Using Radiance for Evaluation Veiling Glare on Monitor Screens

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Acknowledgements

Many thanks to Greg Ward
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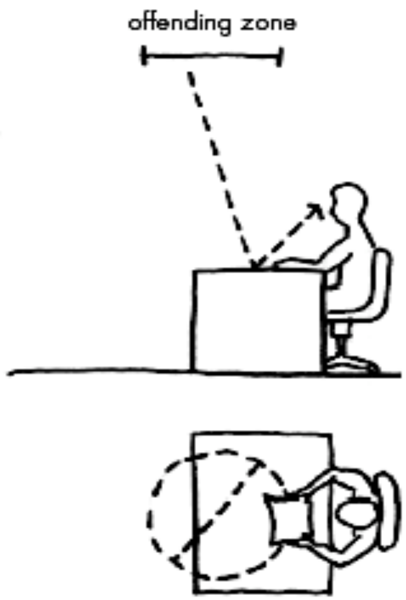
Source: Werner Osterhaus

Different types of glare



The area above and directly in front of the task is most likely to cause veiling reflections.

- Discomfort glare
- Disability glare
- Veiling glare

Light sources reflected by surfaces ⇒ reduction of contrasts

This phenomena is called veiling reflection ⇒ reduction of task visibility

Reflection and Contrast Reduction on LCDs

Diffuse or specular reflection from surround light sources and objects superimposes upon monitor surface

Reflection causes contrast reduction ⇒ not meeting the required contrast value

Reflection obscures some details and contributes to veiling reflection

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Development a model for veiling reflection on LCD screens under daylight conditions

Motivation

- Most common tasks in office rooms are computer based
- LCDs are main displays in office rooms
- As much daylight as possible is desired
- Adequate Contrast is necessary for quality improvement of visibility
- No suitable method for veiling glare evaluation

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Minimum required contrast on flat screen monitors

According to **DIN EN ISO 13406-2:2001** adequate contrast between foreground and background should be :

$$C_m = (L_H – L_L) / (L_H + L_L) >= (5 * L_L^{-0.55} /(1 + 5 * L_L^{-0.55}))$$

$$C_R = (L_H / L_L) >= (1 + 10 * L_L^{-0.55})$$

C_m: Contrast Modulation
C_R: Contrast Ratio
L_H: Luminance of the high state
L_L: Luminance of the low state

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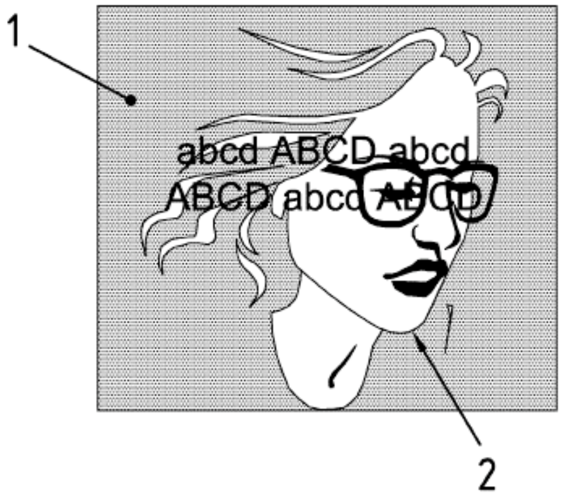

1: Background

2: Undesirable reflected image

By considering the effect of reflections

$$(L_H+L_D+L_S) / (L_L+L_D+L_S) >= 1 + 10 * (L_L+L_D+L_S)^{-0.55}$$

L_D: diffuse reflected luminance

L_S: specular reflected luminance

(Contrast Model 1)

$1 + 10 * L_L^{-0.55}$ and $1 + 10 * (L_L + L_D + L_S)^{-0.55}$

⇒ minimum required contrasts for detection of the objects

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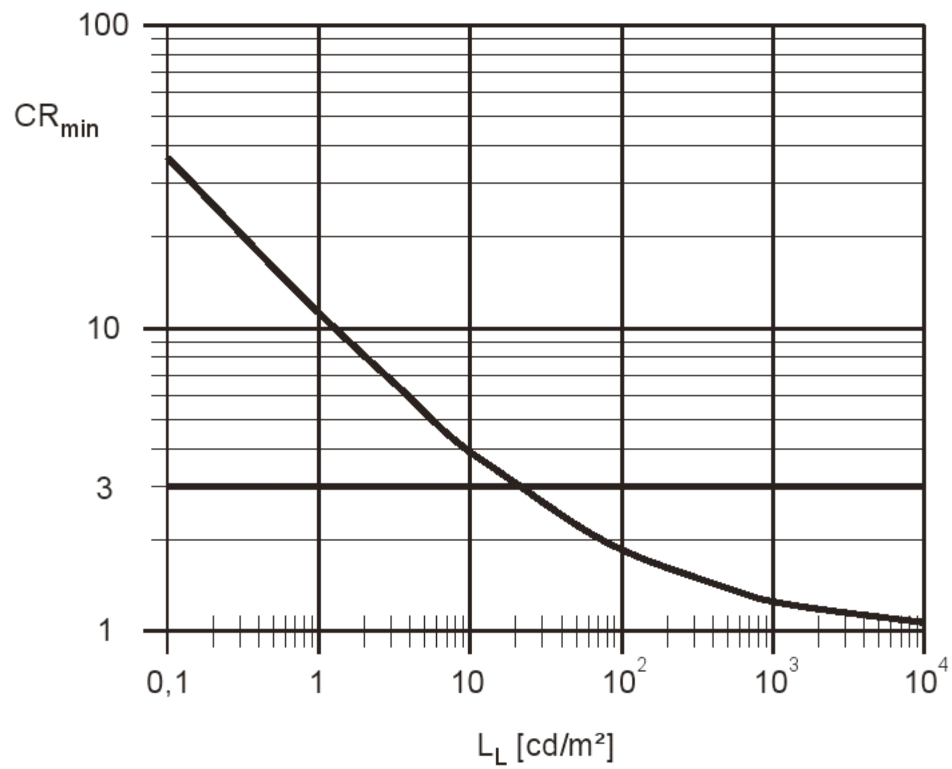
No known experimental validation for the above declared model

Weakness: contrast strives to 1 with increasing L_L



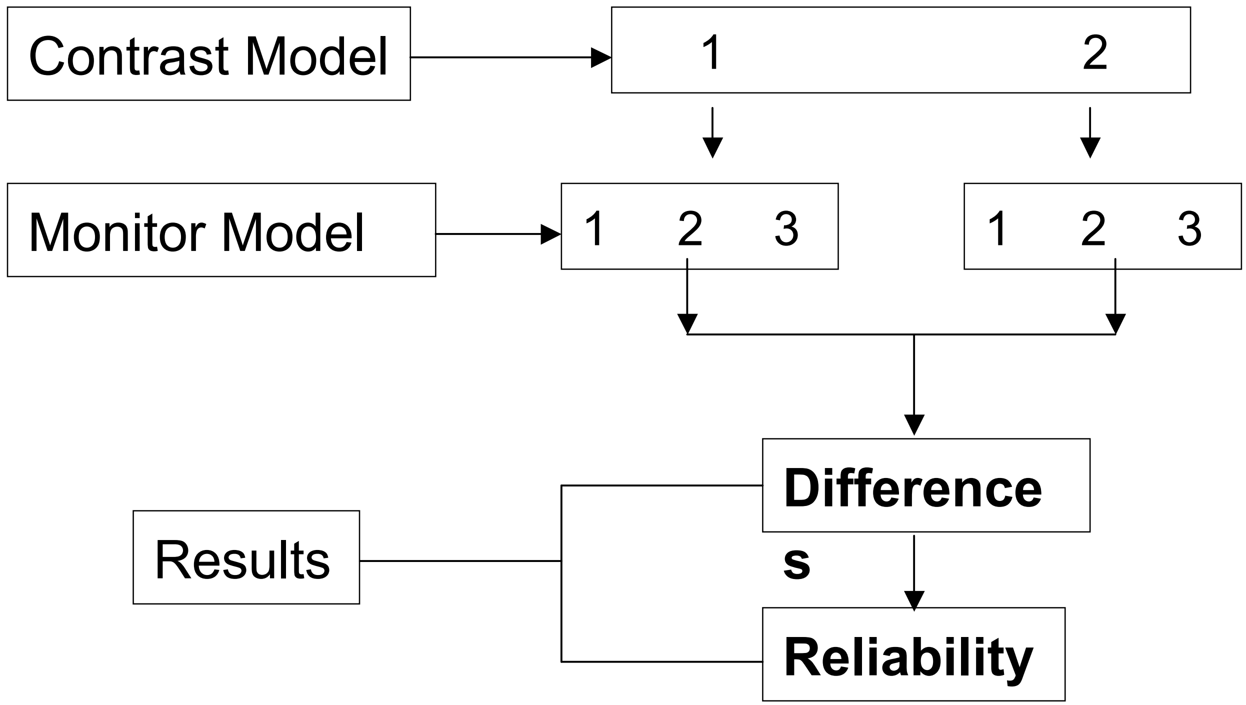
Minimum contrast for visual display according to ISO 9241-3 and ISO 13406-2

Recently proposed formula for minimum required contrast

Formula proposed to improve above mentioned model **(Contrast Model 2)**

$$CR_{min} = 2.2 + 4.84 * L_L^{-0.65}$$

Based on mathematical evaluation of contrast threshold of Kokoschka and experimental results of Blackwell


Contrast Model
1
2
Monitor Model
1 2 3
1 2 3
Results
Differences
Reliability

Three monitor models

Monitor type

EIZO FlexScan L56 LCD

Monitor 1:

Measured data: direct + total reflectance (here integrating sphere, spectral-reflectometer also possible)
Material model: Mix of plastic and glow

Monitor 2:

Measured data: illuminance at screen plane and luminance of screen

Material model: Mix of plastic, glass and glow

Three monitor models
Monitor type

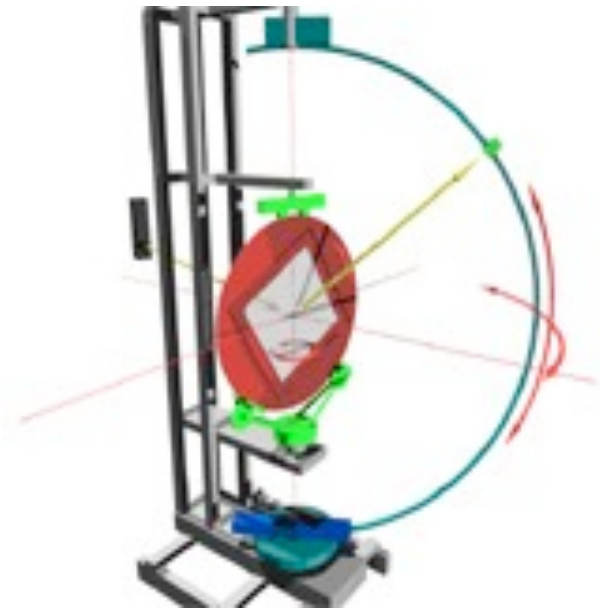
EIZO FlexScan L56 LCD

Monitor 3:

Measured data: direct + total by Integrating sphere
Angle dependency and reflectance distribution form by Goniophotometer

Material model: angle dependent mix of different plastics, possibly glass, and glow

Monitor screen measurement



Measurement of Reflection characteristics

Goniophotometer ⇒

Bidirectional reflectance distribution function –BRDF

$$dL_r(\theta_r, \varphi_r) = B(\theta_i, \varphi_i, \theta_r, \varphi_r)\, dE_i(\theta_i, \varphi_i)$$

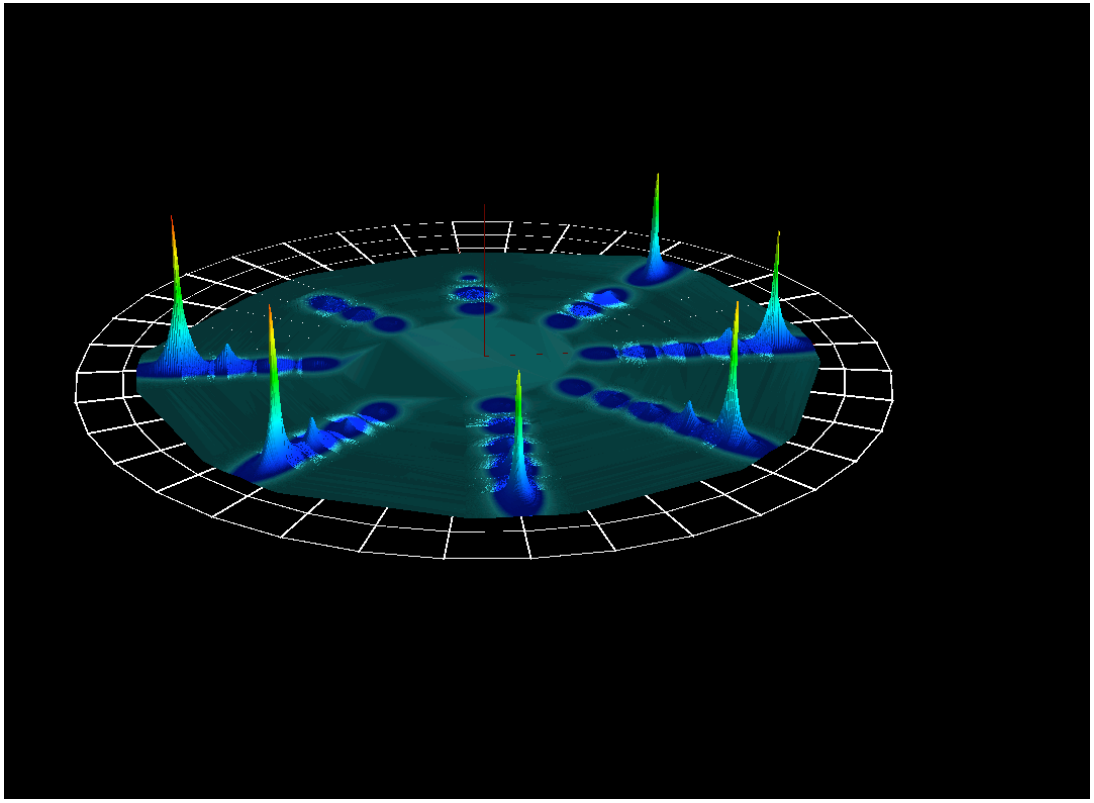
Integrating Sphere ⇒

Total hemispherical reflection

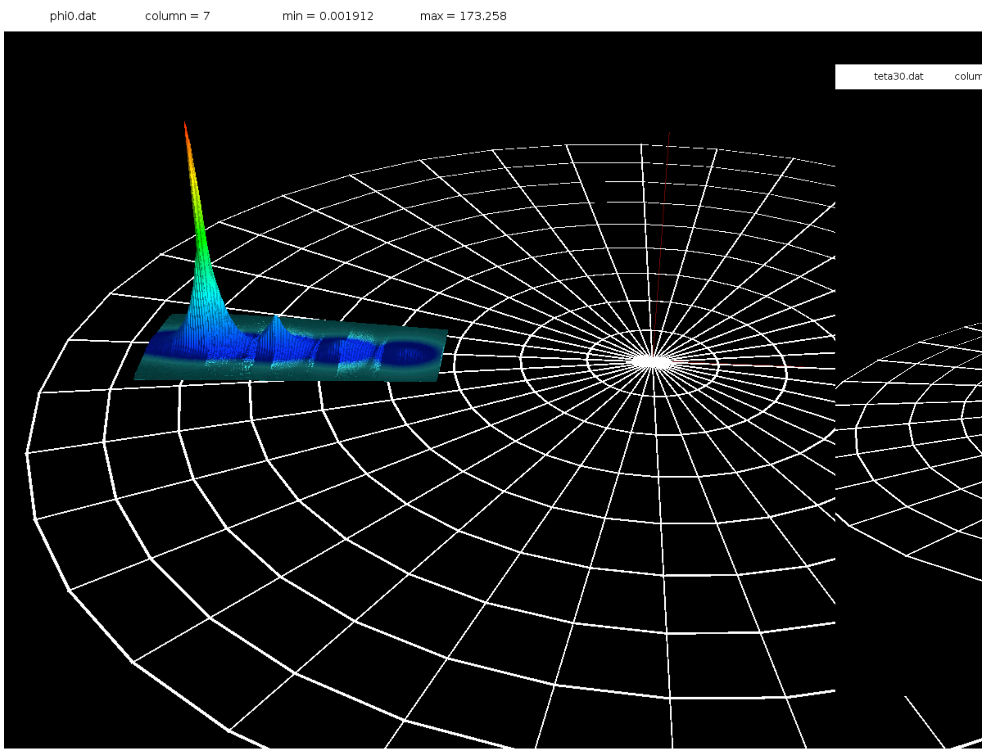
Diffuse hemispherical reflection

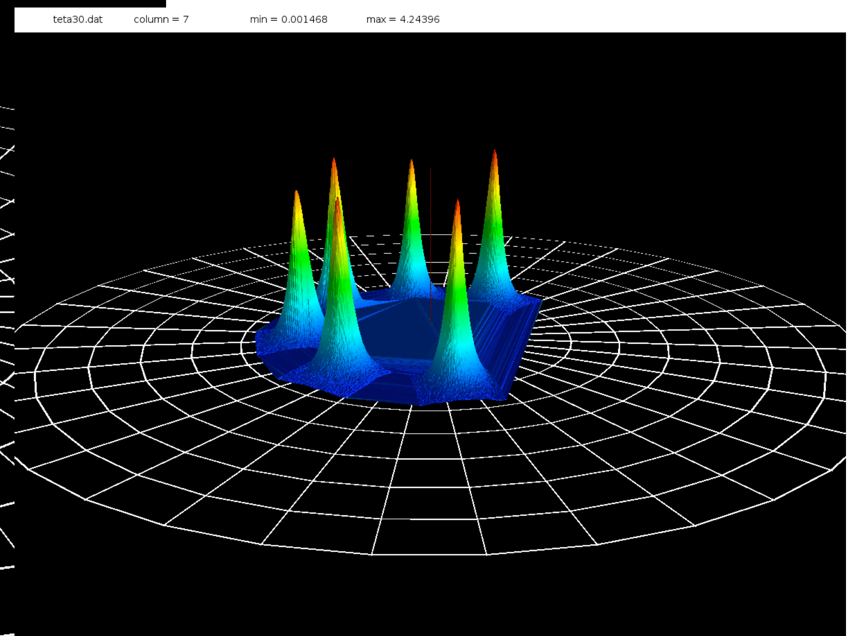
- Monitor screen has different reflection characteristics by different incident angles (angular dependency)
- The bigger the altitude angle, the bigger the specular reflection
- Reflection doesn't change by changing the incident azimuth angles

Reflection distribution curves of measured monitor by different incident angles

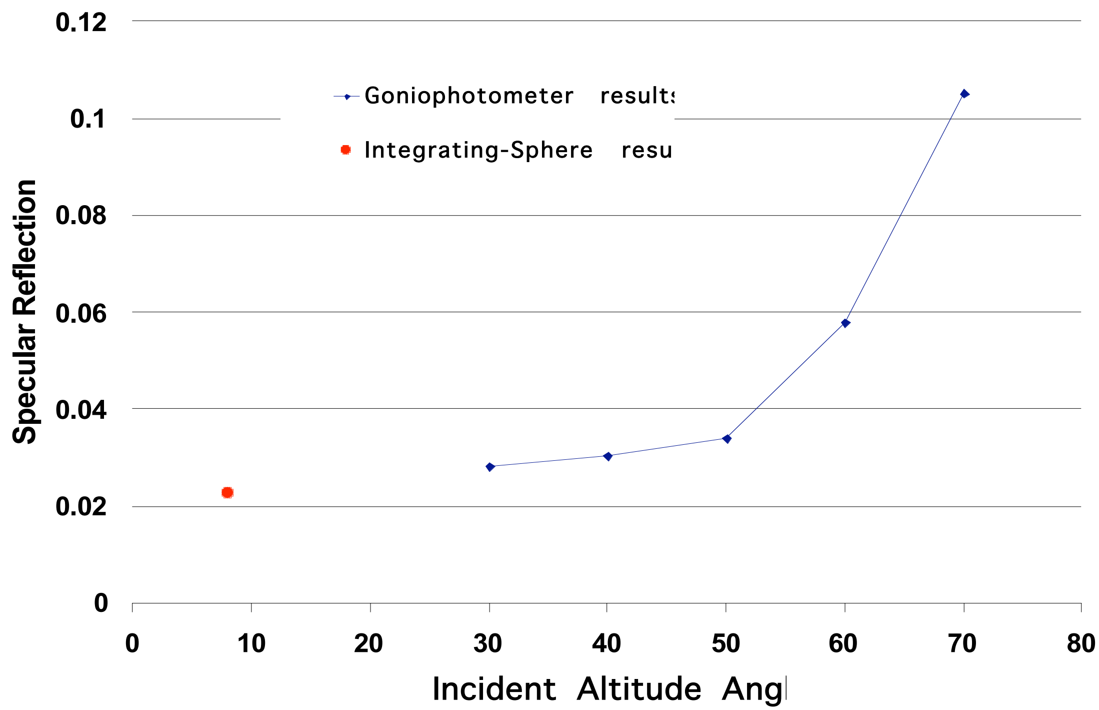


Left : Measured BRDF, azimuth =0 **Right:** Measured BRDF, altitude =20

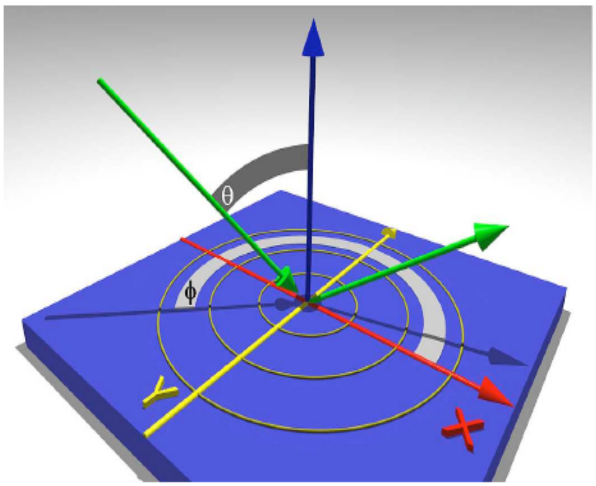




Good agreement of BRDF results of "Gonio-photometer" with "Integrating Sphere" results:



Simulation based on BRDF Measurements



Problem of BRDF in Radiance: missing angular dependency in ambient calculation

Finding a compatible mixture with measured BRDF data by means of

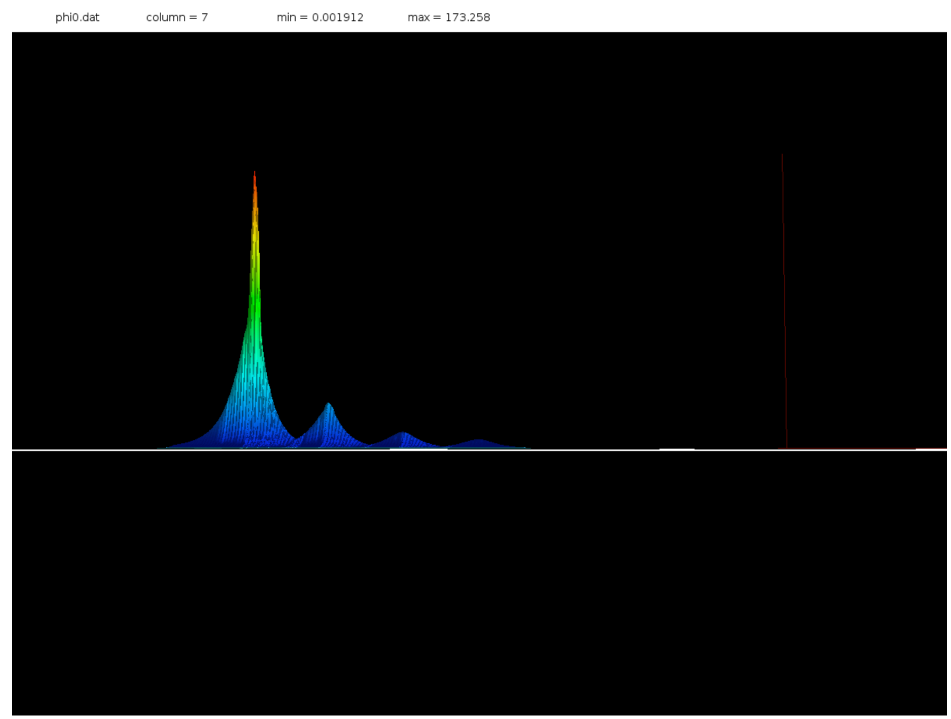
virtual gonio-photometer tool

Simulation Procedure

Finding two compatible materials with measured BRDF data of smallest and biggest incident angles with similar:

- Integral value of BRDf
- Reflectance distribution form

Deduce respective function to mix two materials



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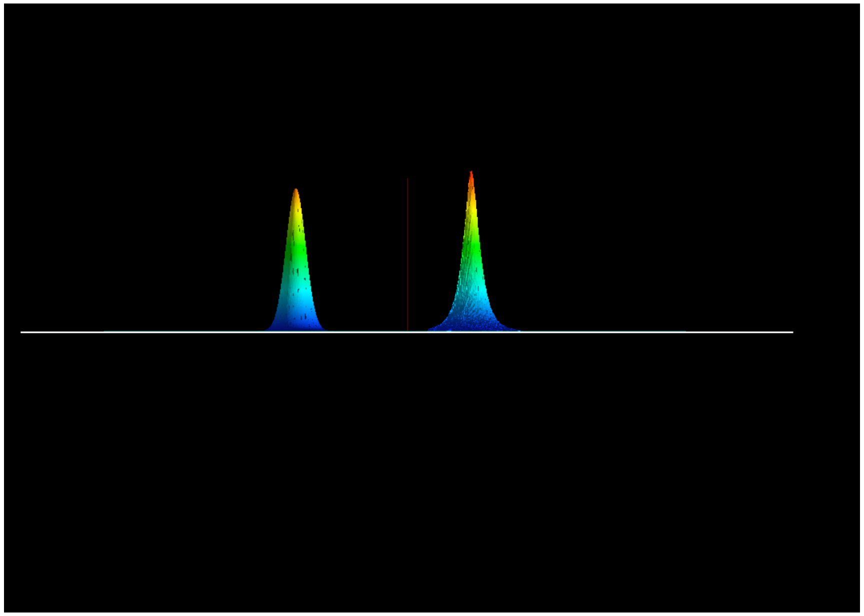
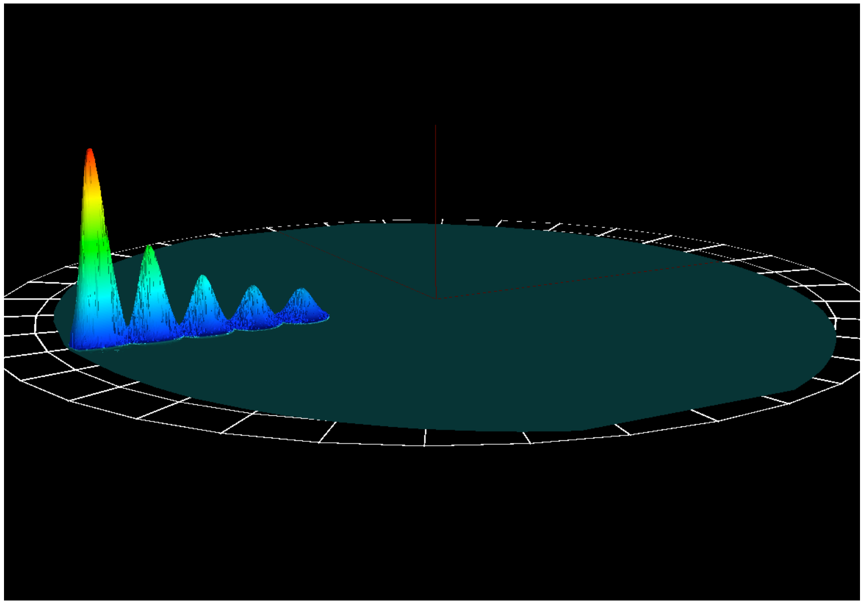
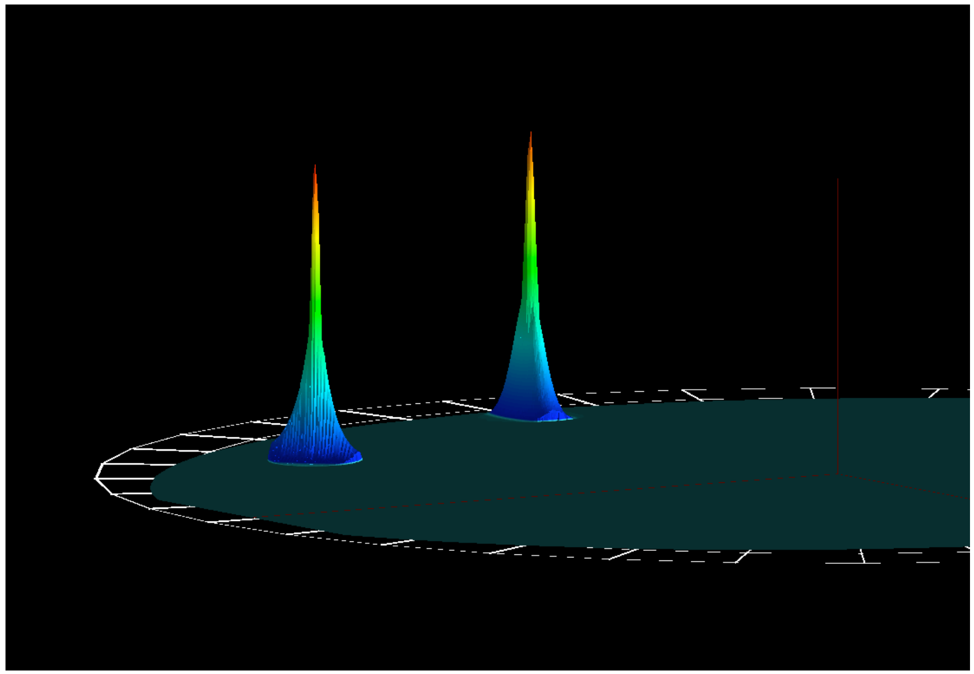
Right Image: Reflection distribution curves of measured monitor, and compatible simulated material by incident angle 30

Left image: angular characteristics of simulated material

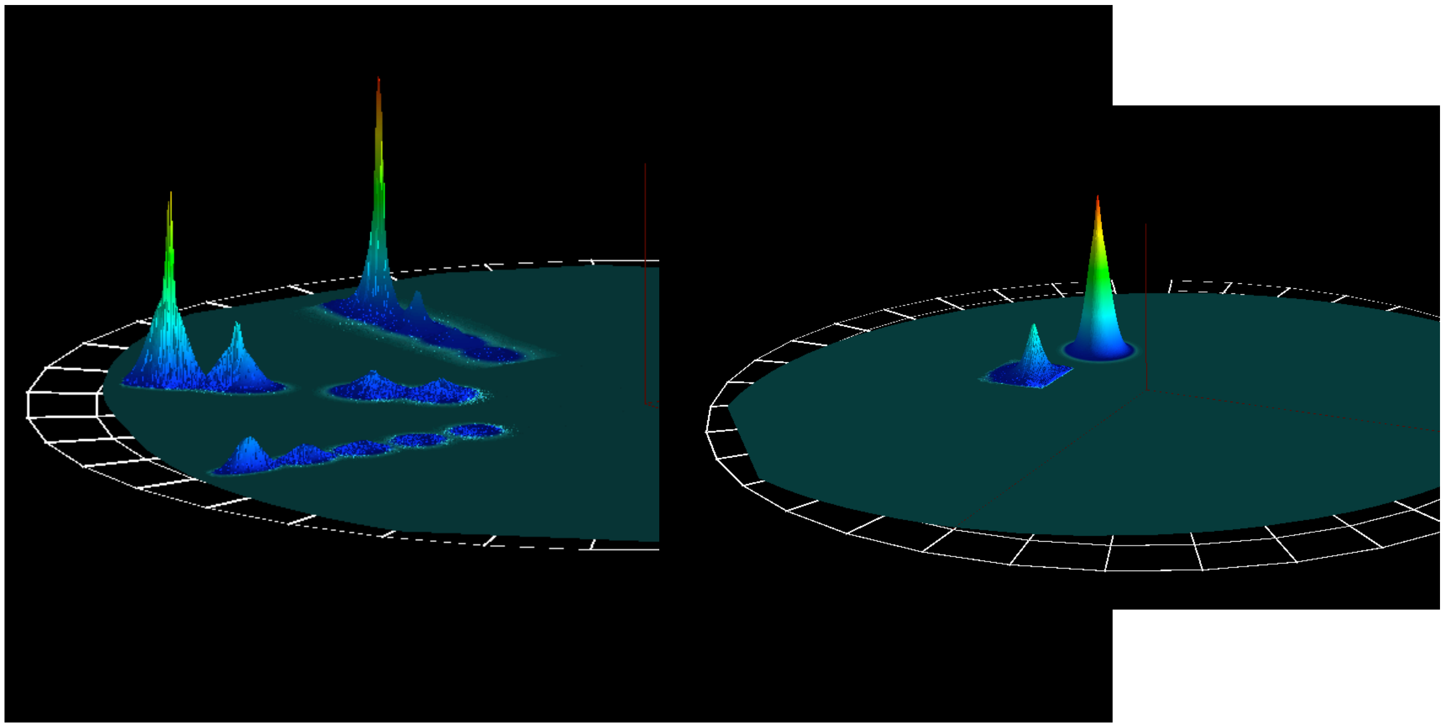




Reflection distribution curves of measured monitor, and compatible simulated material by incident angle 70



Reflection distribution curves of measured monitor, and both compatible simulated materials by incident angles 70 and 30



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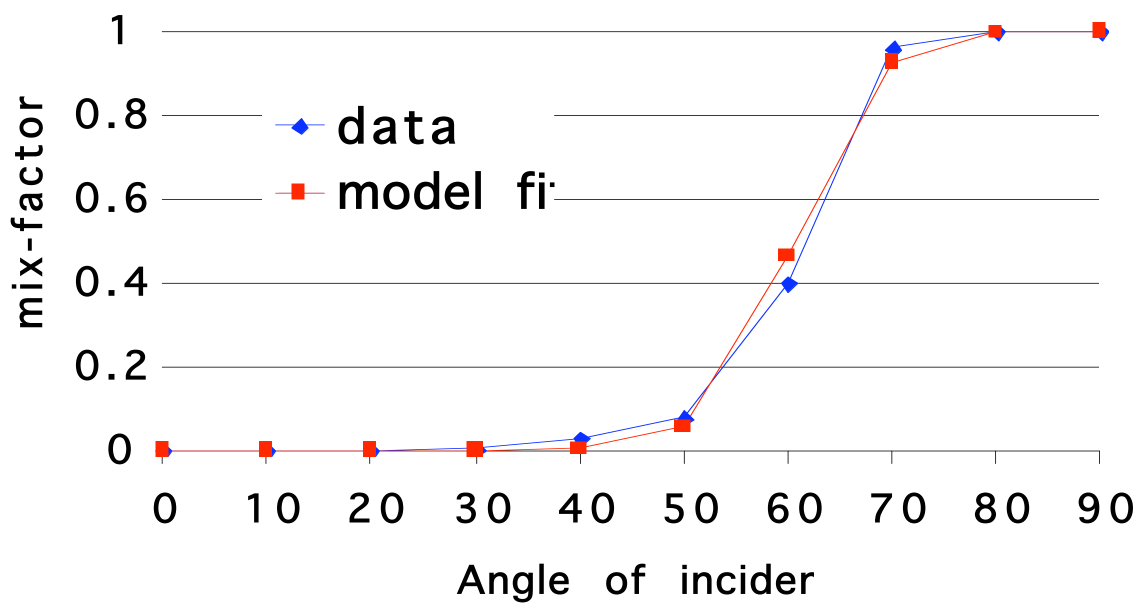
Function file for mixing two materials

$$P = \frac{e^{a+bX}}{1+e^{a+bX}}$$



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Developed model for evaluation veiling reflection

A flat screen monitor located in a room

Modelled and simulated under different daylight conditions by RADIANCE

Simulation Procedure

- Radiance Simulation ⇒ tracing light rays and calculating the accurate luminance values on the screen

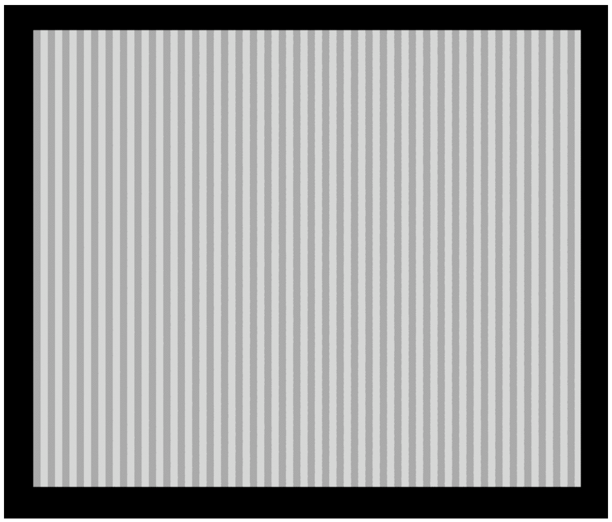
✓**Number of Pixels: 1024 * 768 = 786432**

✓**786432 luminance values**

- Octave programming ⇒ calculating existing and required contrasts between any two adjacent pixels + detection the areas of contrast requirement

- Determining the problematic zones with contrast deficiency

Screen image



Pattern, considered as screen image for performing the evaluation

Screen image ⇒ light background with darker stripes in foreground

Contrast between light and dark area (L_H / L_L) ⇒ close to the minimum required contrast

Screen image by “Brighttext” instead of “Colorpict” ⇒ a pure, pixellated, monochrome image without interpolation

Real Pixel luminance

interpolated pixel Luminance

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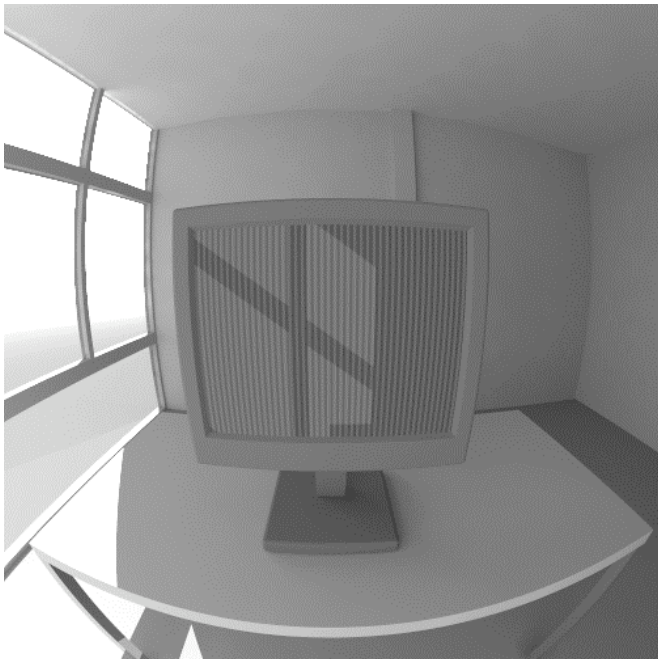
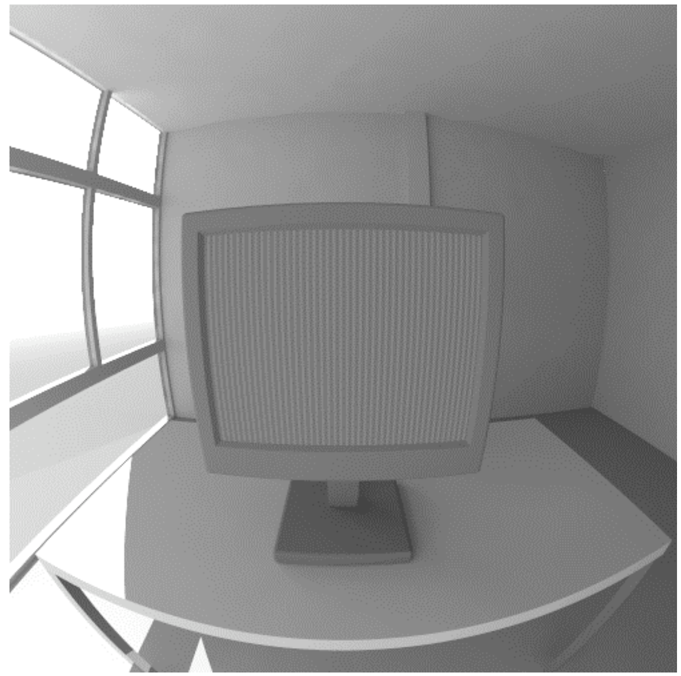
Monitor 1
Sun-altitude 20
Sun-azimuth 60



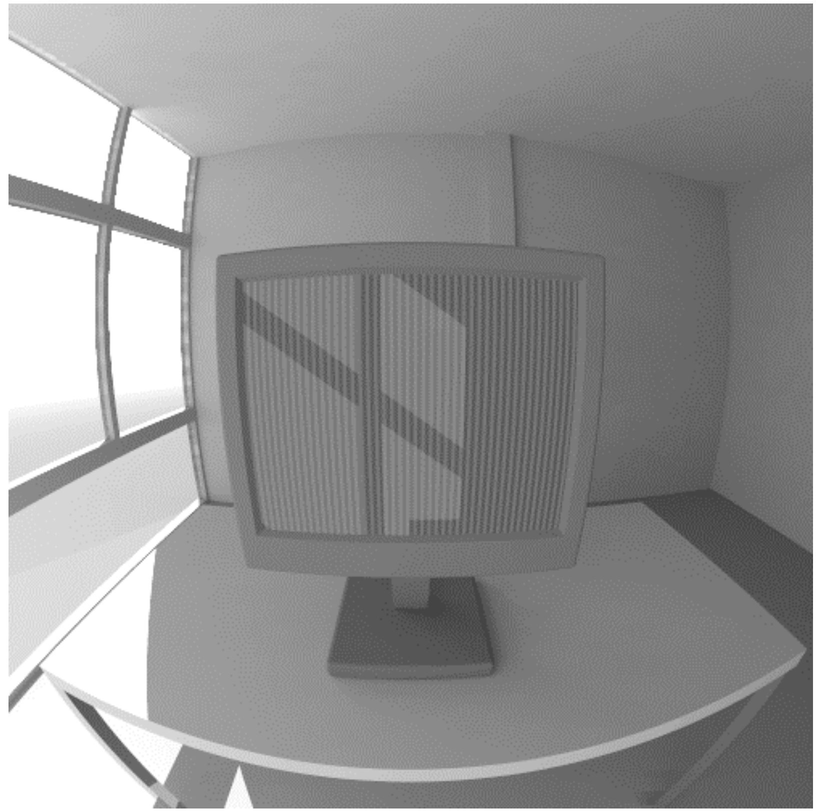
Monitor 2
Sun-altitude 20
Sun-azimuth 60



Monitor 3

Sun-altitude 20

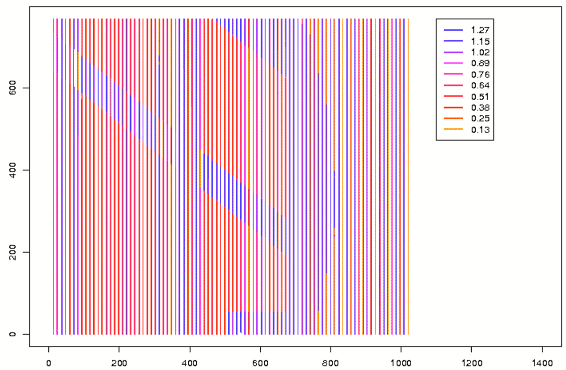
Sun-azimuth 60

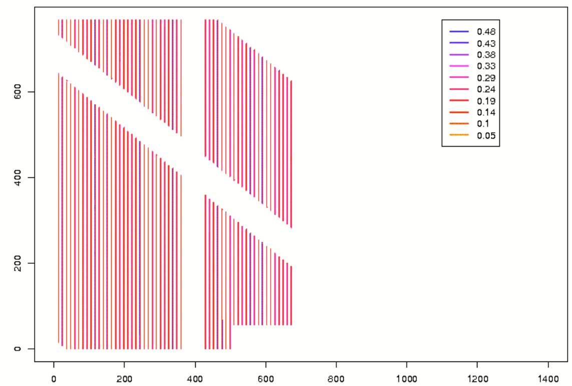


Contrast deficiency

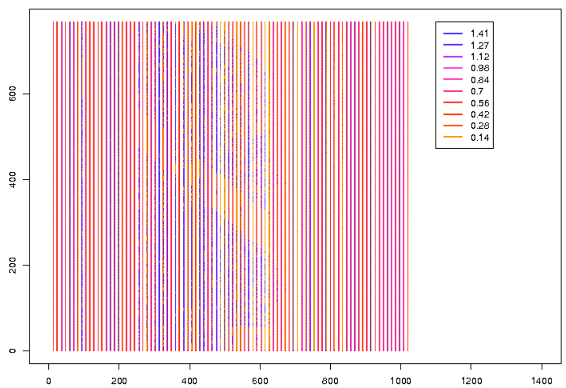
Contrast model 2 | **Contrast model 1**

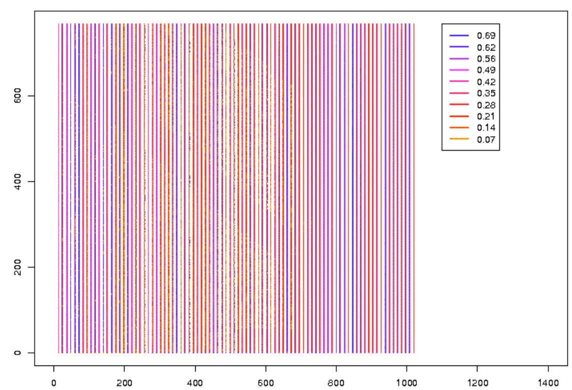
monitor 1



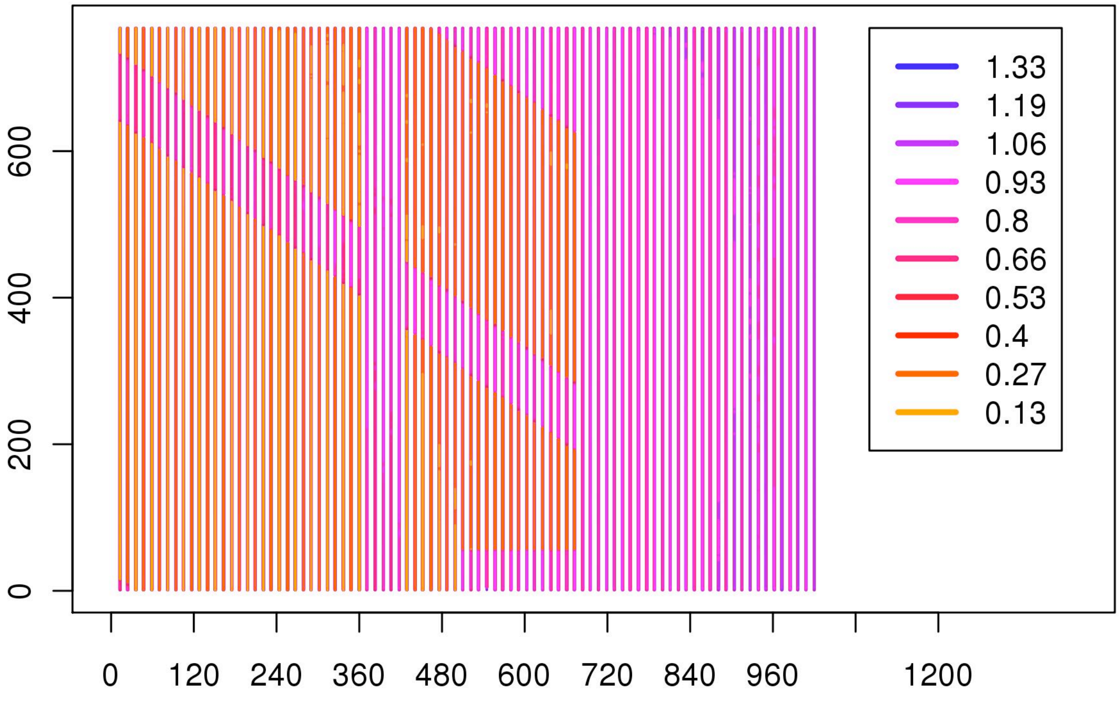


monitor 2





Monitor 2 Contrast model 2



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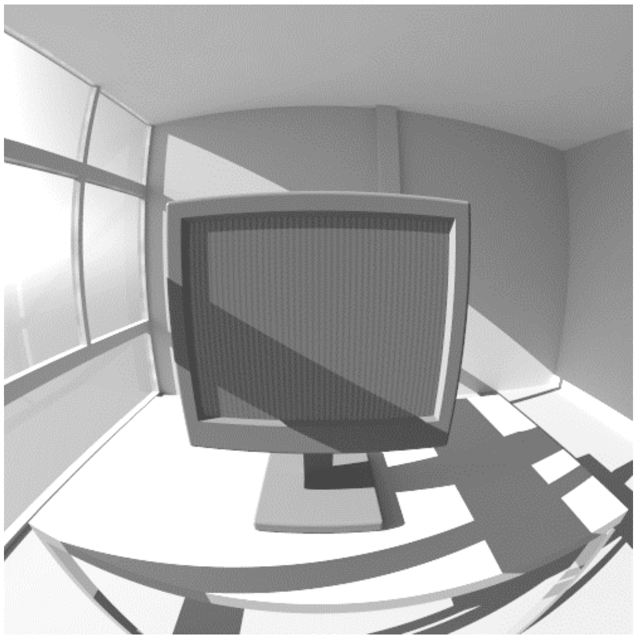
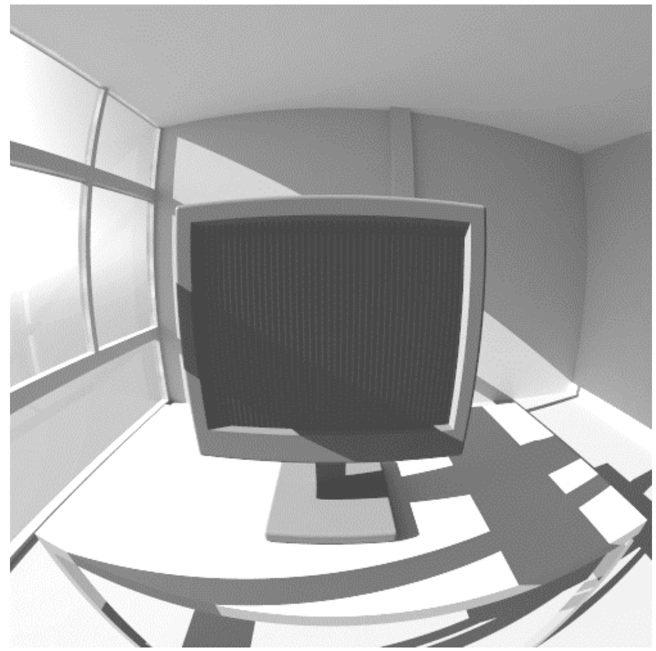
Monitor 1
Sun-altitude 30
Sun-azimuth -10



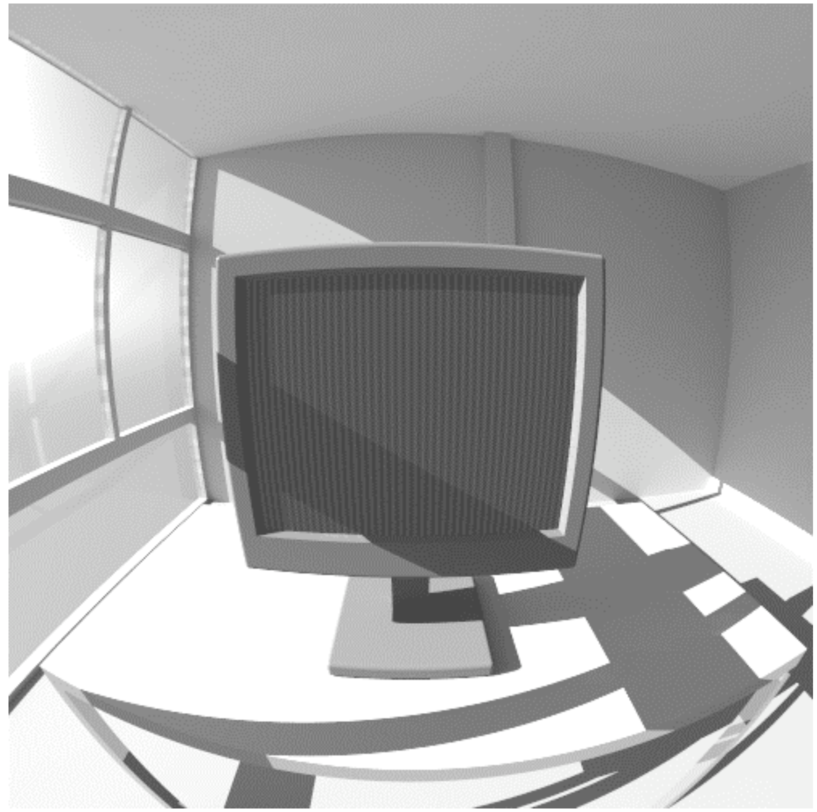
Monitor 2
Sun-altitude 30
Sun-azimuth -10



Monitor 3

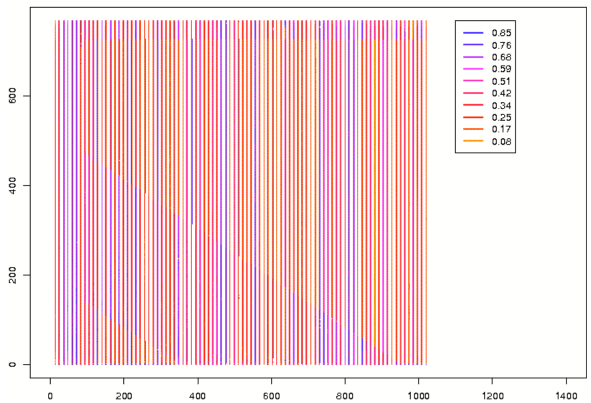
Sun-altitude 30

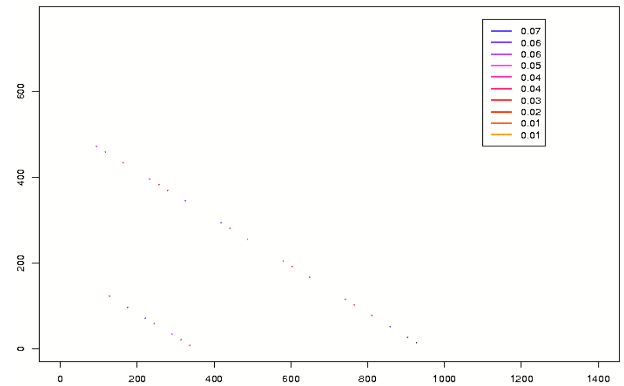
Sun-azimuth -10



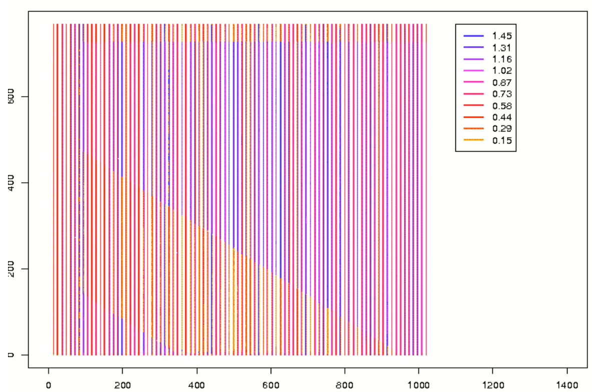
Monitor 2 | Monitor 1

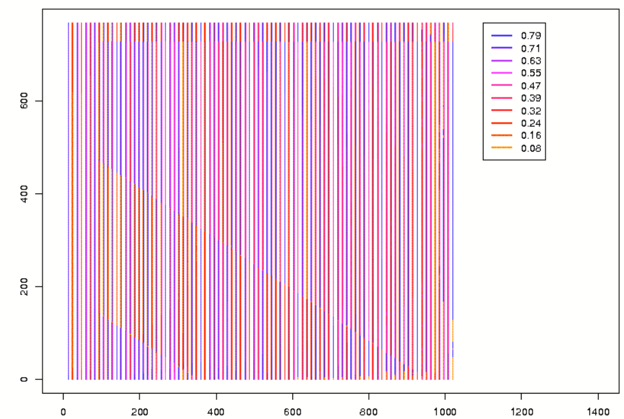
Contrast model 1



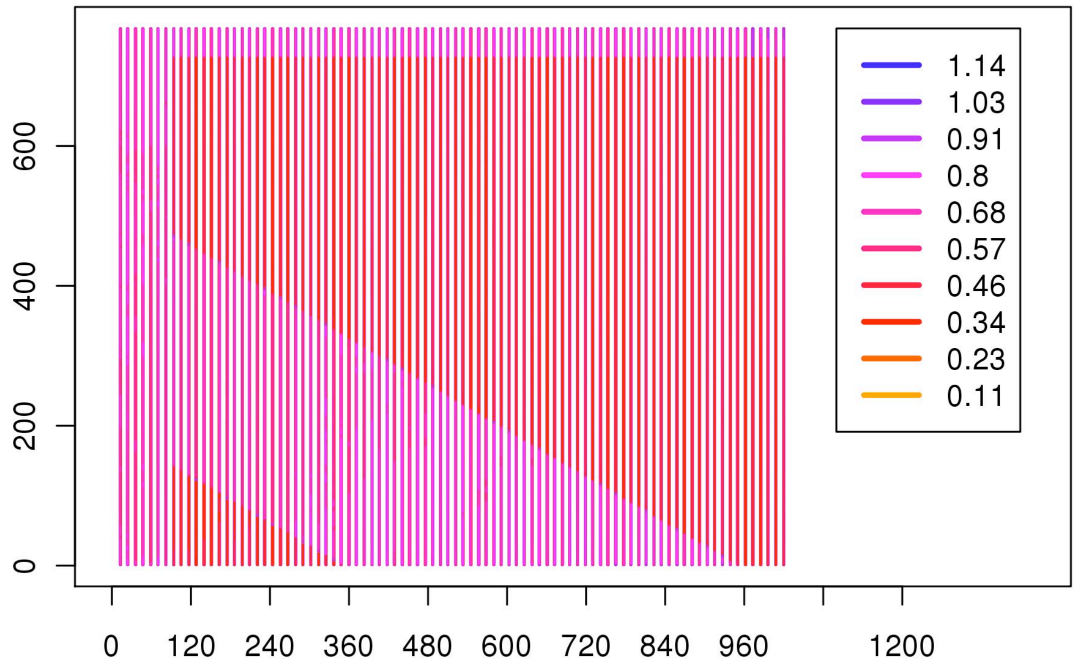


Contrast model 2

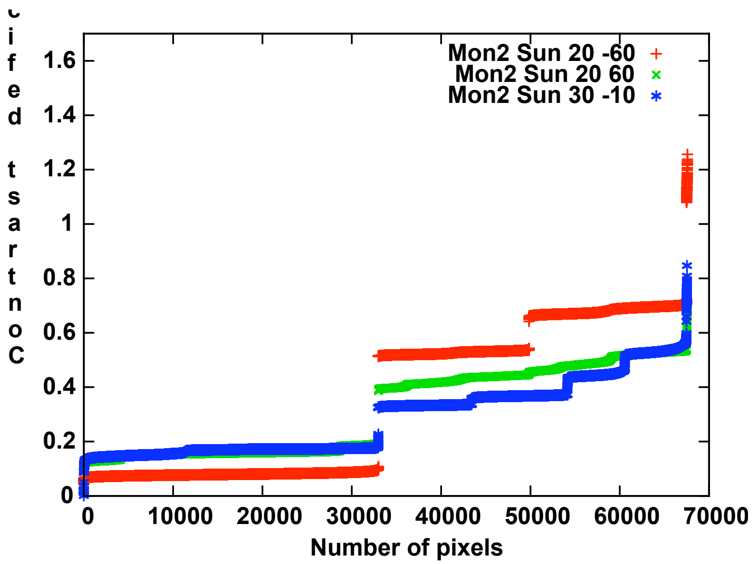




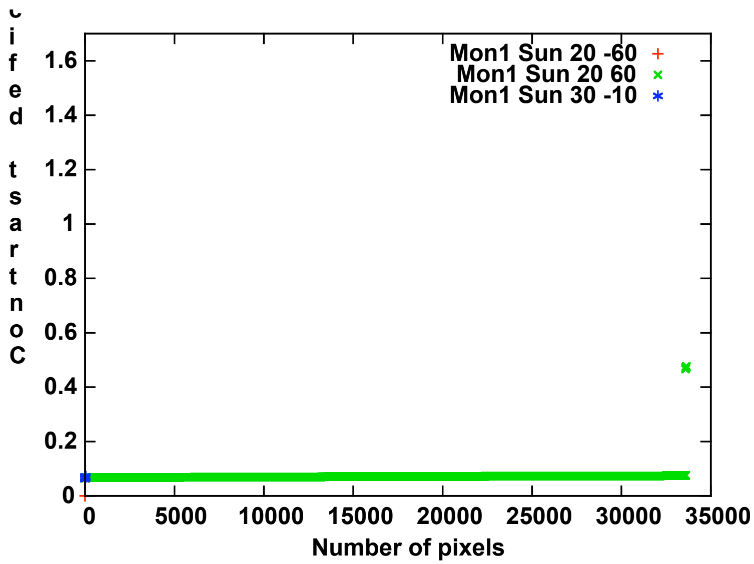
Monitor 2 Contrast model 2



Pixels with contrast deficiency



Monitor 2 Contrast model 1



Monitor 1 Contrast model 1

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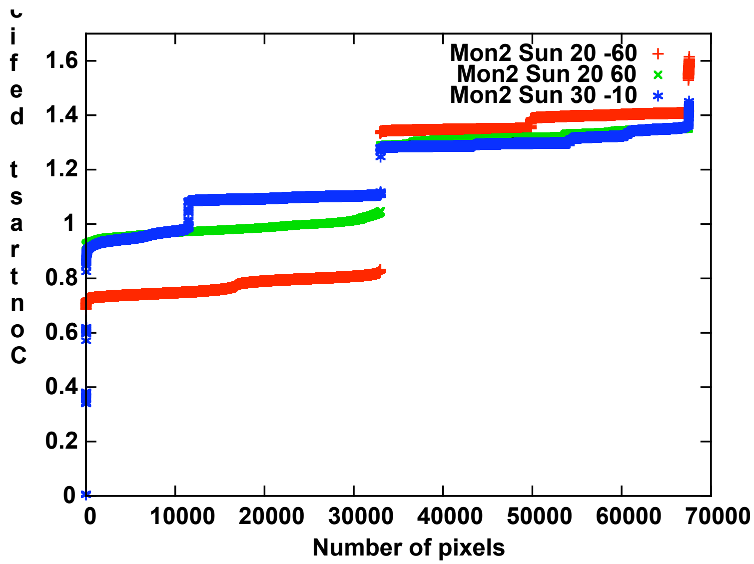
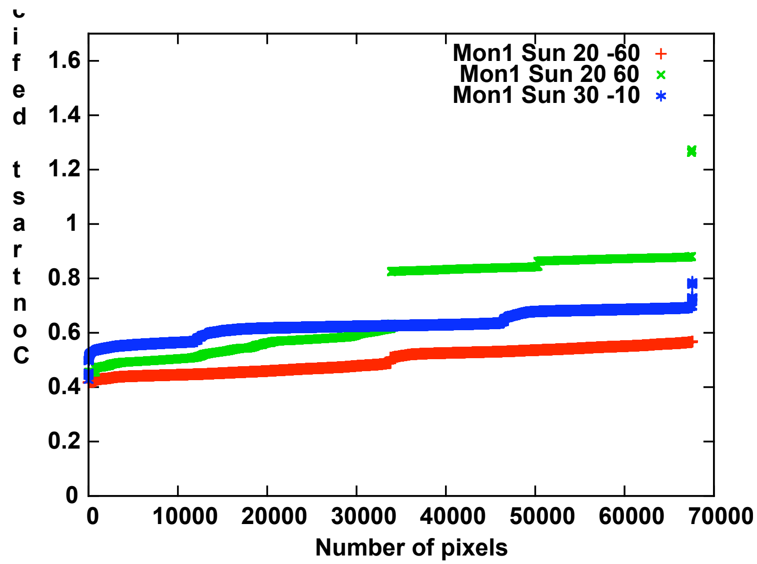
Pixels with contrast deficiency

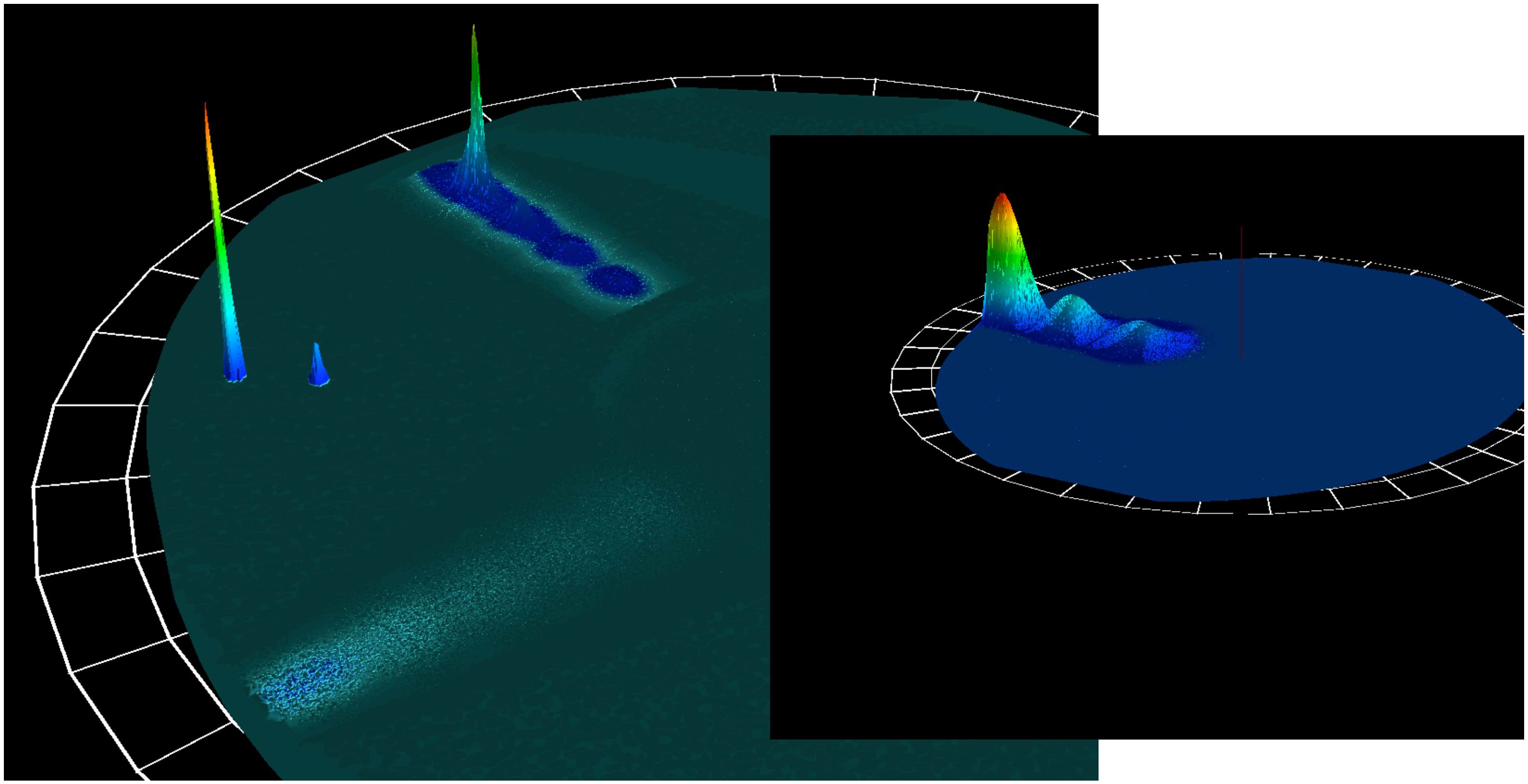




Monitor 2 Contrast model 1

Monitor 1 Contrast model 1

BRDF differences of three monitor models



Conclusions

For an accurate veiling reflection study on monitor screen by means of simulation, it is necessary to have access to:

1- An accurate contrast model, so far not available

Existing contrast model should be validated or be improved by user assessment study.

2- Monitor screen characteristics:

- Direct and total reflection
- Reasonable value of roughness
- Angular dependency characteristic for precisely modeling

Thank you for your attention!!

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