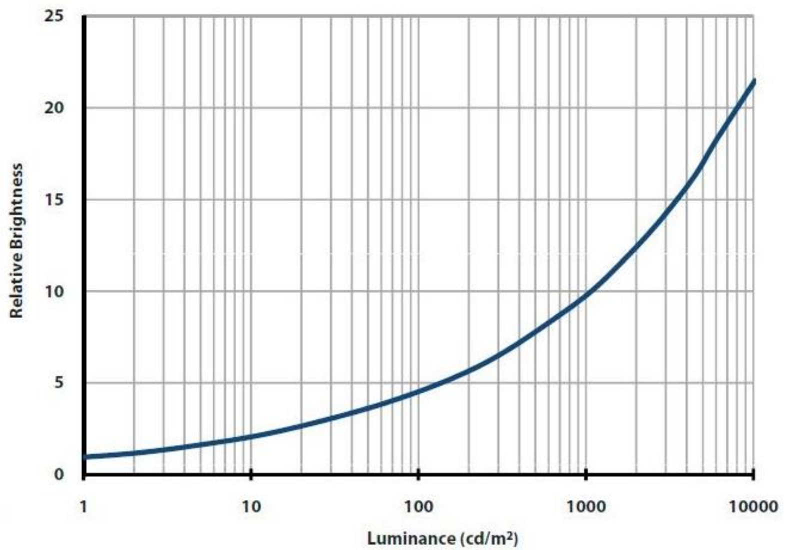

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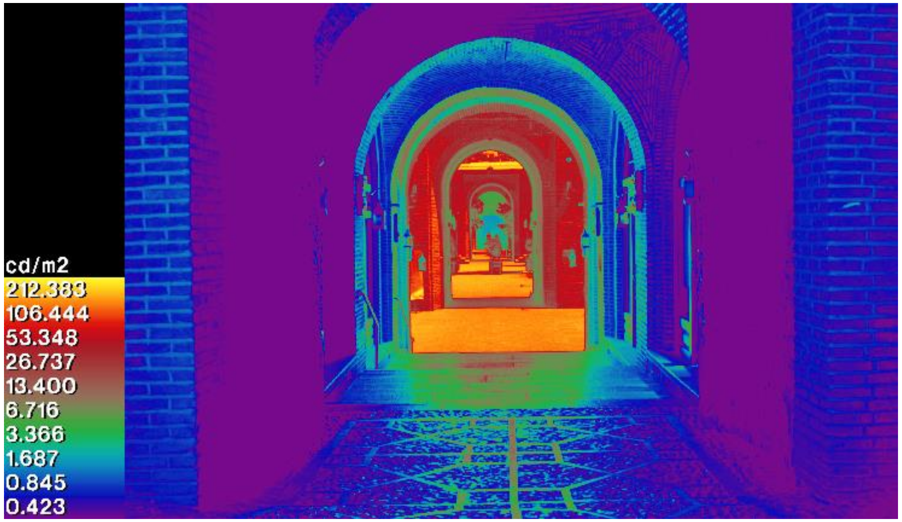

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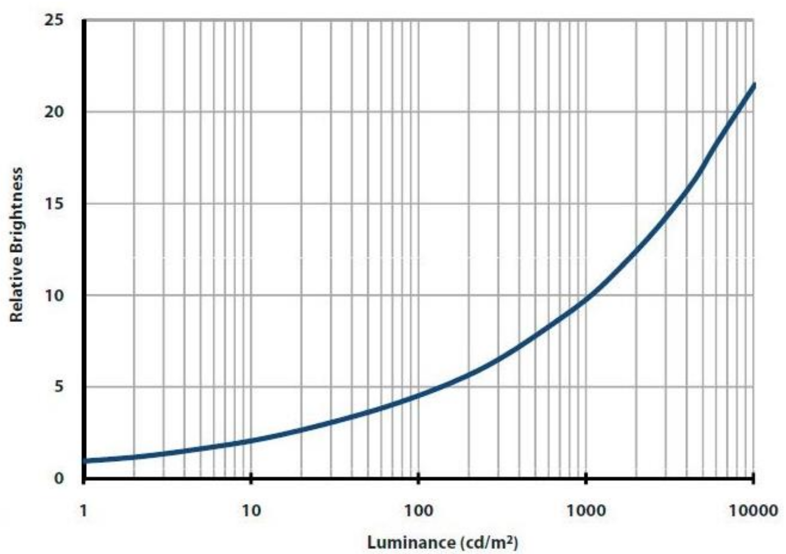

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6. (Per Pixel Data) lighting analysis

i. Single image analysis

a) Numerical analysis

b) Glare / sparkle analysis

6. (Per Pixel Data) lighting analysis

i. Single image analysis

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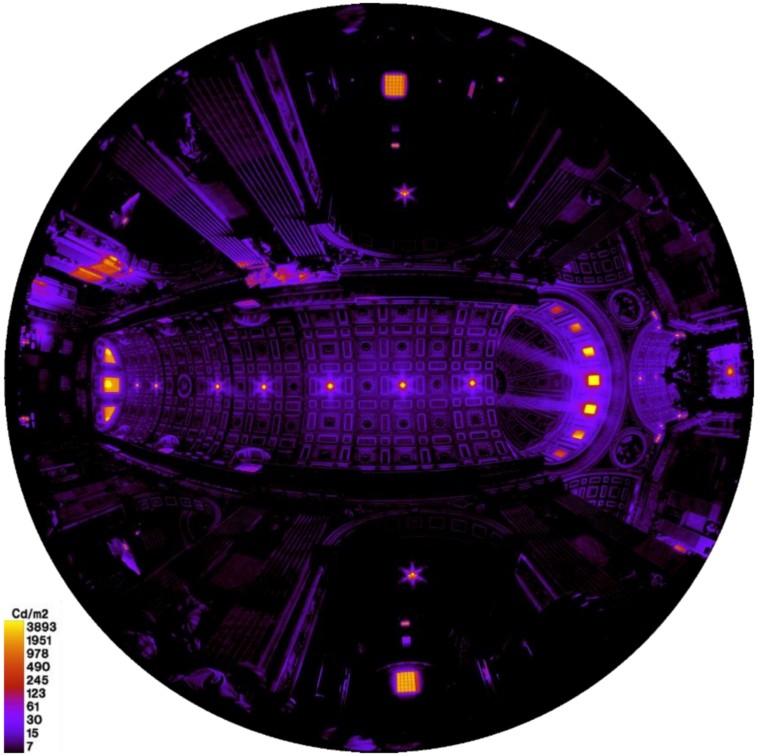
b) Glare / **sparkle** analysis

- To have a high probability of seeing **sparkle**, the **solid angle the source** subtends at the **eye** should be about **0.5 µsr** and a luminace of about **2000 cd/m2** for **exterior** lighting and **4000 cd/m2** for **interior** lighting. (Boyce PR, 2014, p. 210)



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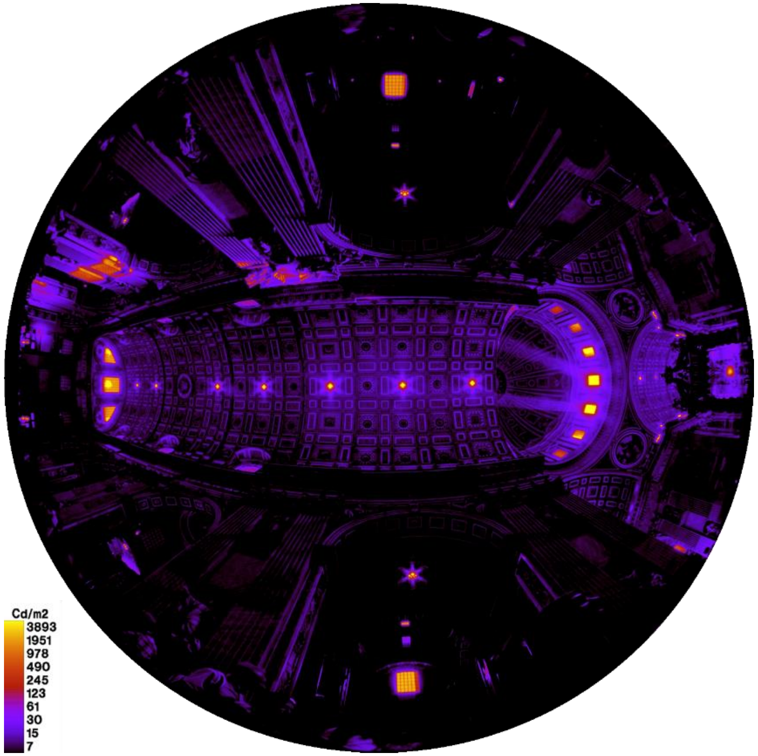
- Higher **luminance** or higher **solid angle** would increase the probability of **glare**



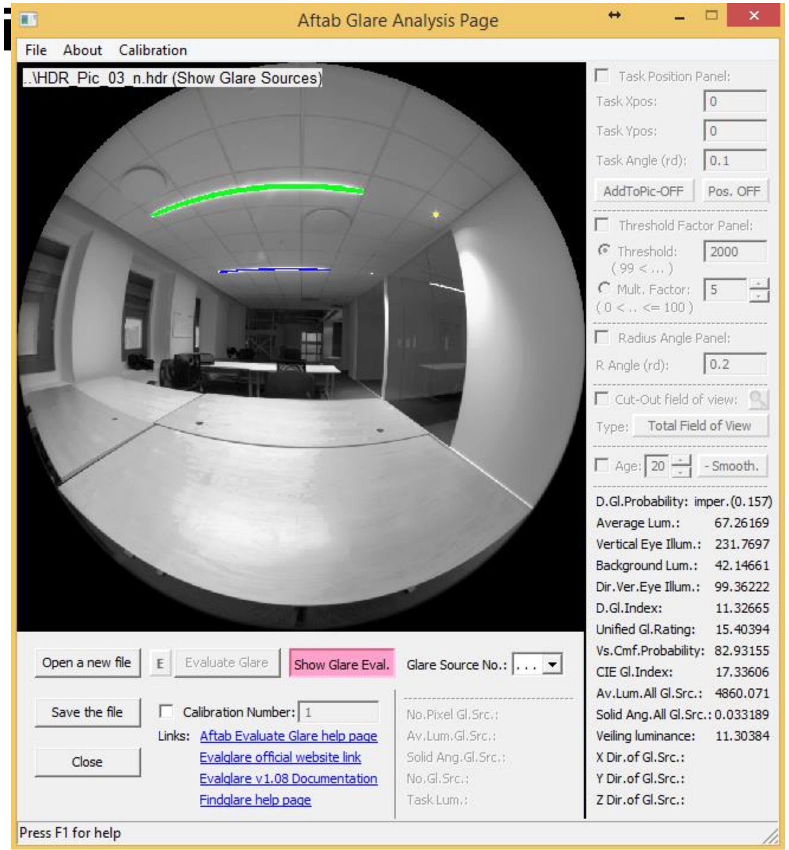
6. (Per Pixel Data) lighting analysi

i. Single image analysis

a) Numerical analysis

b) Glare / sparkle analysis

- By creating physically based HDR images with **an 180˚ fish-eye lens** or **together with measuring vertical eye illuminance at the camera point**, we can calculate some glare metrics like Unified Glare Index (**UGI**), Daylight Glare Index (**DGI**), Daylight Glare Probability (**DGP**), etc.



Measuring UGR by using the Evalglare interface page in Aftab-Alpha software.

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a) Numerical analysis

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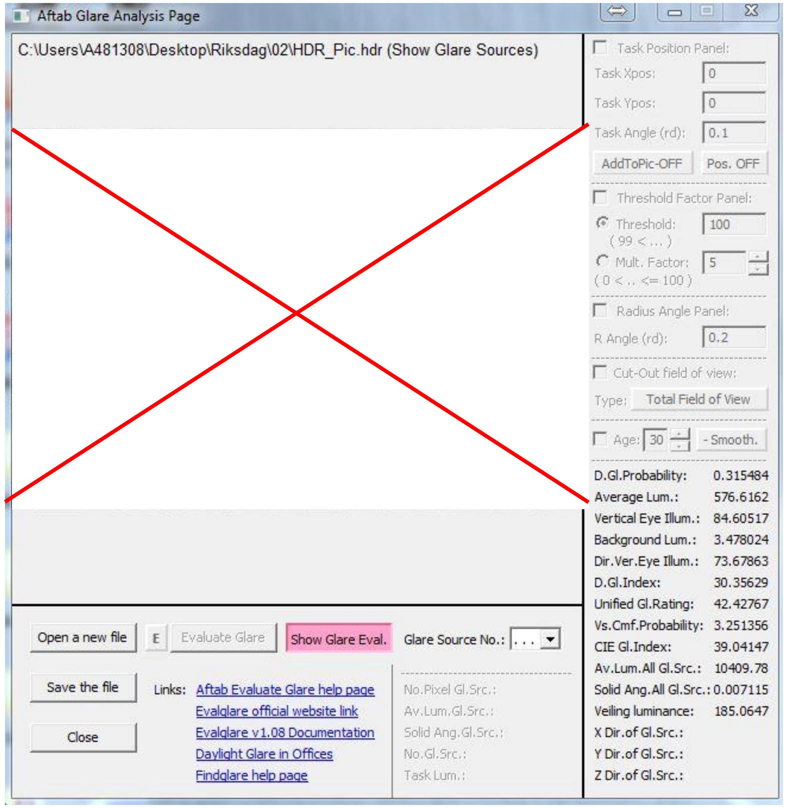


Testing different fabrics to block the sunlight and then measuring DGP from each of the HDR images to decide which fabric works well in this space.

6. (Per Pixel Data) lighting analysis

i. Single image analysis

a) Numerical analysis
b) Glare / sparkle analysis
c) Masking analysis

- It is about **filtering** the original HDR images by a **binary image** or by changing **all the pixel** with **lower** or/and **higher than a specific value** to a **certain value**.

6. (Per Pixel Data) lighting analysis

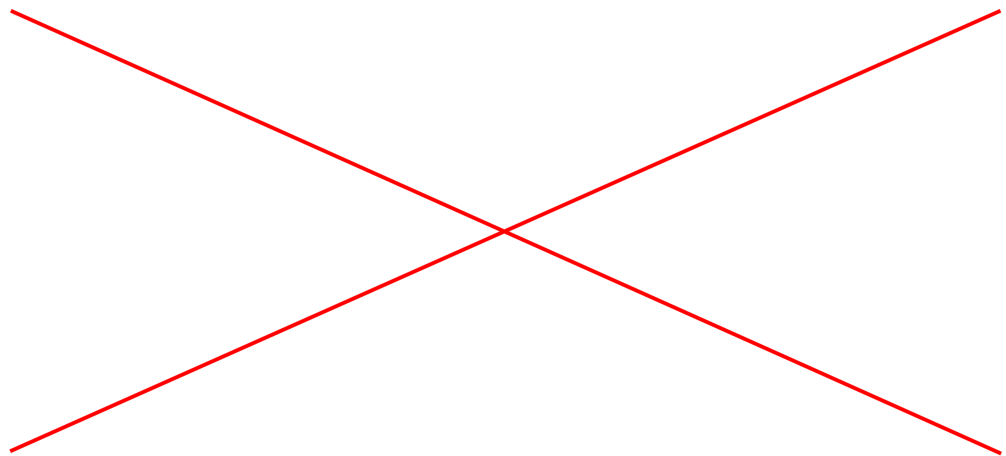
i. Single image analysis

a) Numerical analysis

b) Glare / sparkle analysis

c) Masking analysis

- It is about **filtering** the original HDR images by a **binary image** or by changing **all the pixel** with **lower** or/and **higher than a specific value** to a **certain value**.



Cropping the area of the image that is going to be analyzed.

Applications for luminance based HDR images
Majid Miri

6. (Per Pixel Data) lighting analysis

i. Single image analysis

a) Numerical analysis
b) Glare / sparkle analysis
c) Masking analysis

- It is about **filtering** the original HDR images by a **binary image** or by changing **all the pixel** with **lower** or/and **higher than a specific value** to a **certain value**.

Converting all the brightness values higher than 200 cd/m^2 to zero.

Applications for luminance based HDR images
Majid Miri

6. (Per Pixel Data) lighting analysis

i. Single image analysis

a) Numerical analysis
b) Glare / sparkle analysis
c) Masking analysis

- It is about **filtering** the original HDR images by a **binary image** or by changing **all the pixel** with **lower** or/and **higher than a specific value** to a **certain value**.

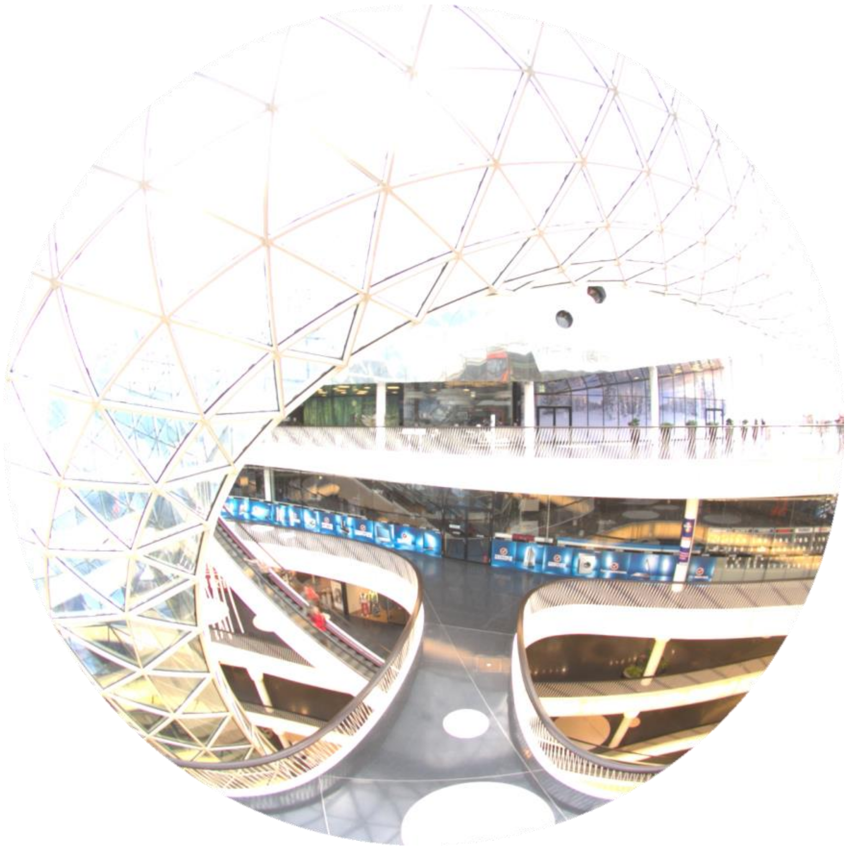
Measuring the average brightness when excluding the black points.

Applications for luminance based HDR images
Majid Miri

6. (Per Pixel Data) lighting analysis

- **i. Single image analysis**
  - a) Numerical analysis
  - b) Glare / sparkle analysis
  - c) Masking analysis
  - d) Human visual sensitivity simulation

- To approximate the **appearance** of an **HDR** image in a **LDR** image based on the **human visual sensitivity** properties, a **tone-mapping** operator can be applied.



Showing the HDR image with +1 Exposure value

Applications for luminance based HDR images
Majid Miri

6. (Per Pixel Data) lighting analysis

i. Single image analysis

a) Numerical analysis

b) Glare / sparkle analysis

c) Masking analysis

d) Human visual sensitivity simulation

- To approximate the **appearance** of an **HDR** image in a **LDR** image based on the **human visual sensitivity** properties, a **tone-mapping** operator can be applied.

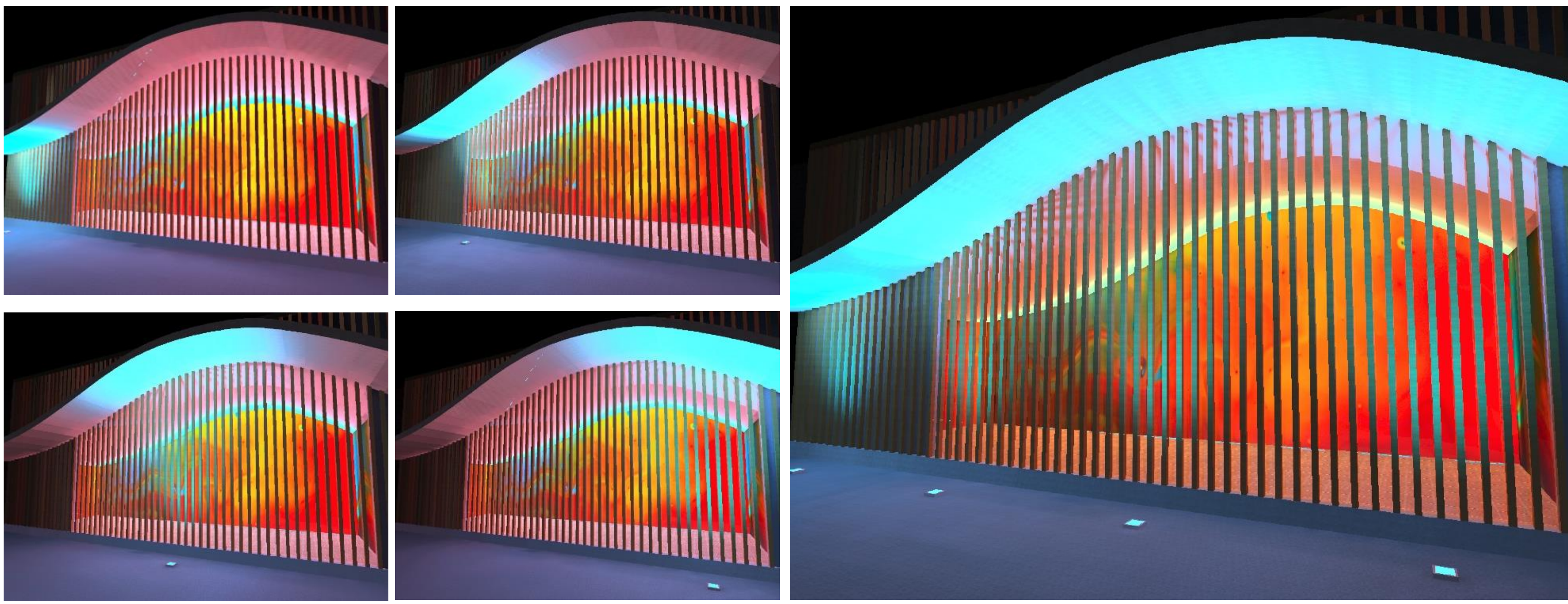
Tone-mapping the image by Human-vision-response algorithm in Radiance

6. (Per Pixel Data) lighting analysis

i. Single image analysis

ii. Multiple image analysis

a) Image subtraction, addition, and multiplication

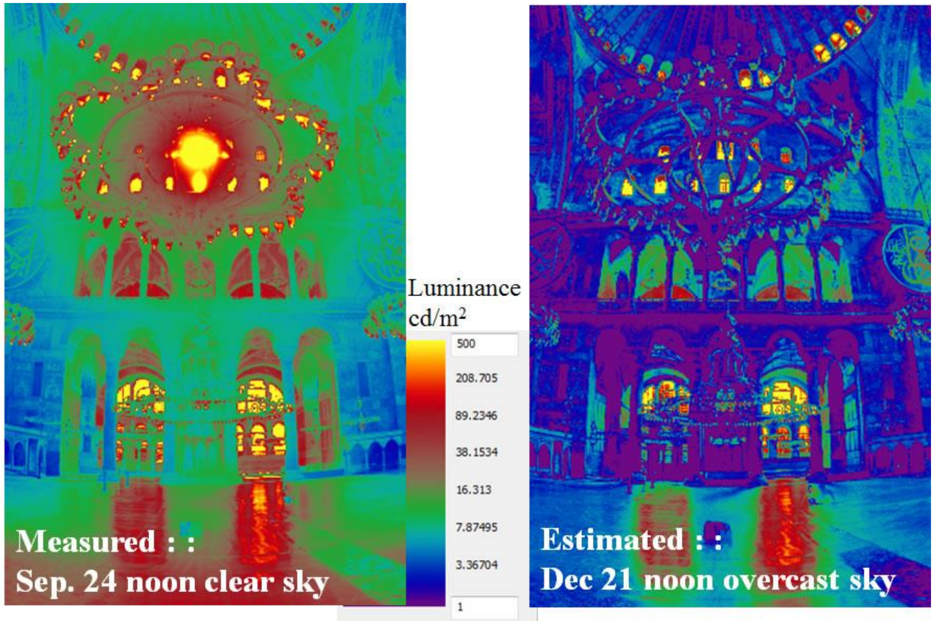


Applying the HDR image technique during a test lighting. We had just one in-ground uplight and wanted to see what would happen if we used two of them to light the trees.

6. (Per Pixel Data) lighting analysis

i. Single image analysis
ii. Multiple image analysis
iii. HDR image based daylight coefficient

- This technique allows us to establish **a statistics based daylight coefficient model** for an existing space by capturing photos of both **interior** and unobstructed **sun and sky dome** simultaneously in a limited period of time. Its main **advantage** is that it **neglects** the **need for a 3D model** of the space and **materials characteristics** of each object in the model for the studied scene. (Inanici M, 2013)

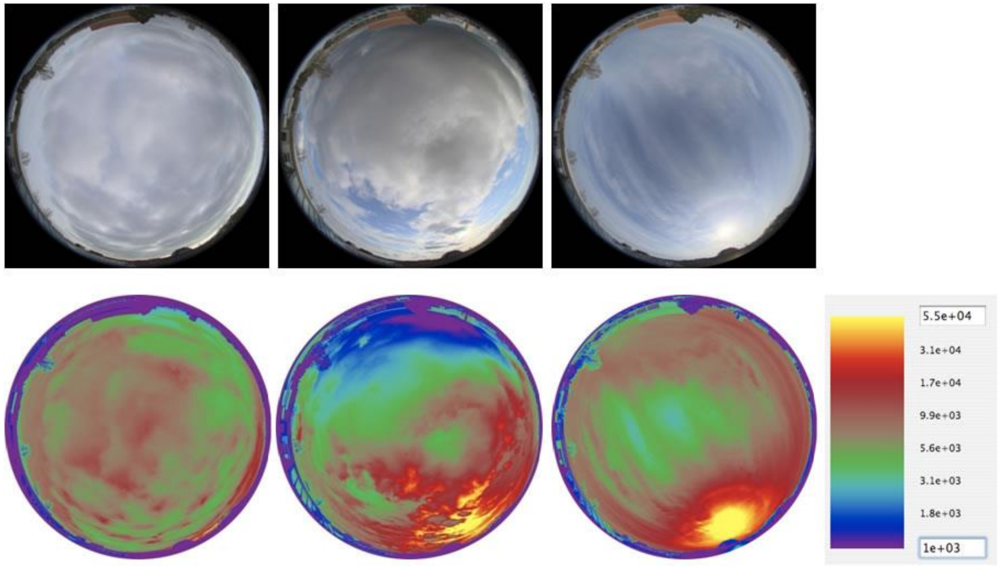


Source: http://faculty.washington.edu/inanici/MI-RESEARCH.html

6. (Per Pixel Data) lighting analysis

i. Single image analysis
ii. Multiple image analysis
iii. HDR image based daylight coefficient
iv. **HDR image based rendering** (image based sky models for daylighting applications)

- This technique allows us to use an **180˚ fish-eye HDR** image as **sky model** in light/daylight simulation software for an **un-built project**. One of its main **advantages** is that it contains all the **surrounding obstructions** with **realistic materials**. However, its **disadvantage** is that it is **time dependent** and only valid to the time that the image was taken. (Inanici M, 2013)



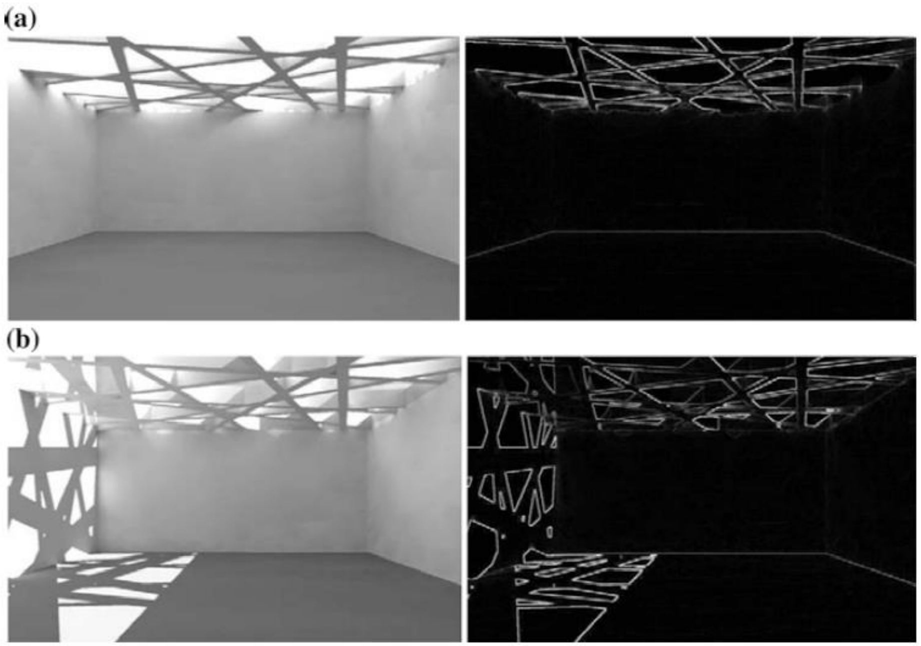
Source: http://faculty.washington.edu/inanici/MI-RESEARCH.html

6. (Per Pixel Data) lighting analysis

i. Single image analysis
ii. Multiple image analysis
iii. HDR image based daylight coefficient
iv. HDR image based rendering

v. Spatial contrast

- Unlike more traditional methods of contrast analysis that rely on brightness ratios and/or standard deviation, **spatial contrast** proposes a compositionally dependent method for **quantifying local variations in brightness** within architectural space, which are **perceptually dependent on their local surroundings** (Andersen M, Rockcastle S, 2013)



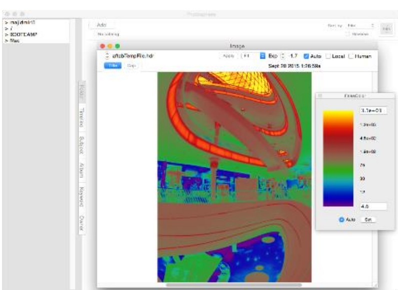
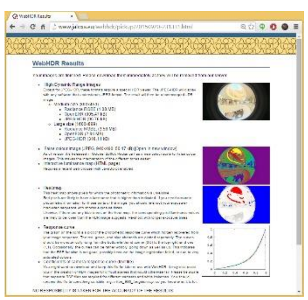
a Rendering on 28 November showing a spatial contrast = 0.83 and
b rendering on 30 May showing a spatial contrast = 0.97

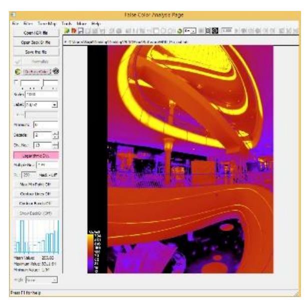
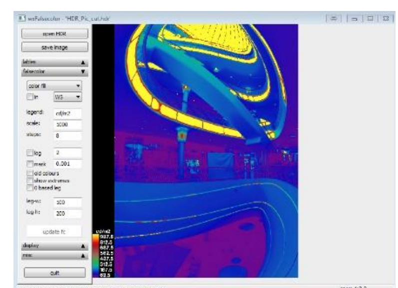
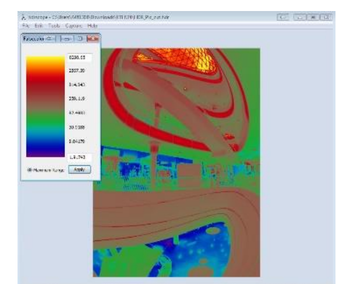
7. Available HDR assembly and analysis tools

	HDR Assembly	HDR Analysis	Operating System	Internet Address
Photosphere	√	√	Mac OS X	http://www.anyhere.com/
WebHDR	√	X	via Internet	http://www.jaloxa.eu/webhdr/
Aftab	√	√	MS Windows/IOS	http://aftabsoft.net/
Wxfalsecolor	X	√	MS Windows	http://tbleicher.github.io/wxfalsecolor/
HDRscope	X	√	MS Windows	http://courses.washington.edu/hdrscope/

[1] It uses Photosphere as its assembly engine.
[2] As the Iphone App is newly developed by the author, at the time of writing this paper it cannot compete other computer software regarding stability and accuracy.

Photosphere WebHDR AFTAB wxfalsecolor hdrscope

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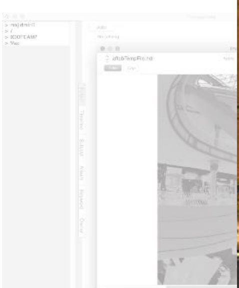
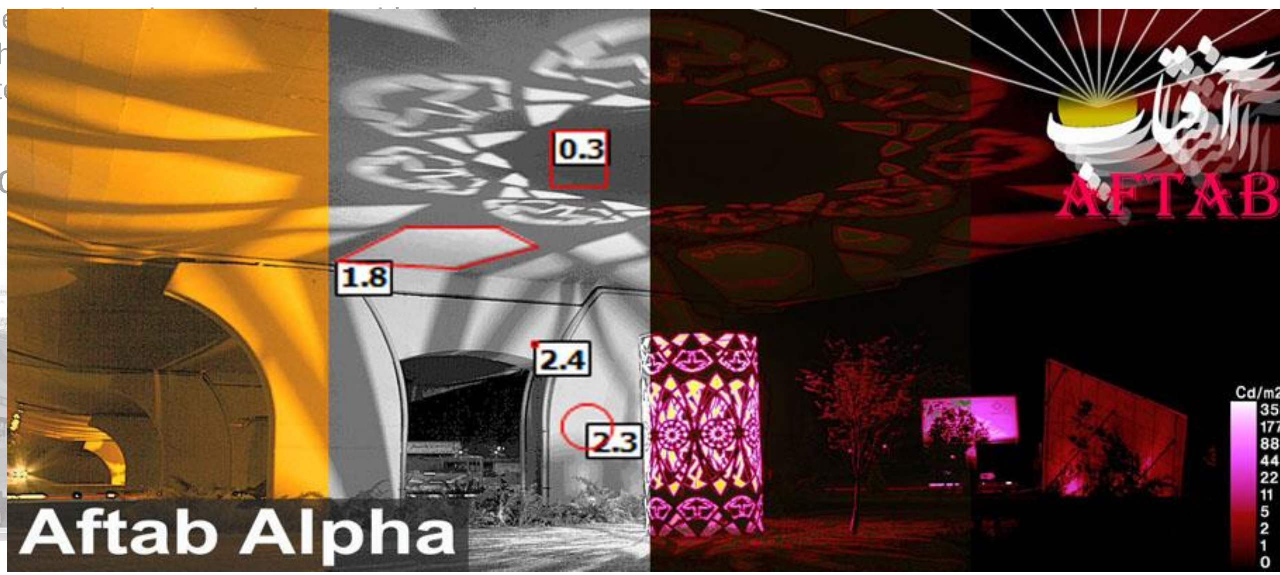
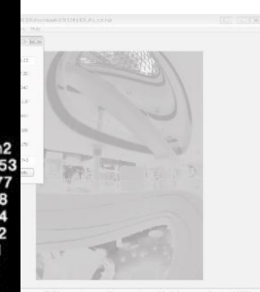
WebHDR	√	X	via Internet	http://www.jaloxa.eu/webhdr/
Aftab	√	√	MS Windows/IOS	http://aftabsoft.net/
Wxfalsecolor	X	√	MS Windows	http://tbleicher.github.io/wxfalsecolor/
HDRscope	X	√	MS Windows	http://courses.washington.edu/hdrscope/

[1] It use
[2] As th ... other
compute

Pho ... drscope







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Wxfalsecolor	X	√	MS Windows	http://tbleicher.gith
HDRscope	X	√	MS Windows	http://courses.wash

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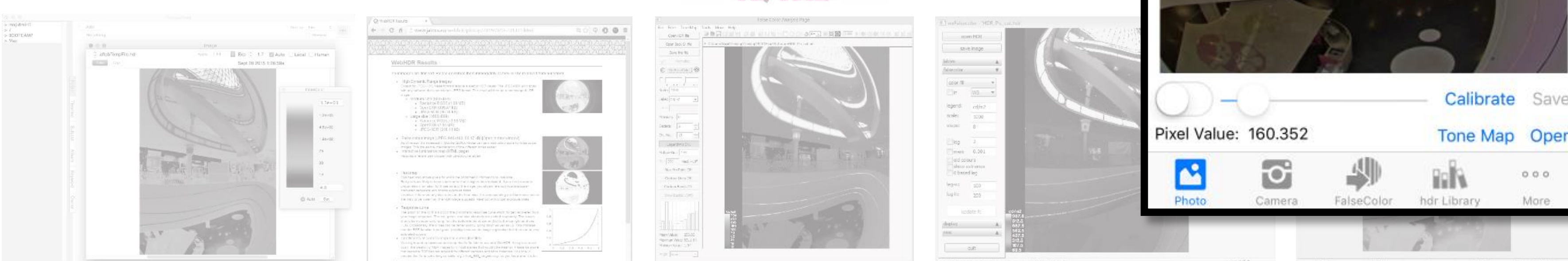
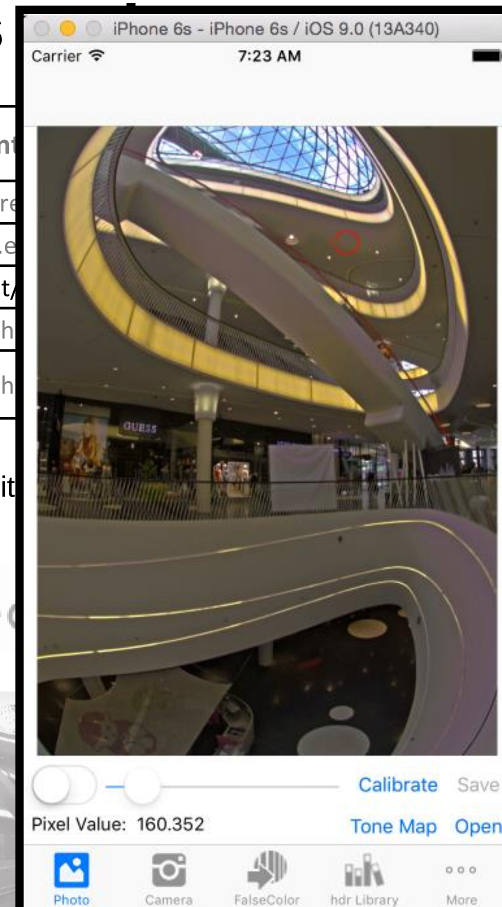
Photosphere WebHDR AFTAB wxfalsec





Download **Aftab Luminance (student version)** from App Store

8. Rules and recommendations

- Measuring the minimum acceptable and preferable background luminance (surrounding walls and ceilings) for the offices (30 cd/m2 for the former and between 60 cd/m2 and 100 cd/m2 for the latter *)
- Measuring the following luminance ratios for offices*:
  - Between a paper task and an adjacent Visual Display Terminal (VDT) screen: 3:1 or 1:3.
  - Between a task and immediately adjacent surroundings: 3:1 or 1:3.
  - Between a task and remote (non-adjacent) surfaces: 10:1 or 1:10.
- Measuring the access zone luminance (L20) **
- Measuring obtrusive light permitted for exterior lighting installation ***
- Measuring average road luminance and longitudinal uniformity of road surface luminance ****

* Recommended Practice for Office Lighting, Illuminating Engineering Society of North America, 2012
** The guide for the lighting of road tunnels and underpasses CIE 88:2004
*** The European standard of EN-12464-2 or CIE 150:2003
**** The road lighting European standard of EN-13201

9. HDR Images in the lighting design process

A. **Define Views**

(B_1. **Interior or Exterior** B_2. **Day time vs. Night time**) → B_3. **Which Type of (Per-pixel) Lighting Analysis**

C. **New Construction or Refurbishment**
(If it is new construction, go to step H.)

D. **Tools ->** Photosphere, ,webHDR, Aftab

E. **Finding Problems / Obstacles**

E_1. **Function**
Obtrusive Light or Glare

E_2. **Environment**
Light Pollution

E_3. **Aesthetics**
Unwanted light on the surfaces

F. **Find the source of problem**

G_1. **Change the fixture to solve problems**

G_2. **The problems cannot be fixed**
Inform the client / keep in mind as a future threat

H. **New Design**

I. **Prepare the 3d model of the space in the lighting analysis software**

J. **Specify the right materials for each surface**

K. **Import the relevant photometric files of future and/or existing light fixtures**

L. **Evaluate different design variants**

M_1. **Function**
Based of existing regulations
Luminance / Illuminance
Usually no need for any HDR images

M_2. **Environment**
Based on environmental certification systems
Luminance / Illuminance

M_3. **Aesthetics**
Luminance
Convert Luminance to brightness
M_{3a}. **Real test lighting for complex spaces**

N. **Final evaluation of design**

10.Conclusion

- Since **brightness** and **luminance** correspond **with each other** and, as we know, **what we see** is more **relevant to brightness** rather than **LUX** level, performing luminance-based light analysis can be much more helpful in order to **understand the lighting conditions** of the space in question.

10.Conclusion

- Since **brightness** and **luminance** correspond **with each other** and, as we know, **what we see** is more **relevant to brightness** rather than **LUX** level, performing luminance-based light analysis can be much more helpful in order to **understand the lighting conditions** of the space in question.
- Considering **recently developed physically based lighting calculation tools** and **HDR assembly software**, and their ability to analyze *visibility*, *appearance* and *visual comfort* of any space, **lighting designers**, **researchers**, **manufactures**, **codes and standard organizations**, etc. can apply luminance based metrics much more than ever before.

10.Conclusion

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- Considering **recently developed physically based lighting calculation tools** and **HDR assembly software**, and their ability to analyze *visibility*, *appearance* and *visual comfort* of any space, **lighting designers**, **researchers**, **manufactures**, **codes and standard organizations**, etc. can apply luminance based metrics much more than ever before.
- Using **realistic luminance based HDR assembly mobile apps**, measuring and understanding the luminance values will be made much easier. Eventually it can also help lighting designers **learn** more about the topic in their everyday field work, and use such experiences to improve their future design solutions.


Cd/m2
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533
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134
67
33
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8
4
Thank you