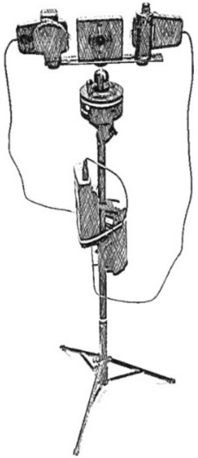
FALL 2018 INNOVATION INCUBATOR PROJECT

LENS TO CAPTURE DISCOMFORT GLARE



CHENEY CHEN & KAI CHANG

*We cannot eliminate glare in buildings but live together with it **wisely**.*

- Cheney Chen

RESEARCH BACKGROUND

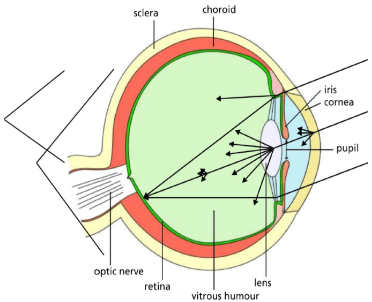
BACKGROUND

What is glare

Glare is a subjective human sensation that describes ‘light within the field of vision that is brighter than the brightness to which the eyes are adapted’ (HarperCollins 2002).

Glare is caused by a significant ratio of luminance between the task (that which is being looked at) and the task glare source.

Disability glare
Discomfort glare
- imperceptible
- perceptible
- disturbing
- intolerable

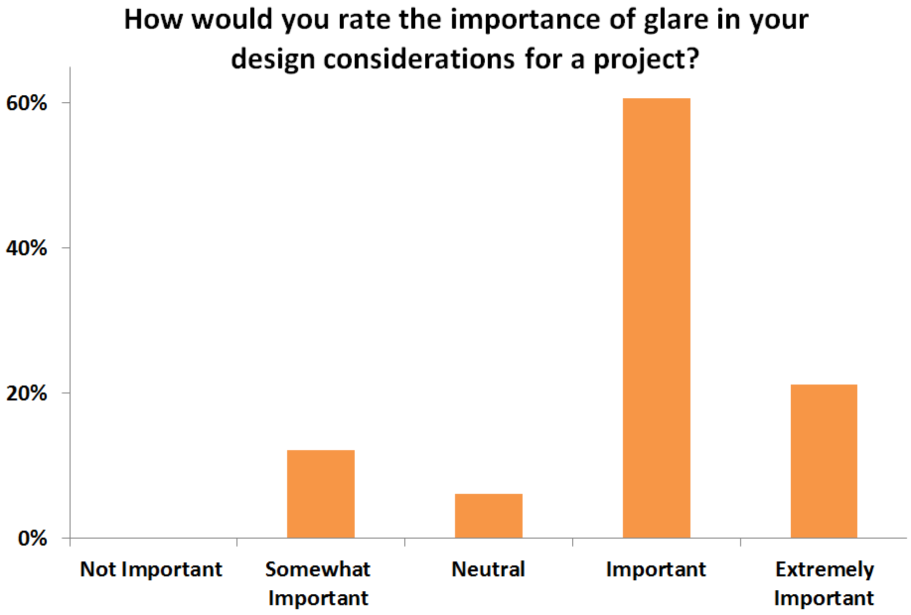


L.E.N.S.

BACKGROUND

Does it matter

Glare can cause annoyance and discomfort, and can actually decrease a person's ability to see. From building design perspective, architects tend to minimize glare in their designs. In a 2011 survey of 135 architects, lighting designers and consultants over 80% of participants voted glare to be either an important or extremely important design consideration.

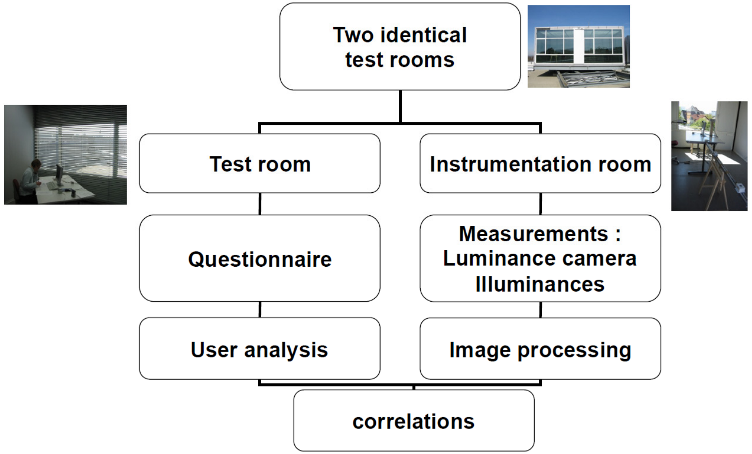


Survey of 135 architects, lighting designers and consultants, source from http://web.mit.edu/tito_/www/Projects/Glare/GlareRecommendationsForPractice1.html

BACKGROUND

How to detect glare

In order to predict or measure the appearance of glare due to daylight, survey, filed measurements and computer simulations are all the possible approaches. Among some glare metrics, Daylight glare probability (DGP) is widely adopted to measure glare. Such image-based metric is based on the vertical eye illuminance as well as on the glare source luminance, its solid angle and a position index.



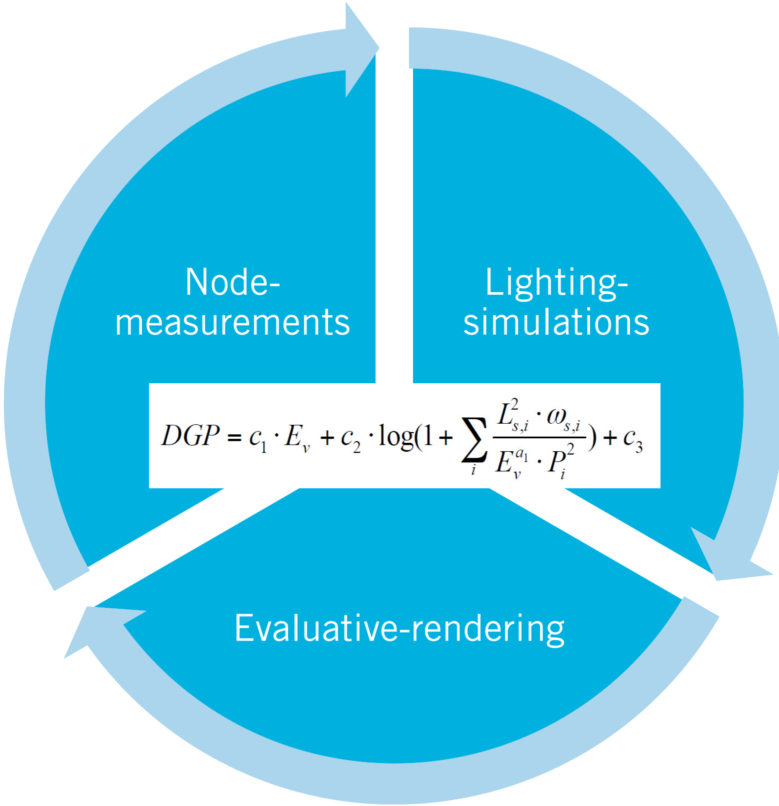
$$DGP = c_1 \cdot E_v + c_2 \cdot \log\left(1 + \sum_i \frac{L_{s,i}^2 \cdot \omega_{s,i}}{E_v^{a_1} \cdot P_i^2}\right) + c_3$$

E_v:	vertical Eye illuminance [lux]	$c_1 = 5.87 \cdot 10^{-5}$
L_s:	Luminance of source [cd/m²]	$c_2 = 9.18 \cdot 10^{-2}$
ω_s:	solid angle of source [-]	$c_3 = 0.16$
P:	Position index [-]	$a_1 = 1.87$

BACKGROUND

Why DGP

The hypothesis of this research is that Daylight Glare Probability (DGP) metric is applicable to high dynamic range (HDR) photographs of daylit scenes, daylight simulations and renderings generated using a rendering software such as 3DS Max. The research objective is therefore to link all the daylight related measures together and eventually generate a systemic workflow to evaluate/predict glare in an architectural design.



$$DGP = c_1 \cdot E_v + c_2 \cdot \log(1 + \sum_i \frac{L_{s,i}^2 \cdot \omega_{s,i}}{E_v^{a_1} \cdot P_i^2}) + c_3$$

BACKGROUND
What is LENS

Lighting-simulations
Evaluative-rendering
Node-measurements
Systematic-workflow

RESEARCH METHODOLOGY

METHODOLOGY

Hardware (instruments)

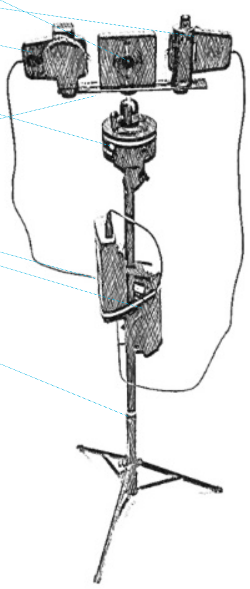
The glare tracer consists of two light meters (REED SD-1128), one bluetooth rotating stand (Brinno ART2000), and one 360 camera (Xiaomi Mijia). They are all mounted together with a dual mount bracket on a compact tripod to capture the potential glare and produce multi angular HDR photography. The operation of the rotating stand and the 360 camera is through mobile phone apps. Light levels are measured and stored simultaneously in data loggers and they are downloadable as text files for analysis.

REED SD-1128 SD Series Light Meter with Datalogger x2

Brinno Pan lapse ART2000

Xiaomi MiJia 360 Sphere Camera

Dual mount bracket and tripod



METHODOLOGY

Software

Modeling & Rendering tools

Rvit/Rhino/3D studio Max

HDR generation tools

Aurora HDR 2018/Photoshop CC/hdrscope

Glare analysis tools

Grasshopper/hdrscope

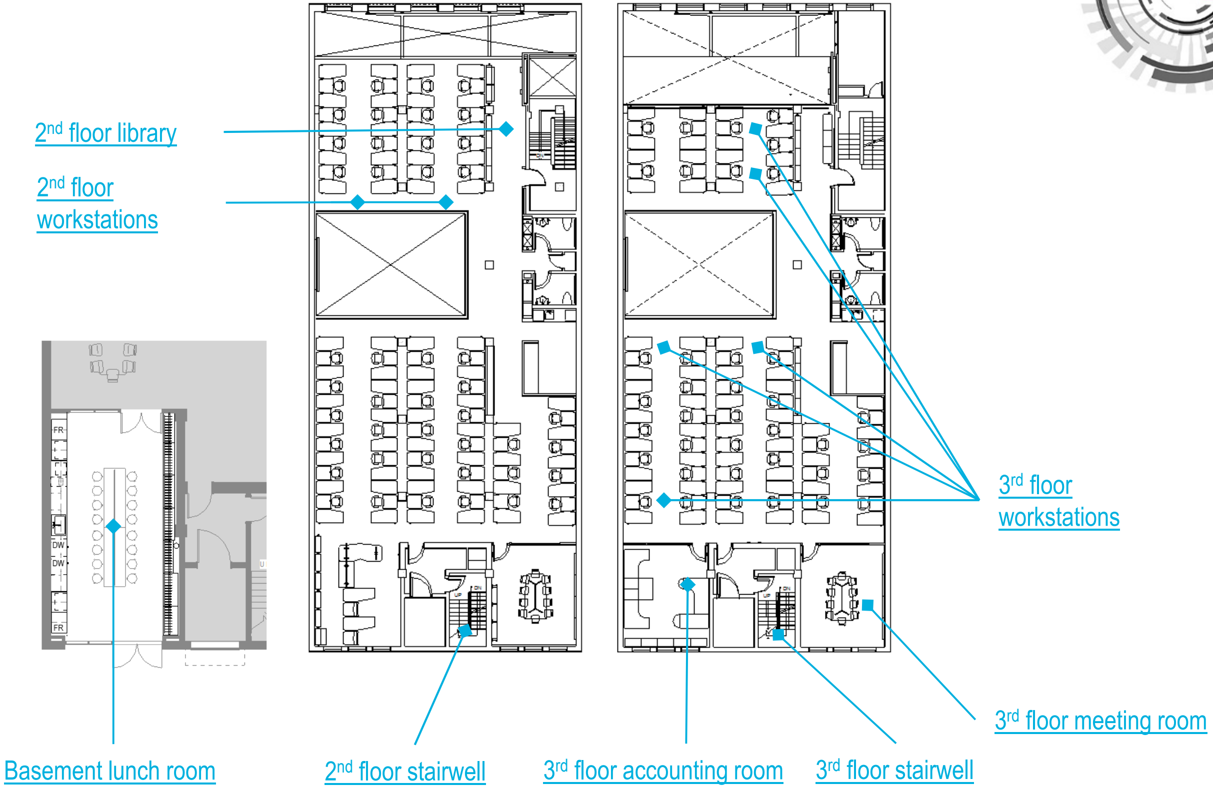
Panorama stitching/viewing tools

Hugin/GoPro VR player

METHODOLOGY

Measurements

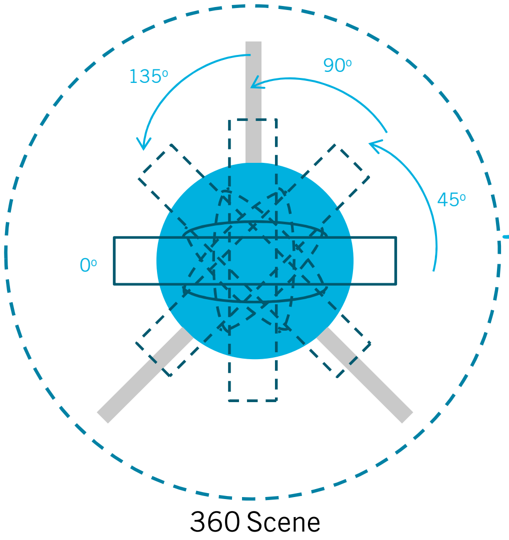
The office glare measurements were carried out on some clear days over a period of three months (January to March 2019) in Vancouver. Many locations were measured, usually at the higher floors (due to the high exposure to the glare) and around the office atrium area (due to the skylight). The lunch room at the basement is well protected by a overhang and the measurement over there is for reference only.

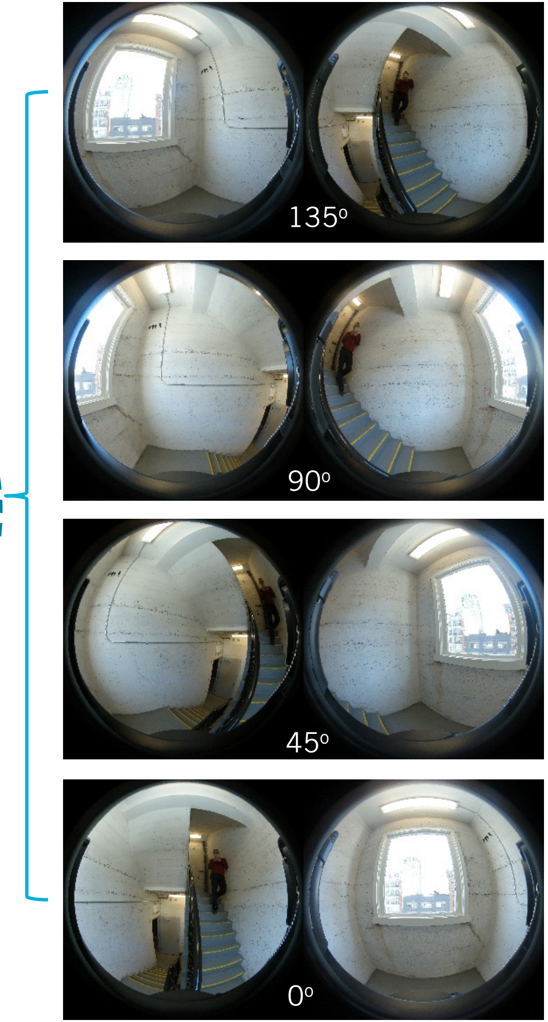


METHODOLOGY

360 photography

Although the camera can capture the 360 scene without any rotation, three rotations (45, 90 and 135) are still conducted in order to produce potential overlap of stitching and verification of a single 360 degree image. Meanwhile, multi angle measurements provide an opportunity to investigate the relationship between the glare source and furniture layout orientations.

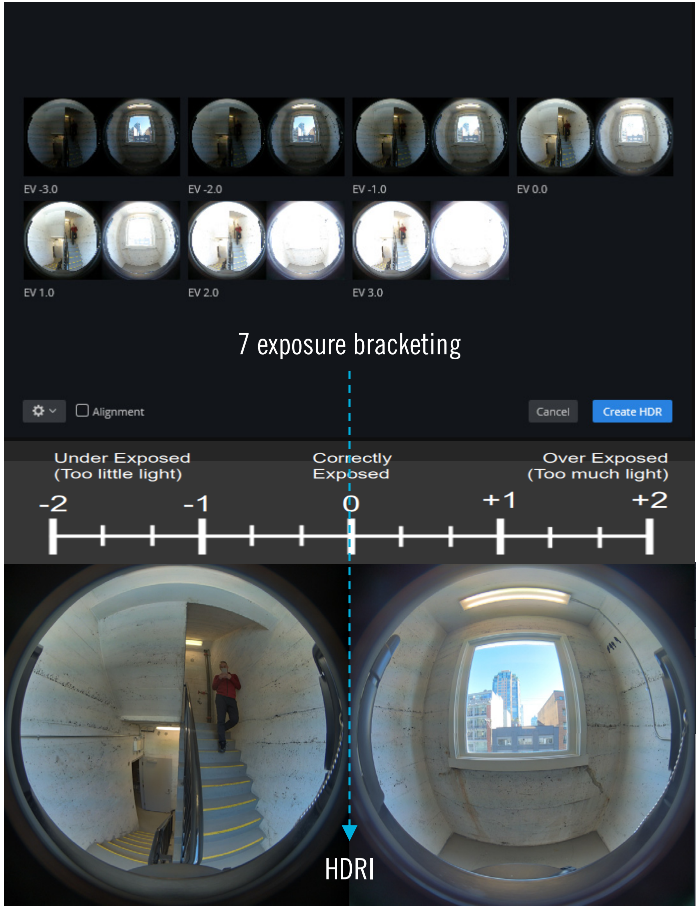




METHODOLOGY

High Dynamic Range Image (HDRI)

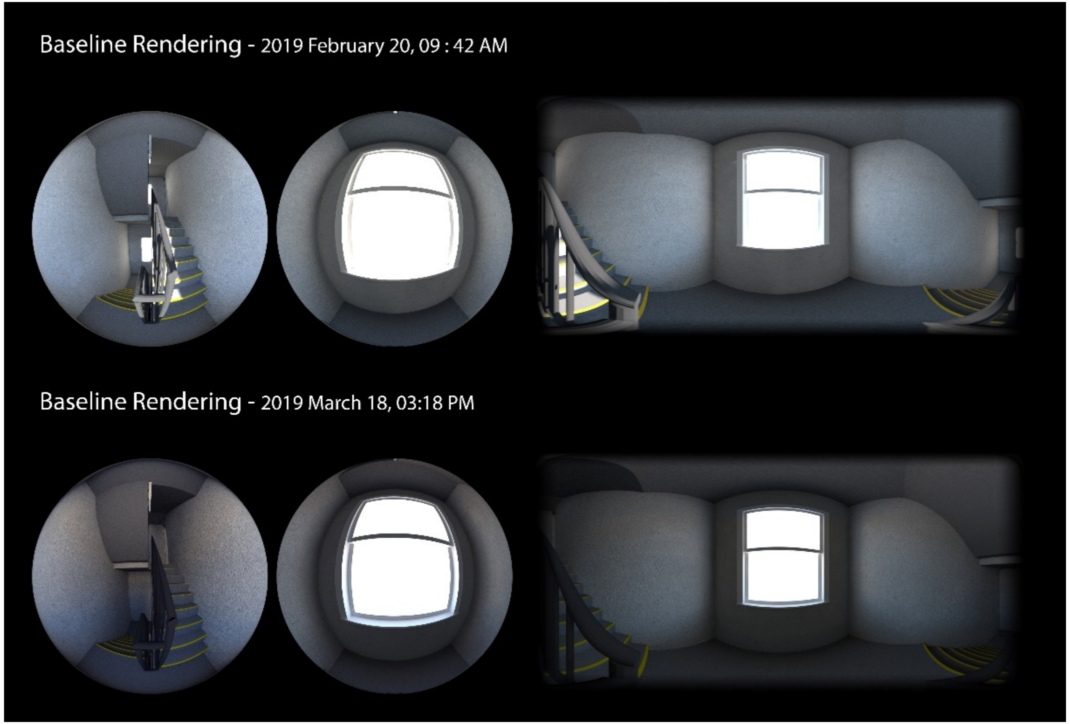
High Dynamic Range Image (HDRI) attempts to represent the full dynamic range of a light scene, from direct sunlight to deep shadow. It is a method to digitally capture and edit all luminance (light) in a single scene. The Per-pixel values of HDR images can represent the luminance level of the scene and most importantly, they can be used to perform both quantitative and qualitative lighting analysis. In this research, seven exposures (from under to over exposures - 3.0, -2.0, -1.0, 0.0, 1.0, 2.0, 3.0) photos are used to produce a single HDRI (although three exposures bracketing was also tested in a pilot study).



METHODOLOGY

3D rendering – baseline approach

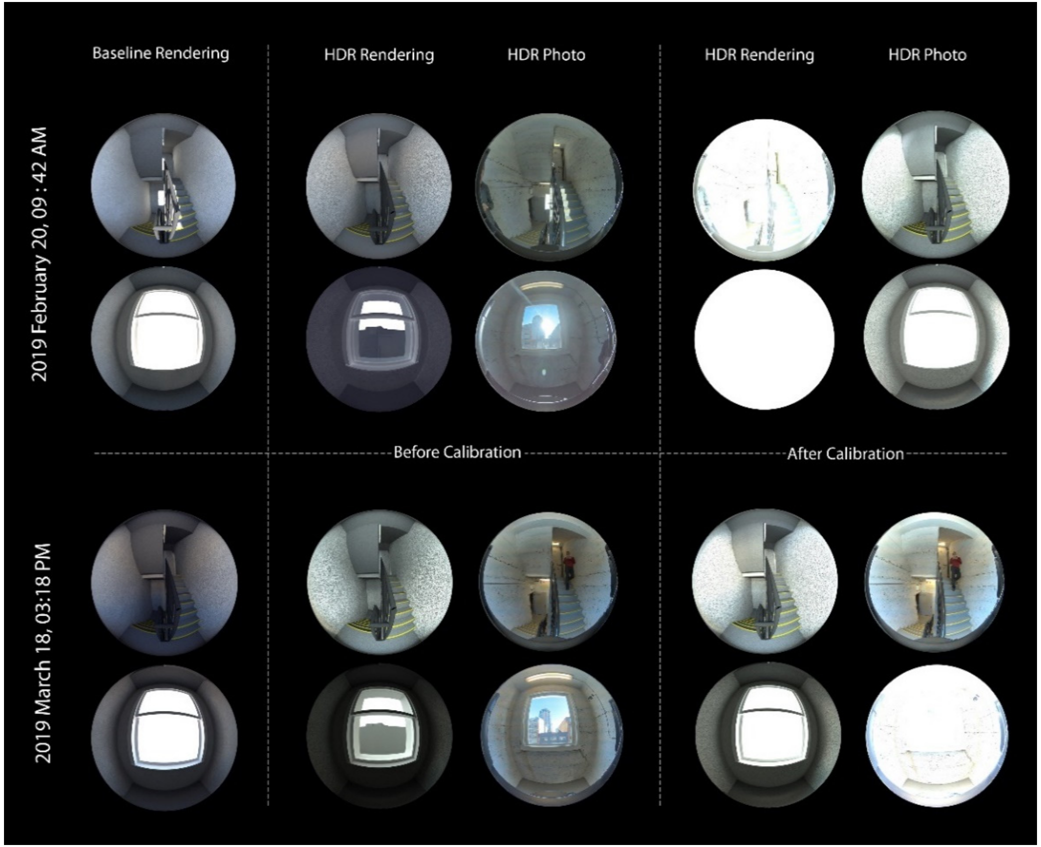
3D rendering is tend to use image synthesis process to simulate the real world environment. There are two rendering approaches engaged in this research. The baseline rendering approach simply uses 3DS Max default sun/light system and respects the sun location through matching photograph date and time.



METHODOLOGY

3D rendering – HDRI based approach

As opposed to the Baseline rendering approach, HDRI based rendering approach drops the default light/sun system in 3DS Max but use HDRI, both with and without calibration, to render the light scenes.

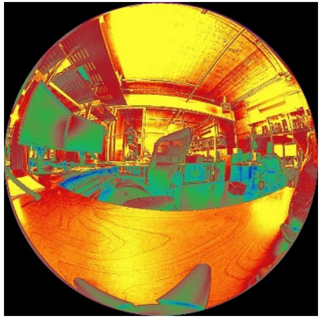


METHODOLOGY

Panorama stitching

Photo stitching is the process of combining multiple images with overlapping fields of view to produce a panorama. The idea has been applied to all the potential image sources produced in the research, including photos, false color images and renderings. It is a pilot test to investigate the potential use of a 360 degree scene for evaluating glare issues in a quick yet holistic manner.

+



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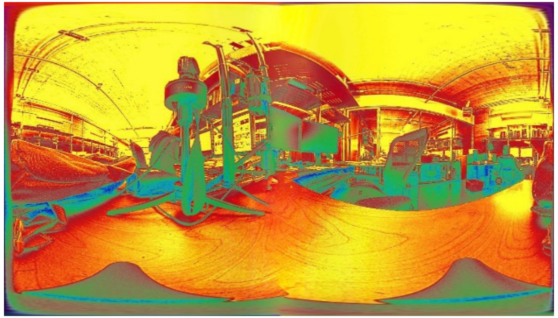


METHODOLOGY

Measurement workflow

Workflow 1 consists of HDR capture, post processing, calibration, glare analysis as well as panorama stitching and viewing. It is an independent approach to evaluate the potential glare for a given light scene provided measurement is conductible.

Workflow 1

Aurora HDR 2018

Adobe Photoshop CC

hdrscope

grasshopper

GoPro VR Player 3.0

MiJia 360
- JPEG image
- Seven exposure bracketing

Aurora HDR
- HDR image generation

Photoshop
- Refined HDR image
- Image mask

Hdrscope
- Calibrated HDR image

Grasshopper
- High-reso falsecolor image
- Glare metrics

Hujin
- 360° enfused panorama

Gopro VR
- 360° view and evaluation

METHODOLOGY

Simulation workflow

Workflow 2 consists of 3D modeling, glare analysis and/or panorama stitching. It is an independent approach to validate other workflows.

Workflow 2

Rhinoceros NURBS modeling for Windows

grasshopper

Revit

- Revit design model

Rhino

- Rhino 3D model

Grasshopper

- High-reso falsecolor image
- Glare metrics

METHODOLOGY

Rendering workflow

Workflow 3 consists of 3D rendering, calibration and HDR scene generation. It is an dependent approach to extend the capability of visualization for a designed light scene.

Workflow 3

Revit
- Revit design model

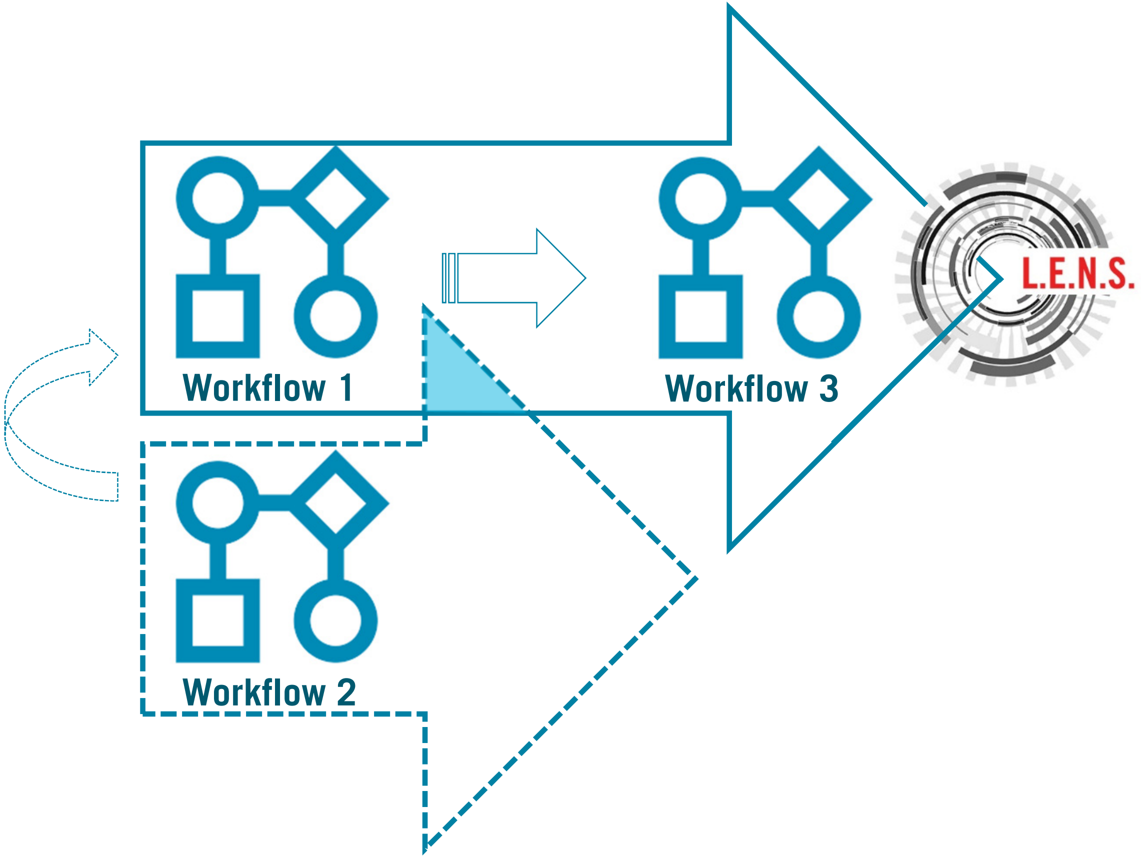
3DS Max
- 3D rendering
- HDR production

Hdrscope
- Calibration
- Glare metrics

METHODOLOGY

Overall workflow

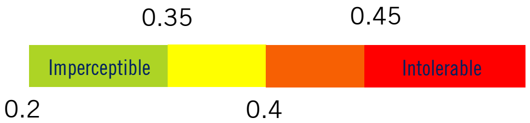
Three workflows are developed individually in the research. Eventually they form a complete L.E.N.S. to systematically evaluate potential glare issues in an architecture design.

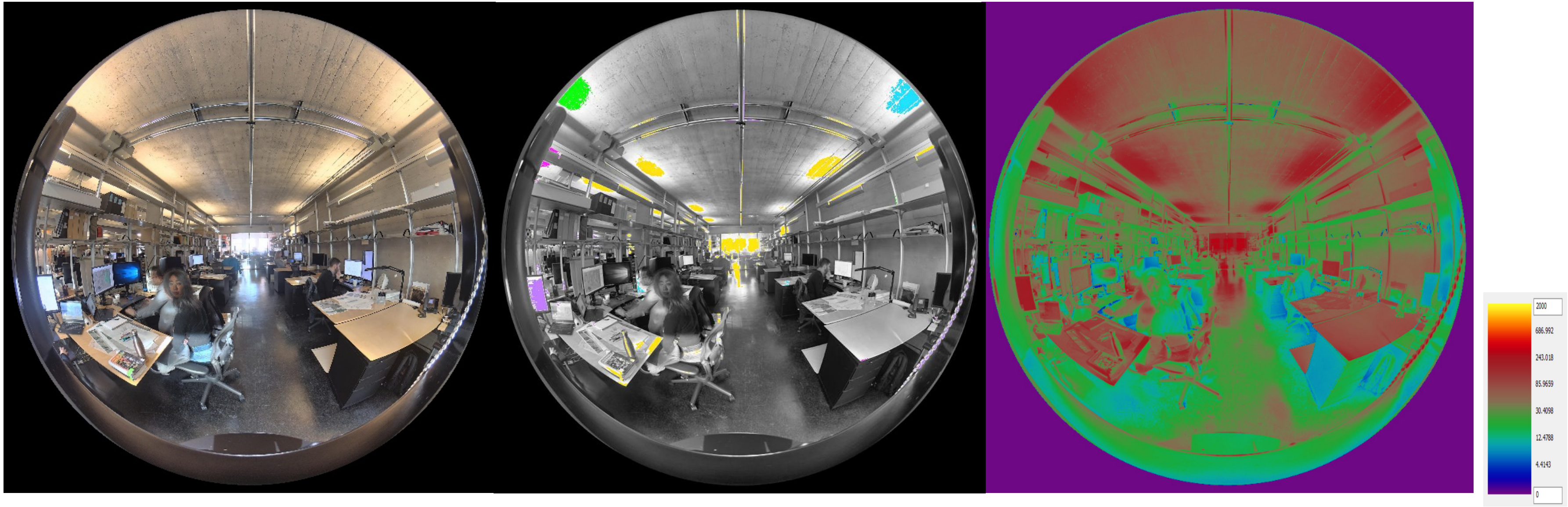


FIELD MEASUREMENTS

MEASUREMENTS

Different types of glare in the office



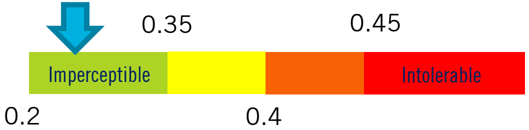


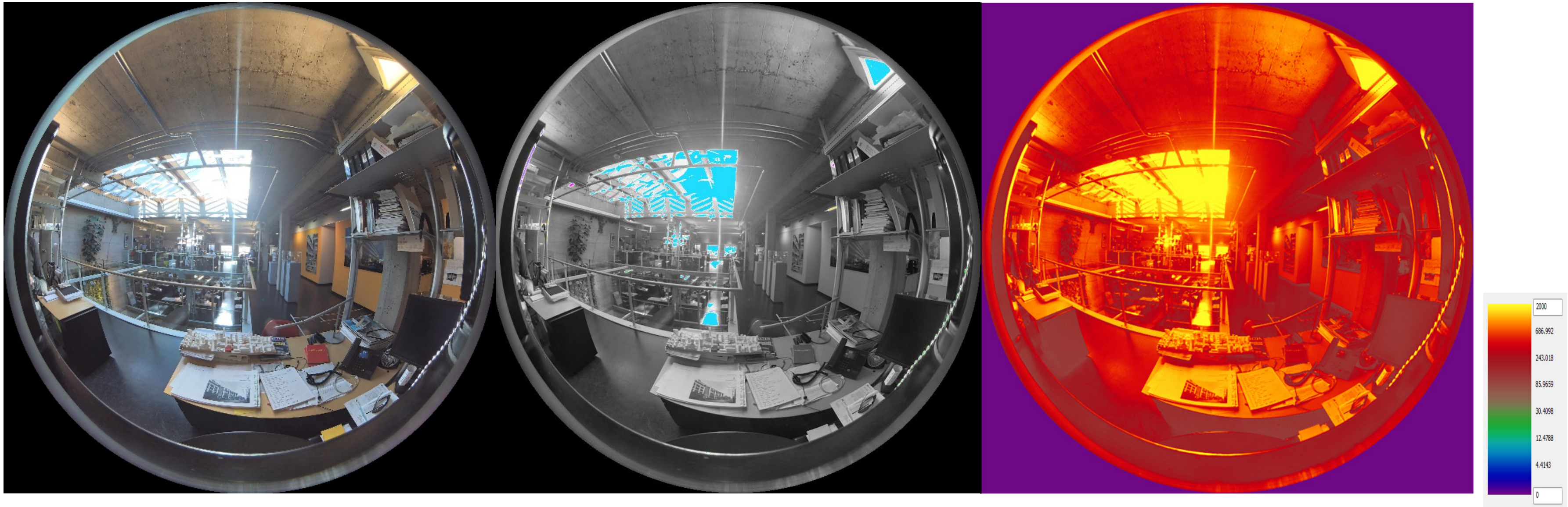
Third floor workstations
DGP=0.05; Measured lux = 137

Low brightness scene. dgp below 0.2! dgp might underestimate glare sources

MEASUREMENTS

Different types of glare in the office





Workstation next to the skylight with diffused/reflected sunlight
DGP=0.264; Measured lux = 1657

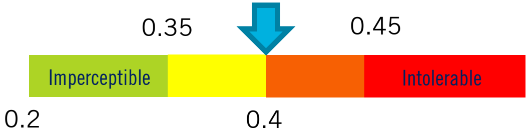
MEASUREMENTS

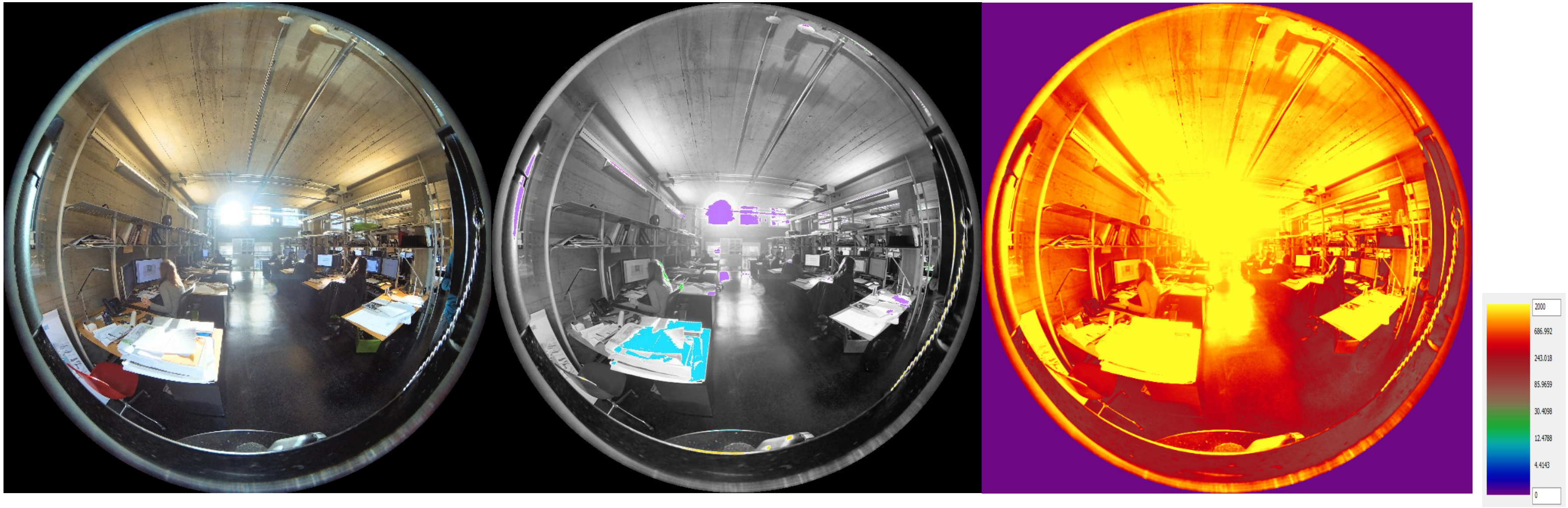
Different types of glare in the office

Workstation next to the skylight with direct sunlight
DGP=0.375; Measured lux = 3700

MEASUREMENTS

Different types of glare in the office

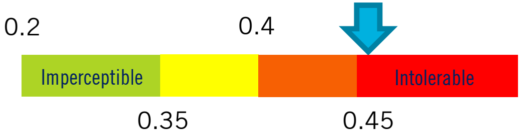




Workstation with reflected sunlight from the opposite building
DGP=0.40; Measured lux = 3830

MEASUREMENTS

Different types of glare in the office



Library with reflected sunlight from the opposite building
DGP=0.46; Measured lux = 5266

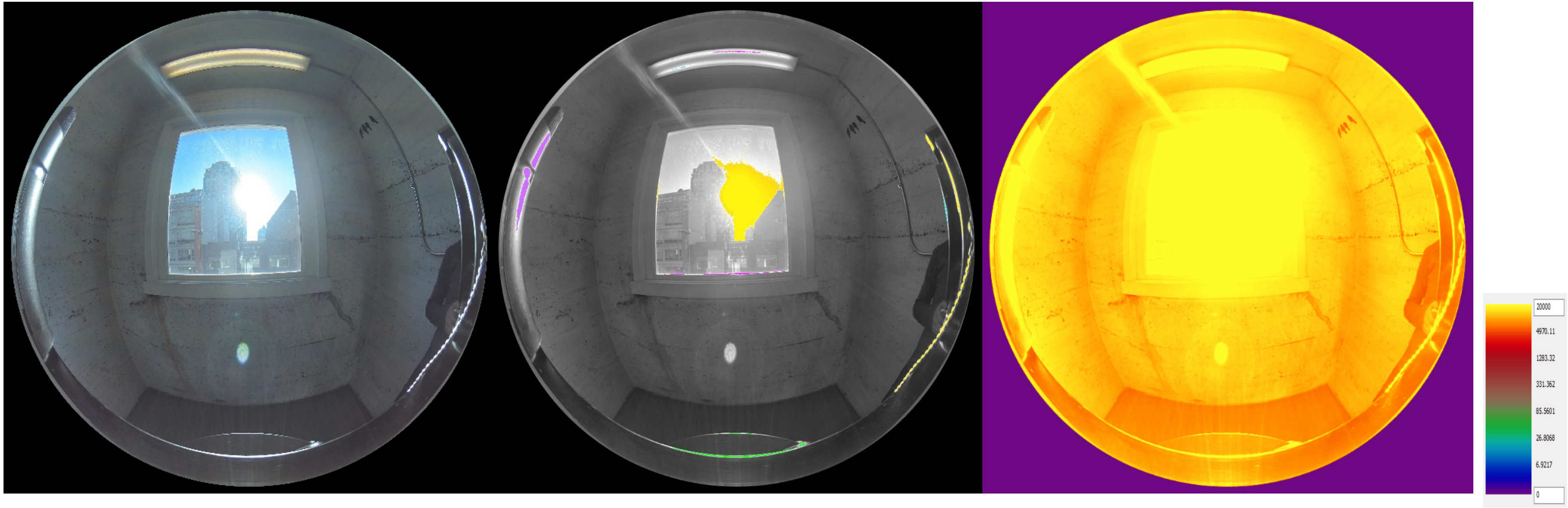
MEASUREMENTS

Different types of glare in the office

0.2 | 0.4

Imperceptible | | | Intolerable

0.35 | 0.45

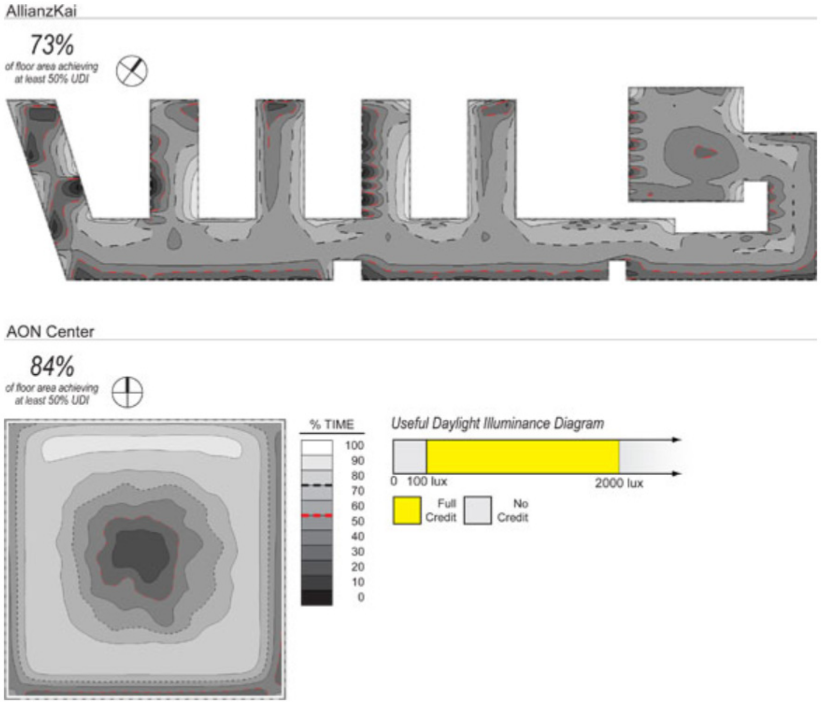


Stair with low altitude direct sunlight
DGP= 1.0; Measured lux = 56469

MEASUREMENTS

UDI and its upper limit

Useful Daylight Illuminance (UDI) is a modification of Daylight Autonomy conceived by Mardaljevic and Nabil in 2005. This metric bins hourly time values based upon three illumination ranges, 0-100 lux, 100-2000 lux, and over 2000 lux. It provides full credit only to values between 100 lux and 2000 lux suggesting that horizontal illumination values outside of this range are not useful. However there is significant debate regarding the selection of 2000 lux as an 'upper threshold' above which daylight is not wanted due to potential glare or overheating. There is little research to support the selection of 2000 lux as an absolute upper threshold. Actually my measurements indirectly suggest that 2000 lux is debatable.



Source from https://patternguide.advancedbuildings.net/using-this-guide/analysis-methods/useful-daylight-illuminance

MEASUREMENTS

Case study - the accounting office

The office measurement was carried out from 9:20am to 9:22am on 20th February 2019. Eight HDRIs are produced based on total of 36 camera bracketing images. They captured the 360° light scene of the office at a step of 45°.

0° / 52089lux

45° / 44891lux

90° / 634lux

135° / 407lux

180° / 592lux

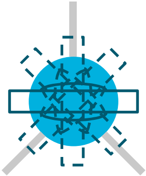
225° / 667lux

270° / 499lux

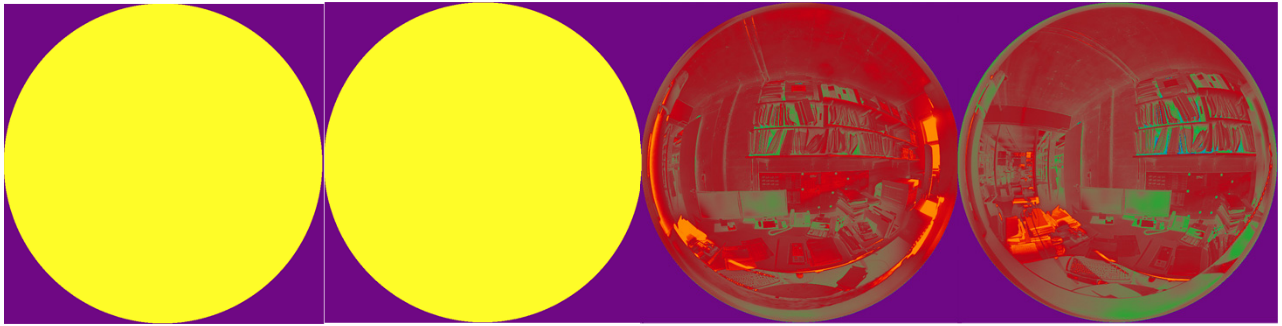
315° / 24200lux

MEASUREMENTS

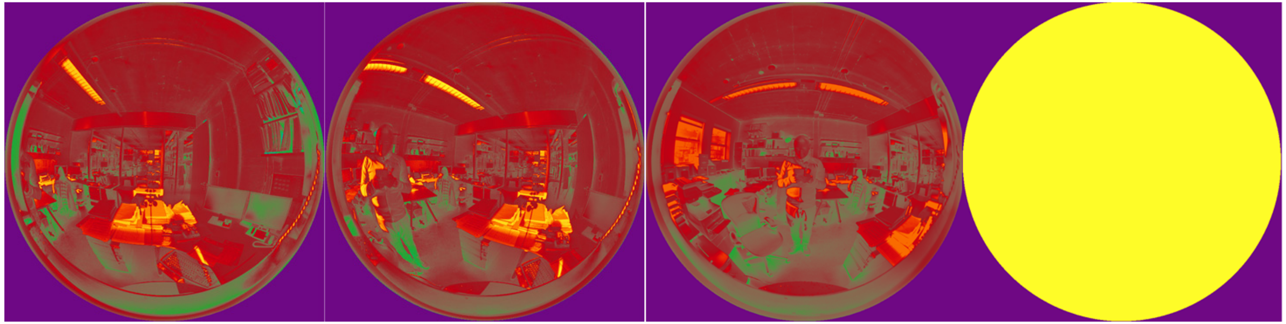
Case study - the accounting office



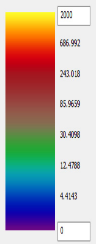
False color images are generated based on the calibrated HDR images with a maximum scale of 2000lux. Apparently at certain orientations (0^o, 45^o and 315^o), the direct sunshine captured by the lens overrides the light scenes. But the rest scenes are at acceptable levels.



0^o / 52089lux | 45^o / 44891lux | 90^o / 634lux | 135^o / 407lux



180^o / 592lux | 225^o / 667lux | 270^o / 499lux | 315^o / 24200lux



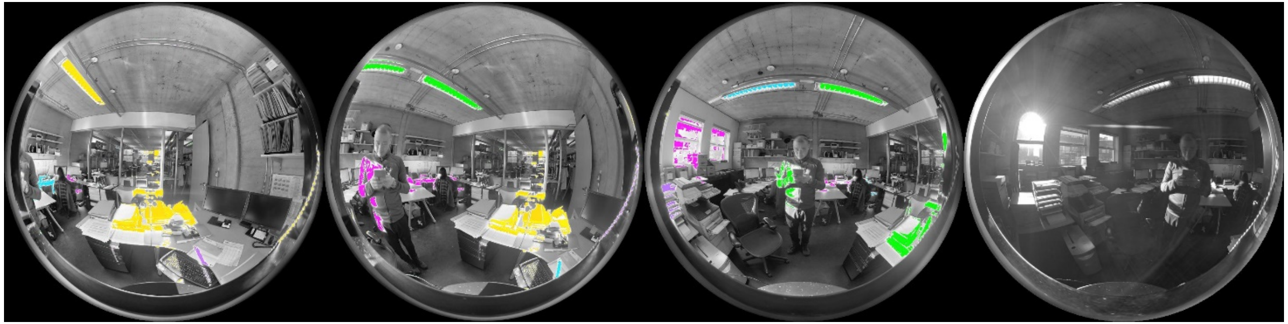
MEASUREMENTS

Case study - the accounting office

Evalglare computes DGP for each lighting scene:

- DGP < 0.35 imperceptible glare
- 0.35 <= DGP < 0.4 perceptible glare
- 0.4 <= DGP < 0.45 disturbing glare
- DGP >= 0.45 intolerable glare

0° / DGP=1 | 45° / DGP=1 | 90° / DGP=0.19 | 135° / DGP=0.19



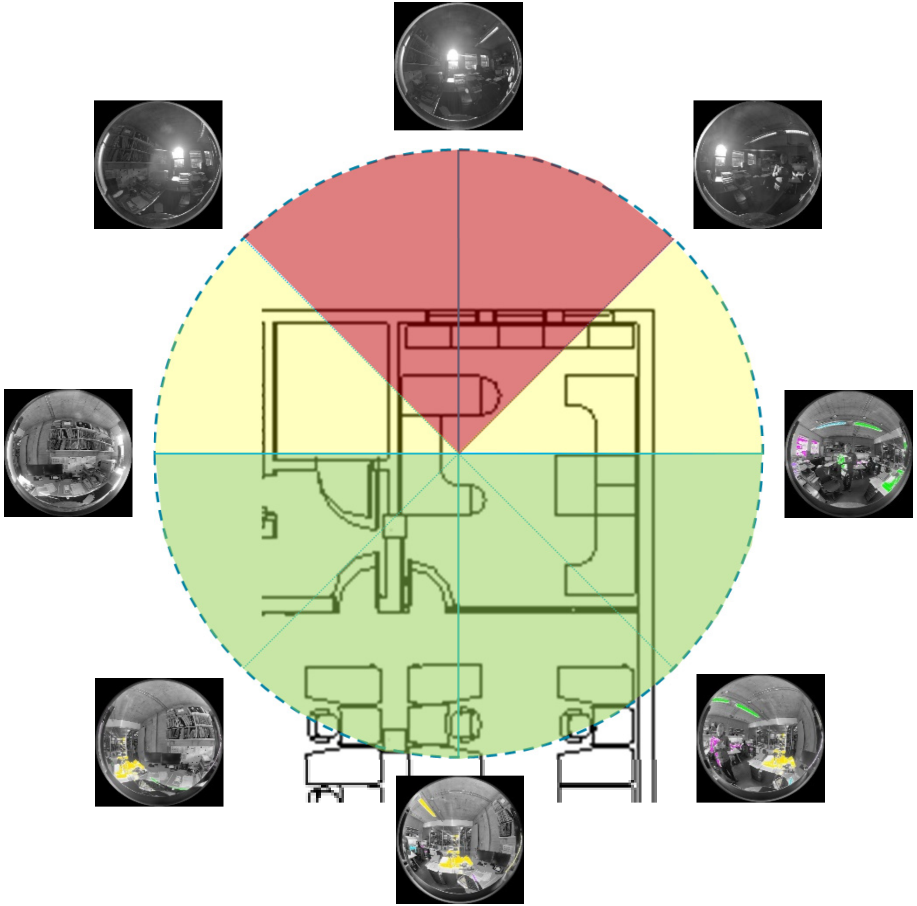
180° / DGP=0.20 | 225° / DGP=0.21 | 270° / DGP = 0.19 | 315° / DGP=1

MEASUREMENTS

Case study - the accounting office

Orientation/angle is the key strategy to avoid glare within a space, if the intolerable glare source is unavoidable. By changing the directions, occupant's visual perception could adapt easily from intolerable glare to imperceptible glare.

Red – Dead zone
Yellow – Buffer zone
Green – Safe zone

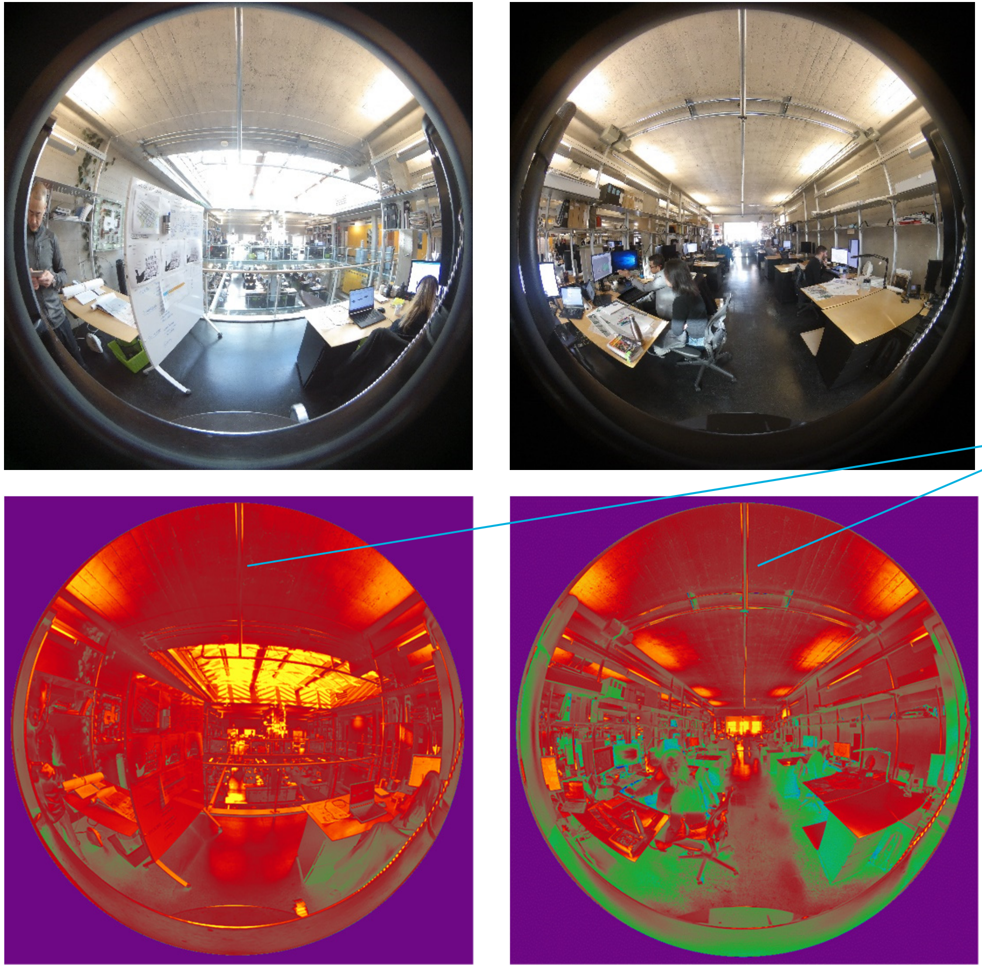


PANORAMA STITCHING

PANORAMA STITCHING

FC stitching

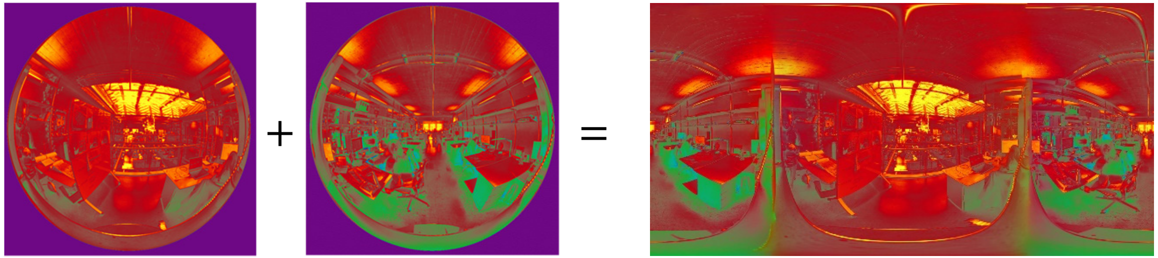
A pair of fish-eye HDRIs generated at the third floor next to the atrium are calibrated and converted into the false color images. Due to the similar color scale, they are good candidates for panorama stitching.



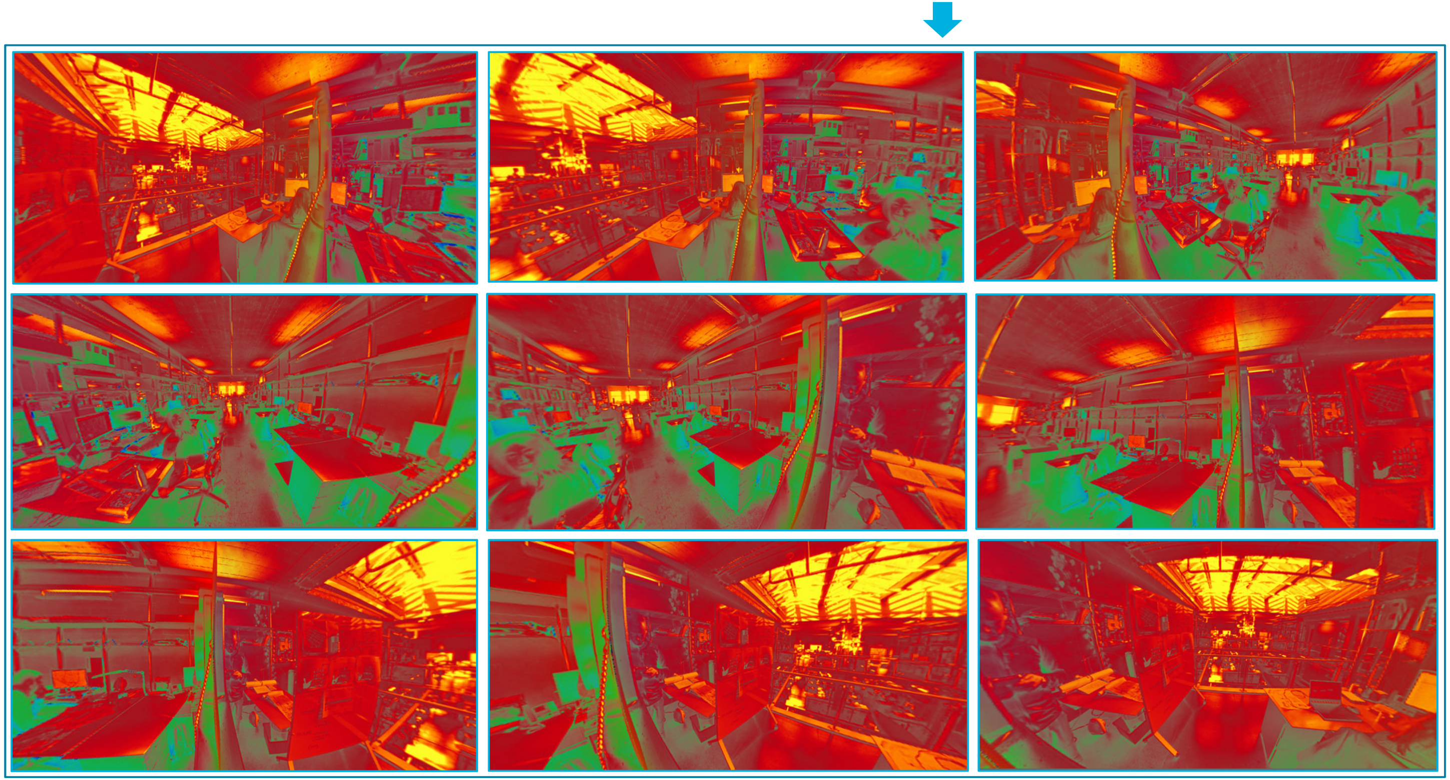
Both color and photograph matching is possible after calibration

PANORAMA STITCHING

360-degree photo



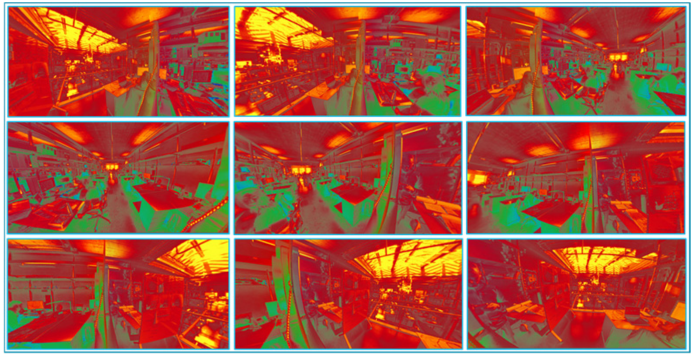
A 360-degree photo is a controllable panoramic image that surrounds the original point from which the shot was taken. Instead of using the hemispherical fish eye photos, the process demonstrates the false color outputs can be converted into 360-degree format as well.

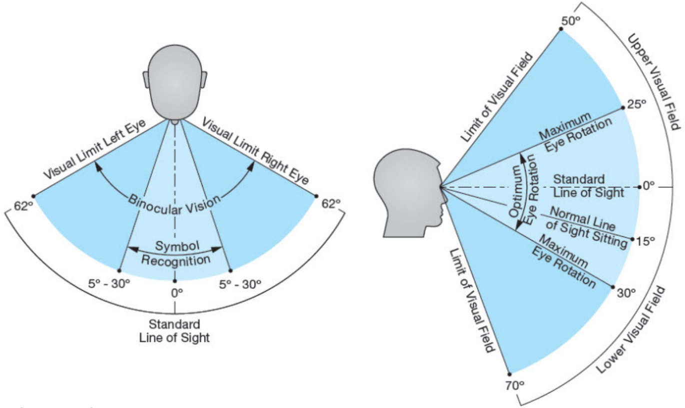


PANORAMA STITCHING

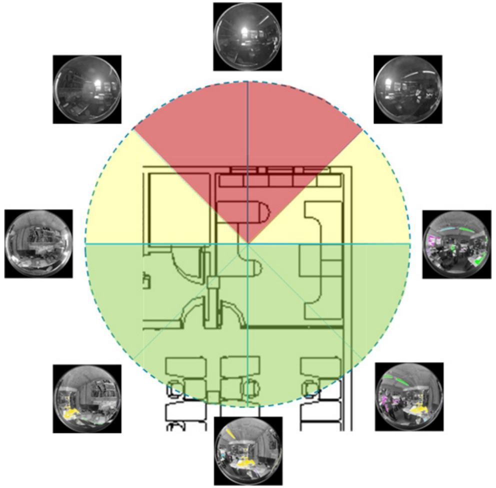
Why panorama

The rationale of generating false color 360-degree image is to explore the direction and range searching potentials in a given space in order to avoid glare issue. In theory, it is doable provided the improper contrast (judged by color scale) could be reduced or 'eliminated' within human field of vision.





Source from
https://www.extron.com/company/article.aspx?id=environconhumanfact

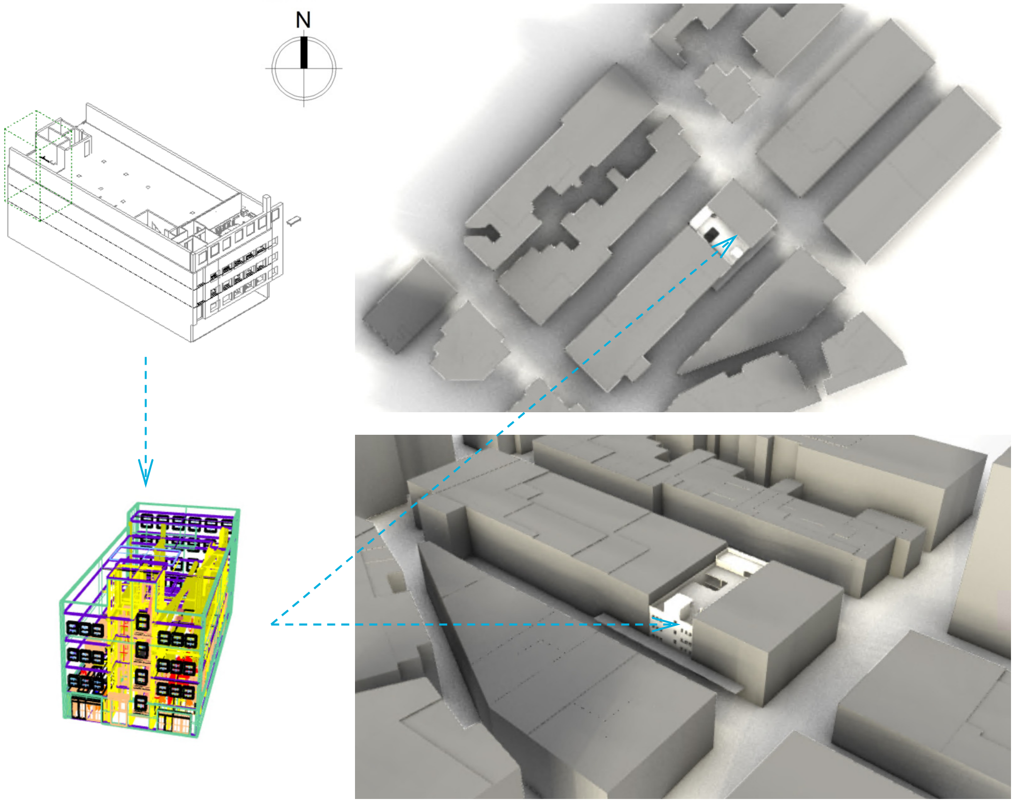


SIMULATIONS

SIMULATIONS

Office modeling

The office Revit model is exported into Rhino first. Together with the urban context, the Rhino model is able to conduct glare analysis for a given space within the office.



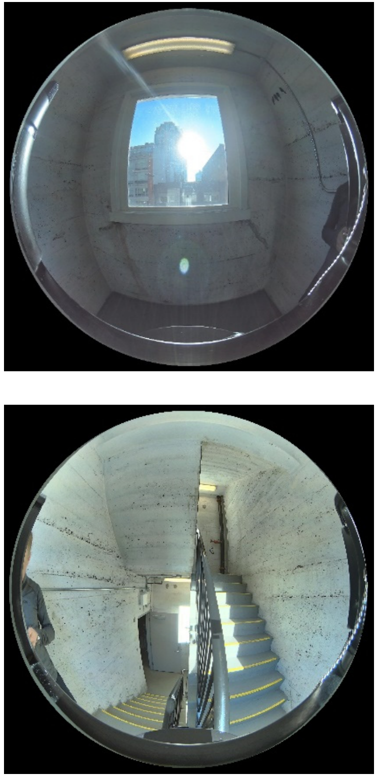
Revit model

Rhino model

SIMULATIONS

Simulation scenes

A relatively simple scene (due to the requirements of cross comparison among the field measurements, the simulations and the renderings), a stair with SE window, is selected. Two days, 10am on 20th Feb 2019 and 3pm on 18th Mar 2019 (both are clear days but one receives direct sunlight and the other receives diffused one through the window), are consistently used for all the comparisons.



Front and back HDR photos
10am on 20th Feb 2019
Direct sunlight

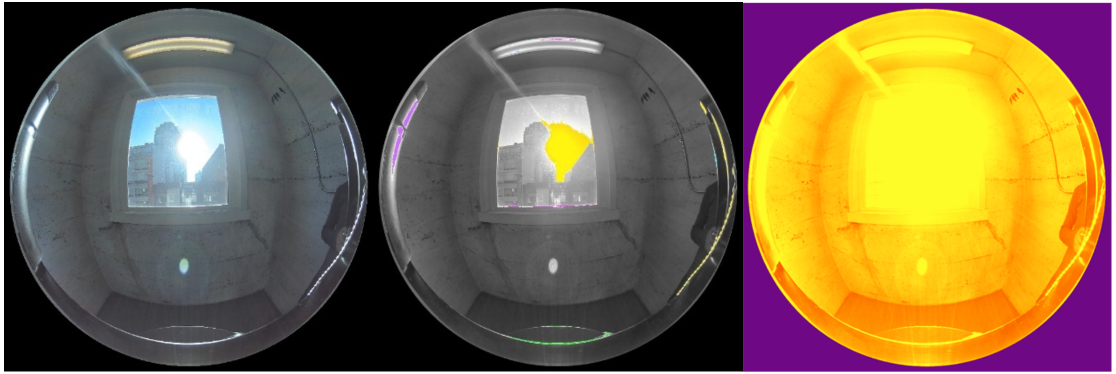
Front and back HDR photos
3pm on 18th Mar 2019
Diffused sunlight

SIMULATIONS

10am/20th Feb 2019_Front view

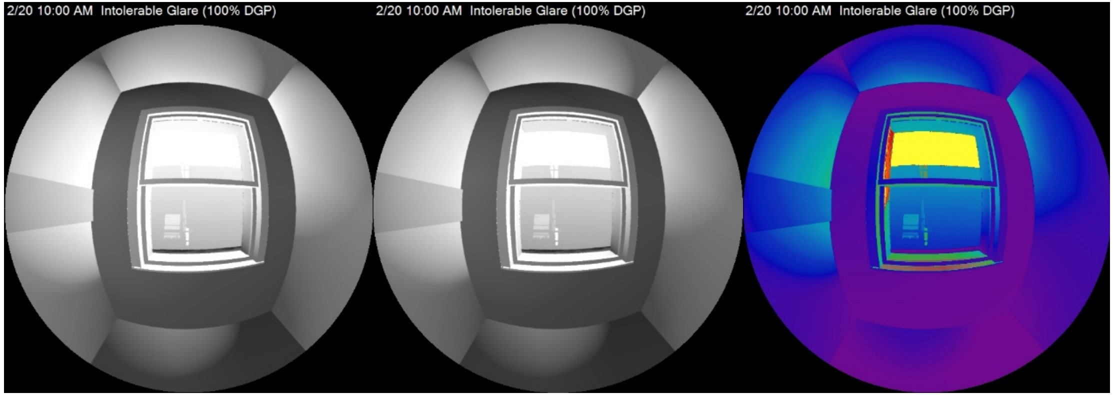
Measurement

DGP= 1
Intolerable glare



Simulation

DGP= 1
Intolerable glare

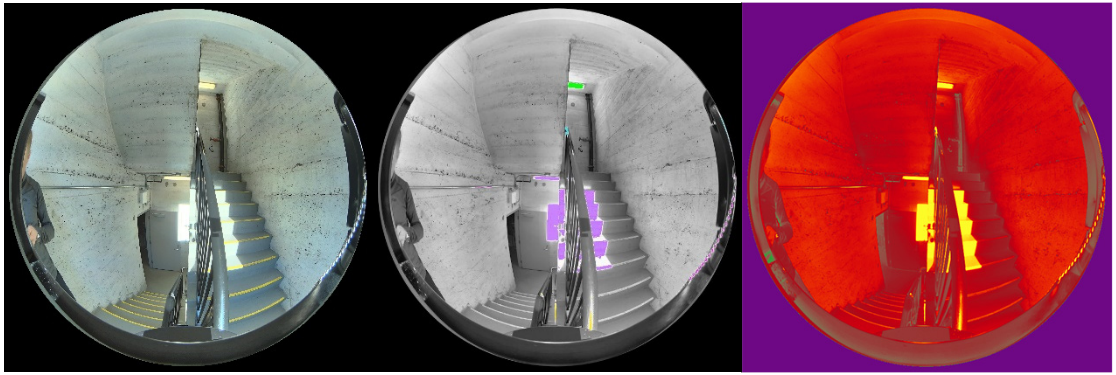


SIMULATIONS

10am/20th Feb 2019_Back view

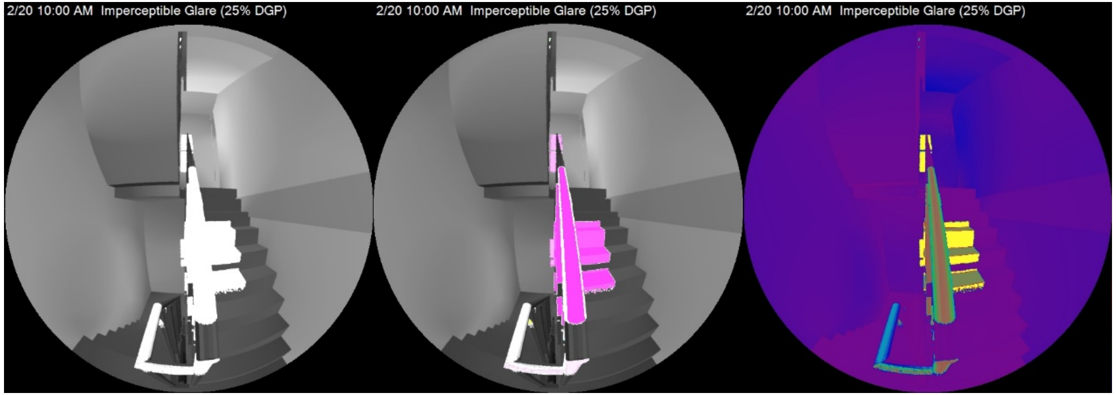
Measurement

DGP= 0.24
Imperceptible glare



Simulation

DGP= 0.25
Imperceptible glare



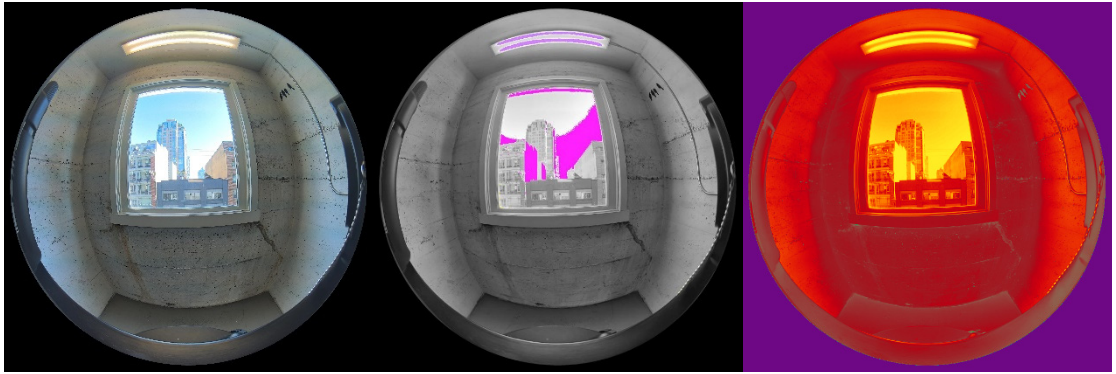
SIMULATIONS

3pm/18th Mar 2019_Front view

Measurement

DGP= 0.235

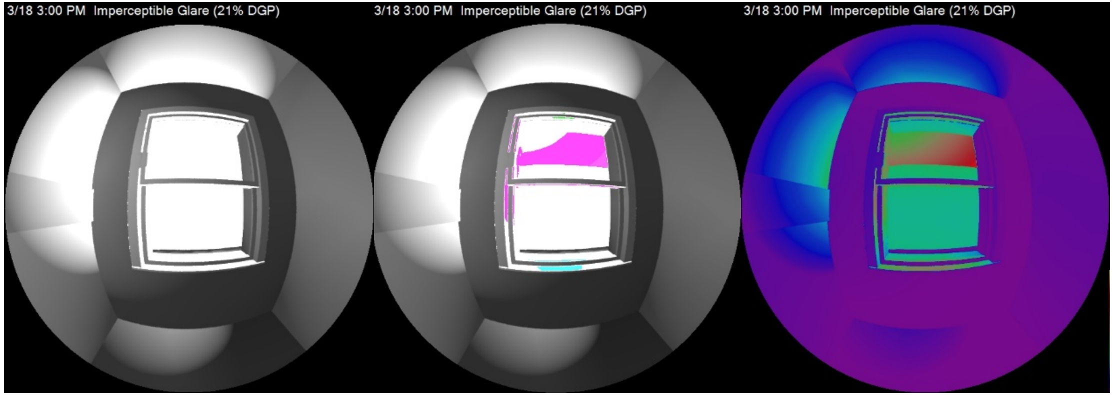
Imperceptible glare



Simulation

DGP= 0.21

Imperceptible glare



SIMULATIONS

3pm/18th Mar 2019_Back view

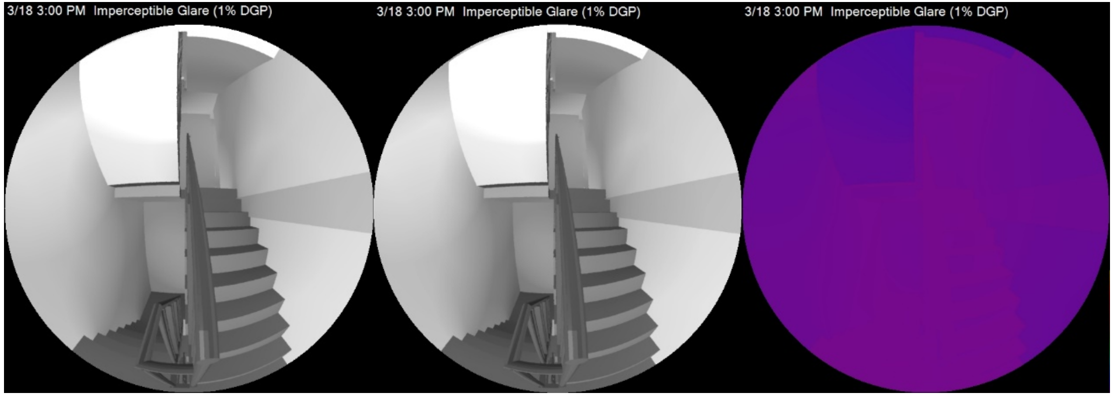
Measurement

DGP= 0.12
Imperceptible glare

But

Simulation

DGP= 0.01
Imperceptible glare

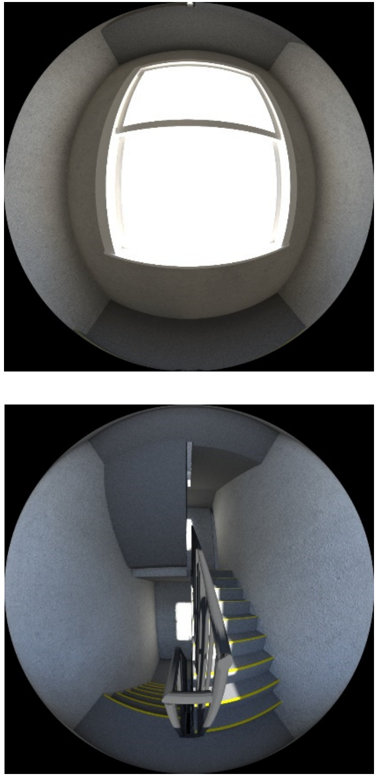


RENDERING

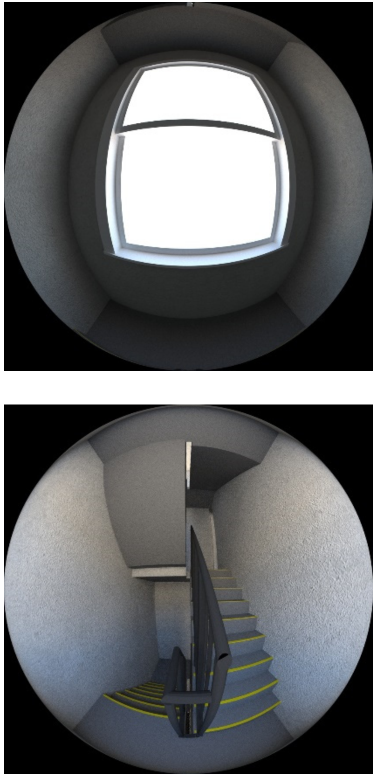
RENDERING

Rendering scenes

Same as the simulations (to make consistent comparisons among photographs, simulations and renderings), the stair with SE window is selected for rendering with 3DS Max embedded light system. Two days, 10am on 20th Feb 2019 and 3pm on 18th Mar 2019 (both are clear days but one receives direct sunlight and the other receives diffused one through the window), are rendered.



Front and back renderings
10am on 20th Feb 2019
Direct sunlight

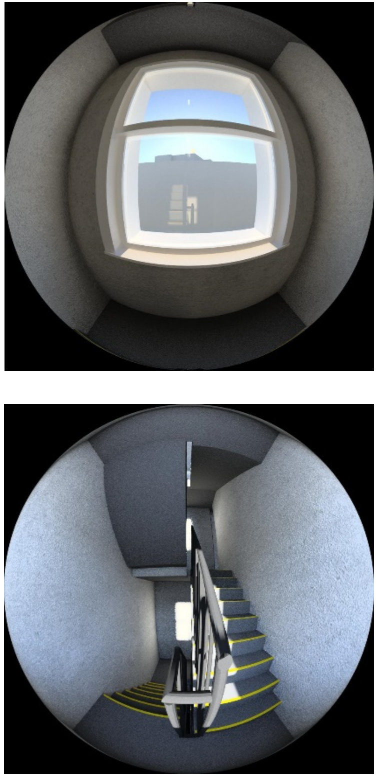


Front and back renderings
3pm on 18th Mar 2019
Diffused sunlight

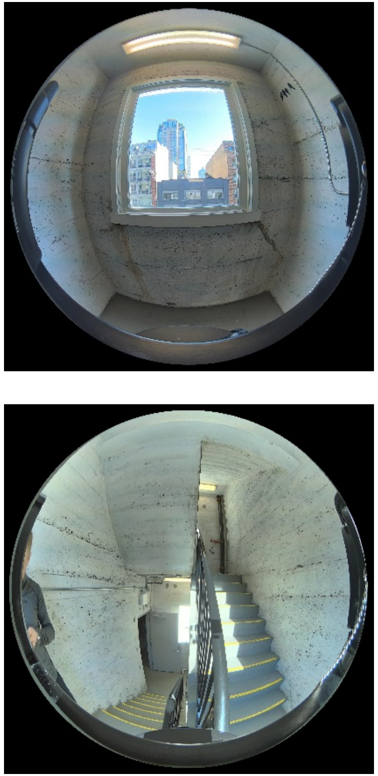
RENDERING

Rendering HDRIs

HDRIs are generated based on multi renderings. Visually, they are quite comparable with HDR photos taken on site. It confirms the use of default sun/light system in 3DS Max matches the real world photograph and therefore they are the good candidates for glare analysis.



Front and back HDR renderings
10am on 20th Feb 2019
Direct sunlight

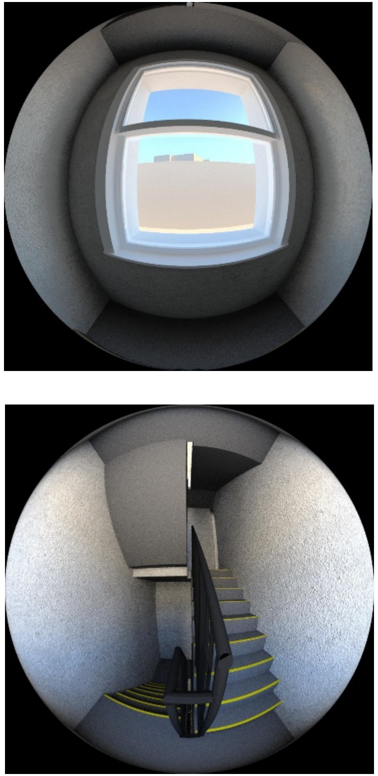


Front and back HDR photos
10am on 20th Feb 2019
Direct sunlight

RENDERING

Rendering HDRIs

HDRIs are generated based on multi renderings. Visually, they are quite comparable with HDR photos taken on site. It confirms the use of default sun/light system in 3DS Max matches the real world photograph and therefore they are the good candidates for glare analysis.



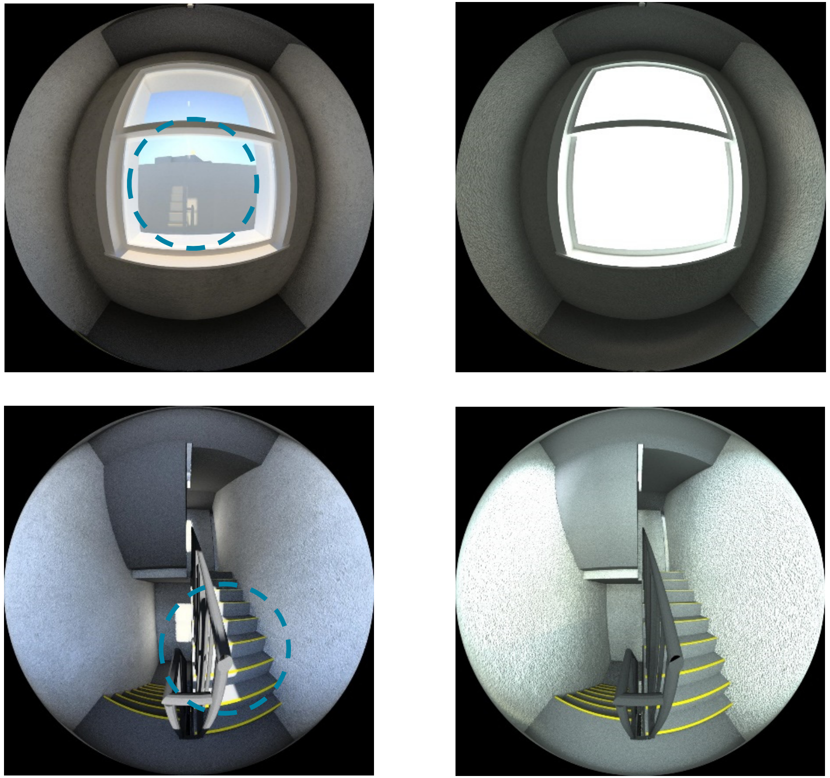
Front and back HDR renderings 3pm on 18th Mar 2019 Diffused sunlight

Front and back HDR photos 3pm on 18th Mar 2019 Diffused sunlight

RENDERING

Rendering approaches

Different rendering approaches are also compared. It is noticed that the HDR photo based renderings may lose some valuable details but they are captured via the baseline rendering approach. However, baseline renderings still need to be calibrated with the measured lux levels to produce accurate glare results.



Renderings with 3DS system
<u>Baseline approach</u>

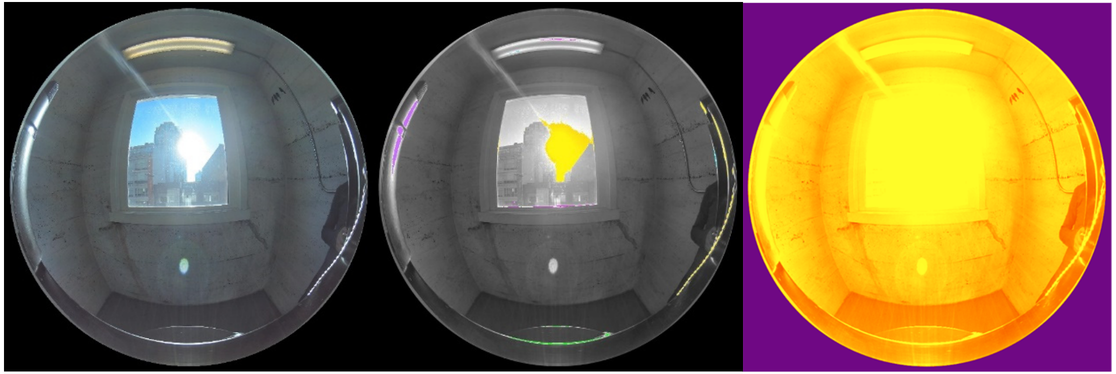
Renderings with calibrated HDR photographs
<u>HDR photo based approach</u>

RENDERING

10am/20th Feb 2019_Front view

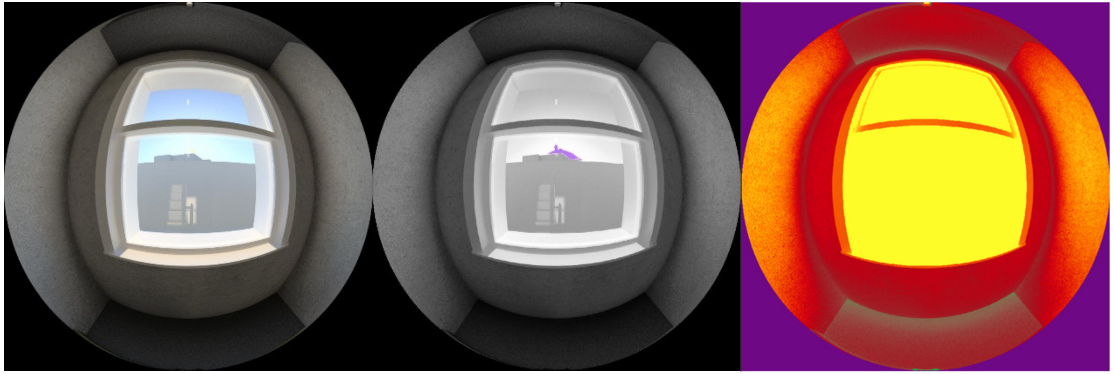
Measurement

DGP= 1
Intolerable glare



Rendering

DGP= 1
Intolerable glare



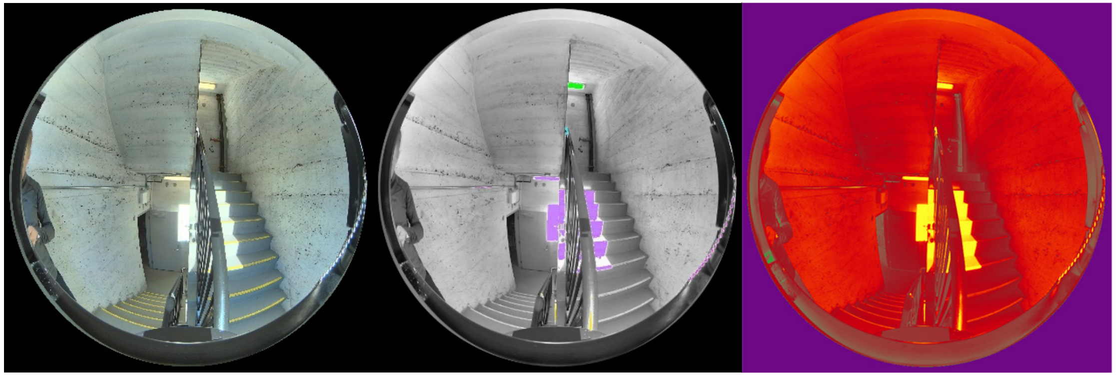
RENDERING

10am/20th Feb 2019_Back view

Measurement

DGP= 0.24

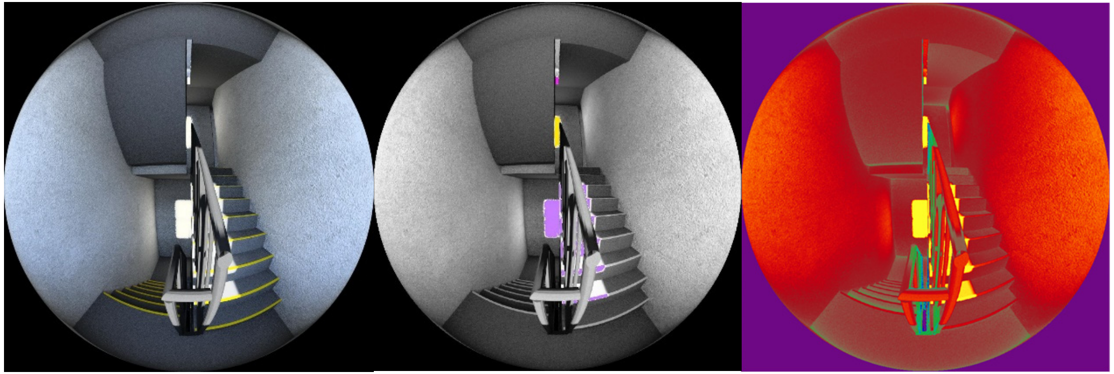
Imperceptible glare



Rendering

DGP= 0.27

Imperceptible glare

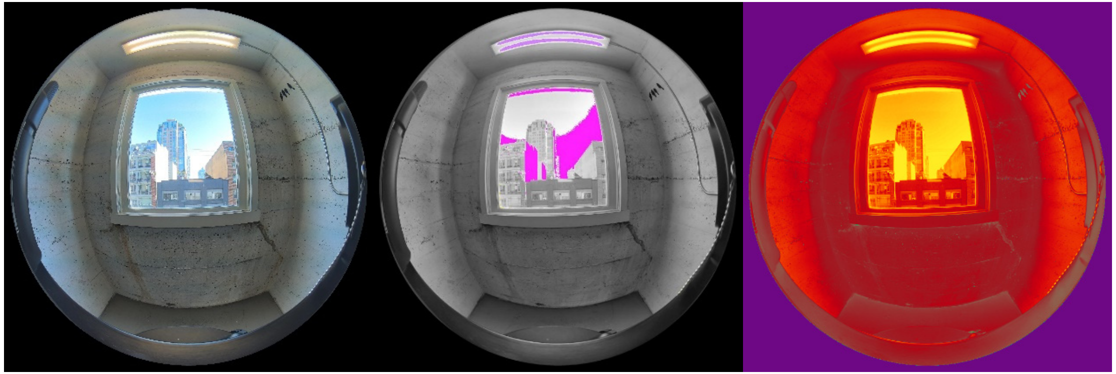


RENDERING

3pm/18th Mar 2019_Front view

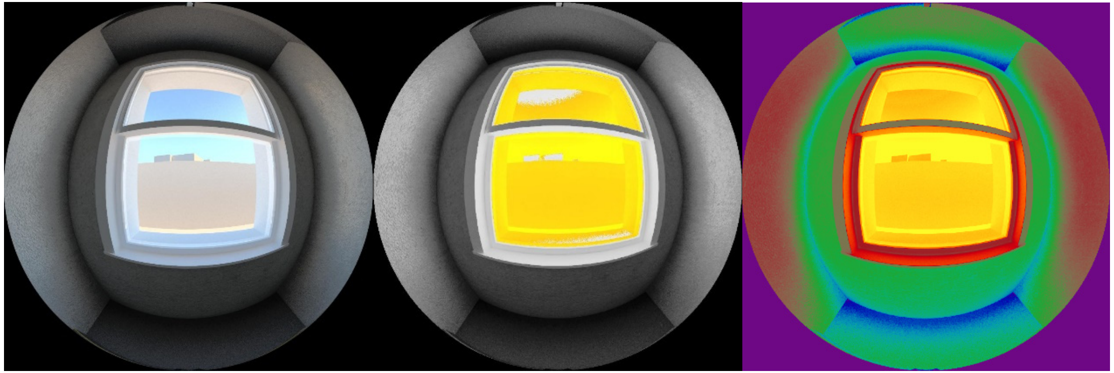
Measurement

DGP= 0.235
Imperceptible glare



Rendering

DGP= 0.28
Imperceptible glare



RENDERING

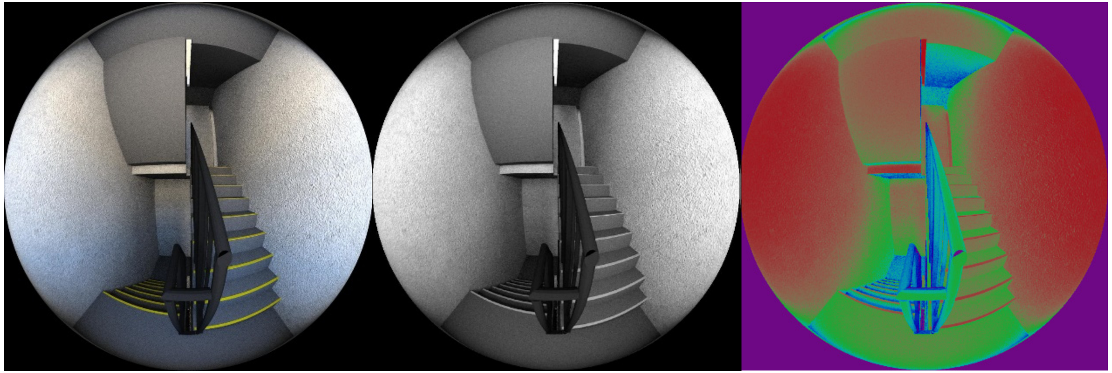
3pm/18th Mar 2019_Back view

Measurement

DGP= 0.12
Imperceptible glare

Rendering

DGP= 0.14
Imperceptible glare

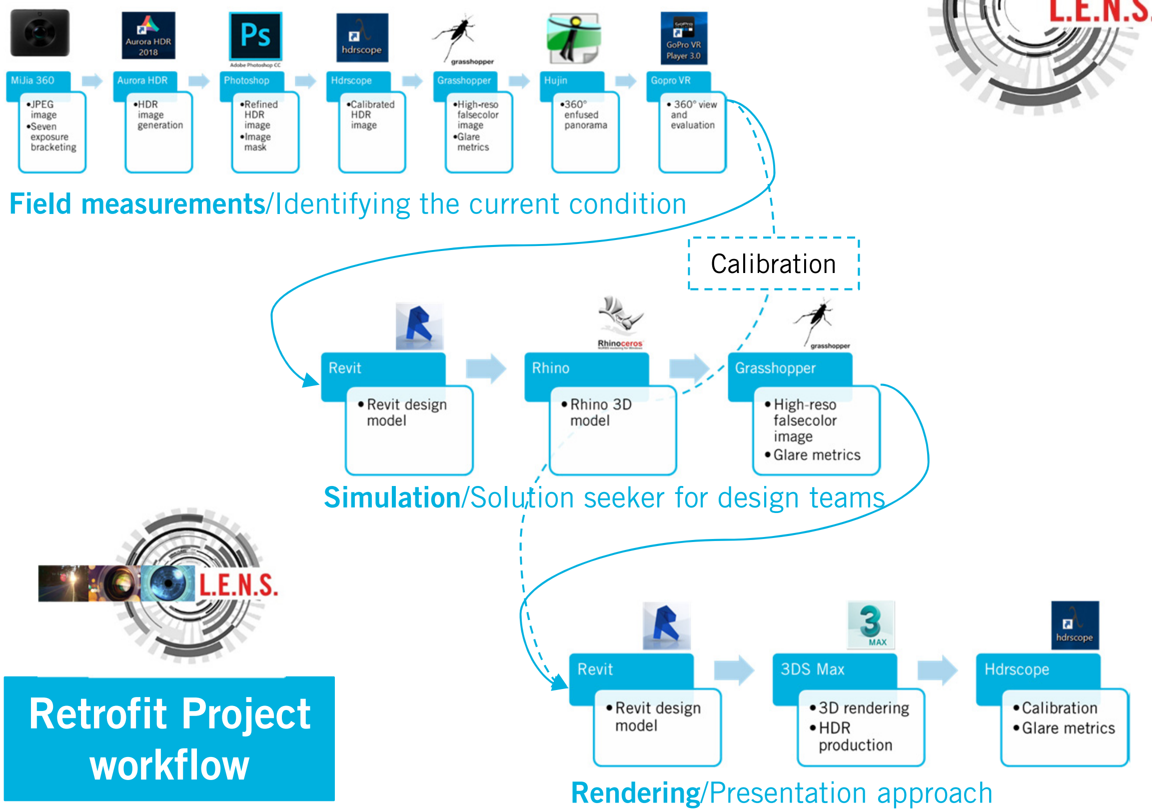


CONCLUSION

CONCLUSION

A complete workflow for retrofit projects

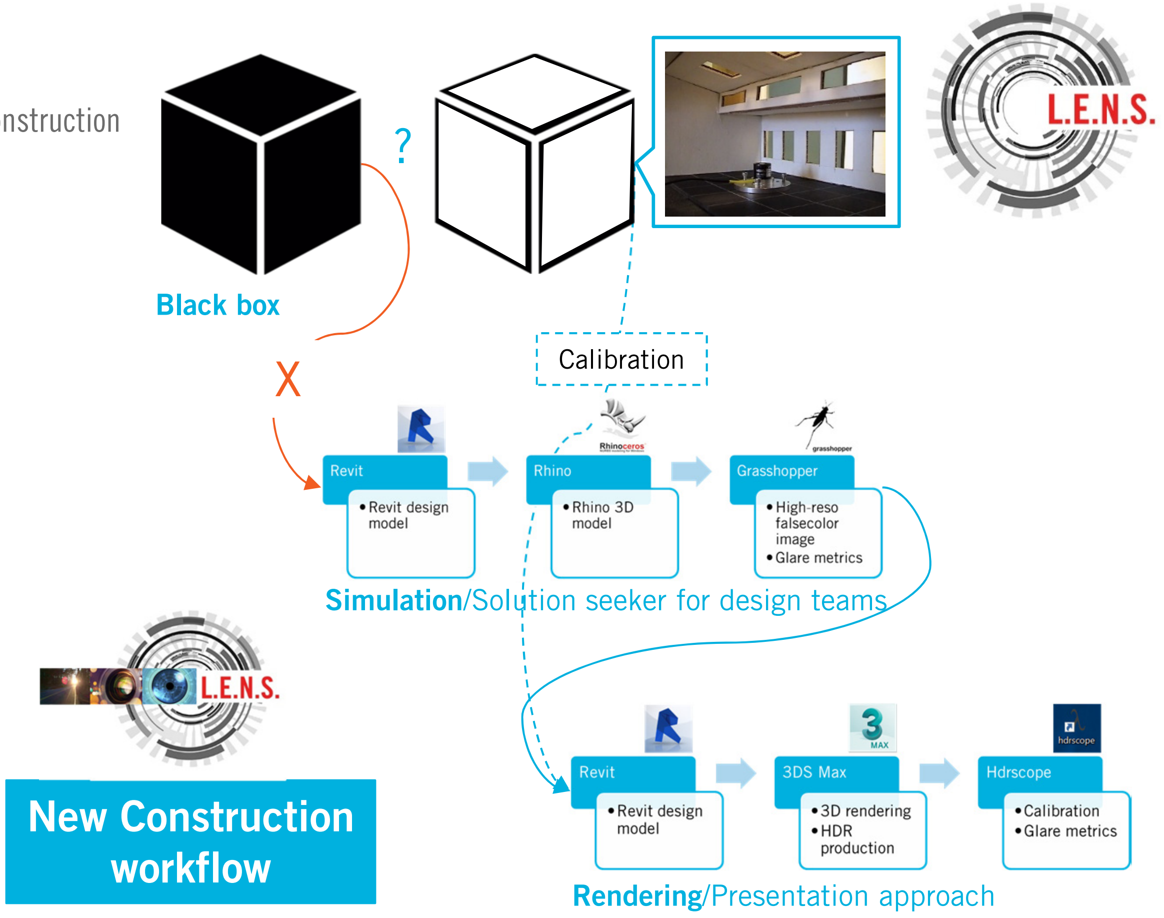
The overall workflow has been approved to be a usable one for evaluating glare in a retrofit project. Filed measurements are to capture current light scenes and measure the illuminances on site as a benchmark/baseline. Simulation can follow the filed measurement and validate/introduce mitigation measures to solve the potential glare issues detected on site. Eventually calibrated renderings are to be developed for visualization and the benefit of understanding the potential glare issues/solutions quantitatively.



CONCLUSION

An incomplete yet developable workflow for new construction

The current workflow may not fully support new construction due to the lack of field measurement opportunity. However, simulation and rendering parts still work independently. Actually the current black box on the top of the workflow may change into a transparent one if scaled physical model (as per new construction space) and lighting measurement could be carried out. Calibration would then be possible with some reliable lux levels and support the downstream workflows.



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