Predicting Visibility during the Design Phase+

Designing Visually Accessible Spaces
NIH Grant 2 R01 EY017835-06A1

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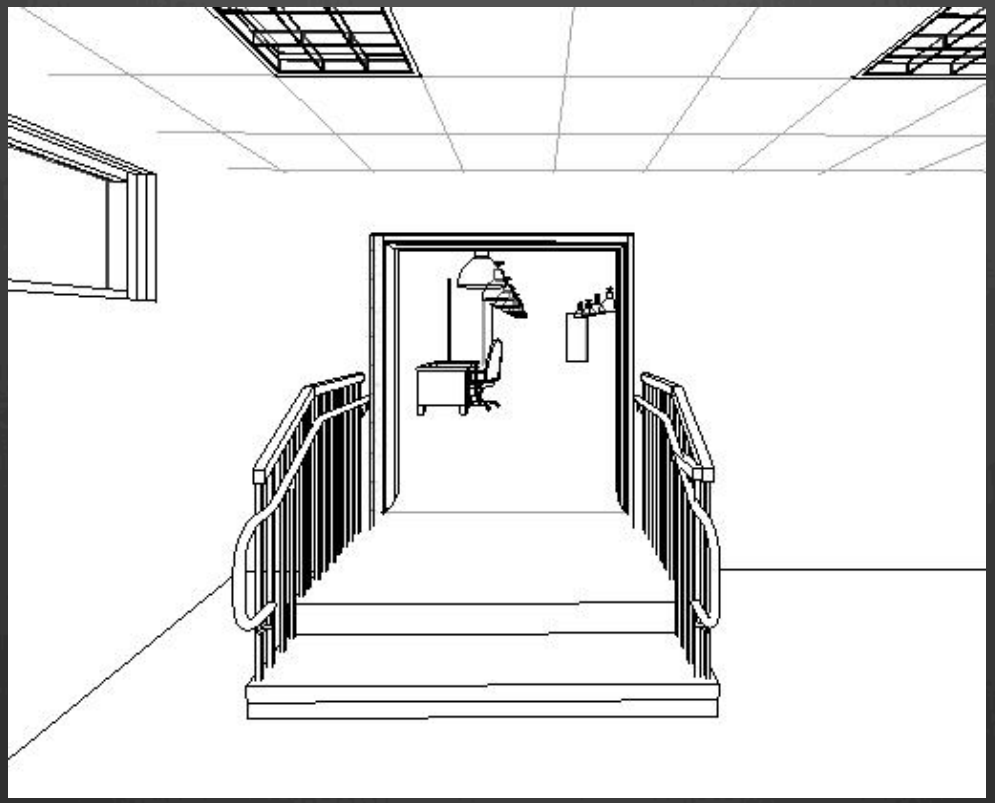
Indiana University PI

Other research team members from:
University of Minnesota
University of Utah

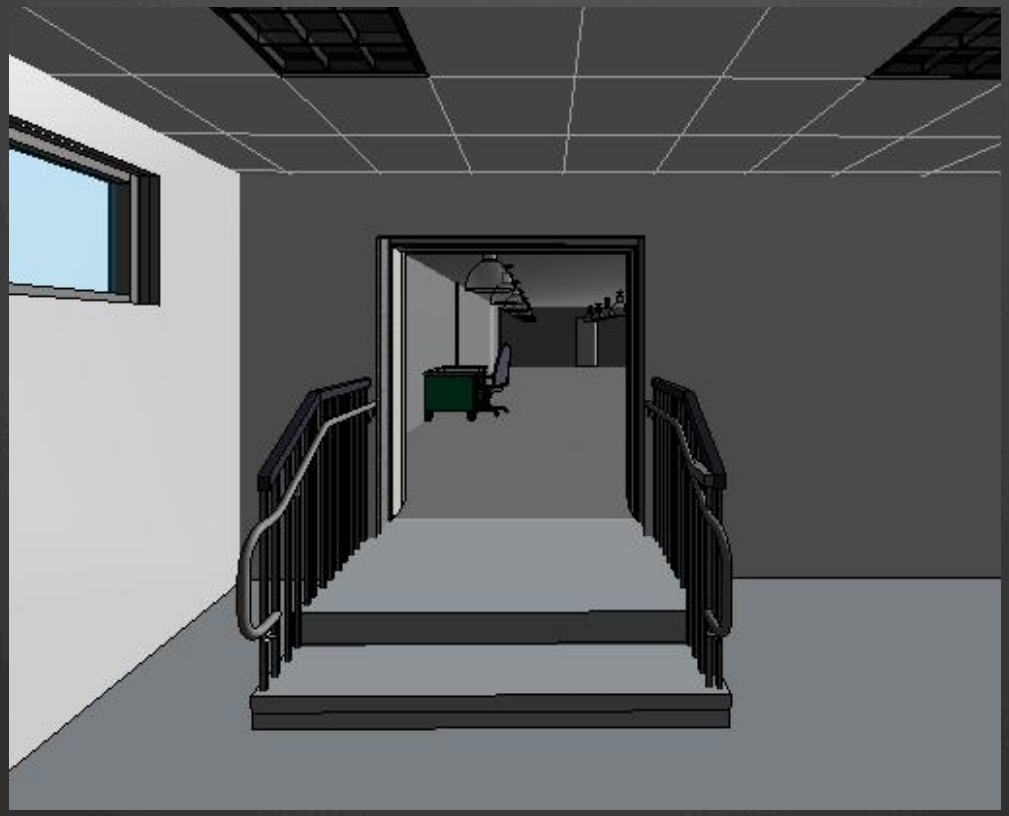
2018

Design Phase Tools



3d CAD

Design Phase Tools



Sketchup

Design Phase Tools

Revit

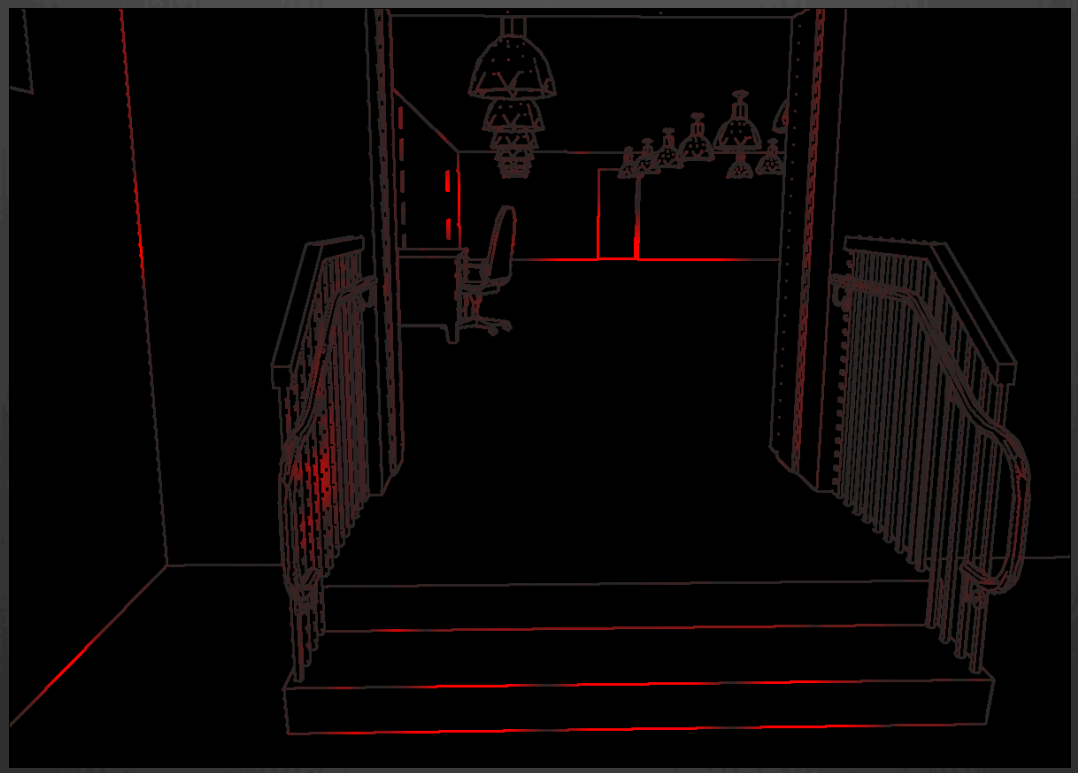
Design Phase Tools

Radiance with specified materials/photometry

Design Phase Tools

Moderate Low Vision Filter

Design Phase Tools

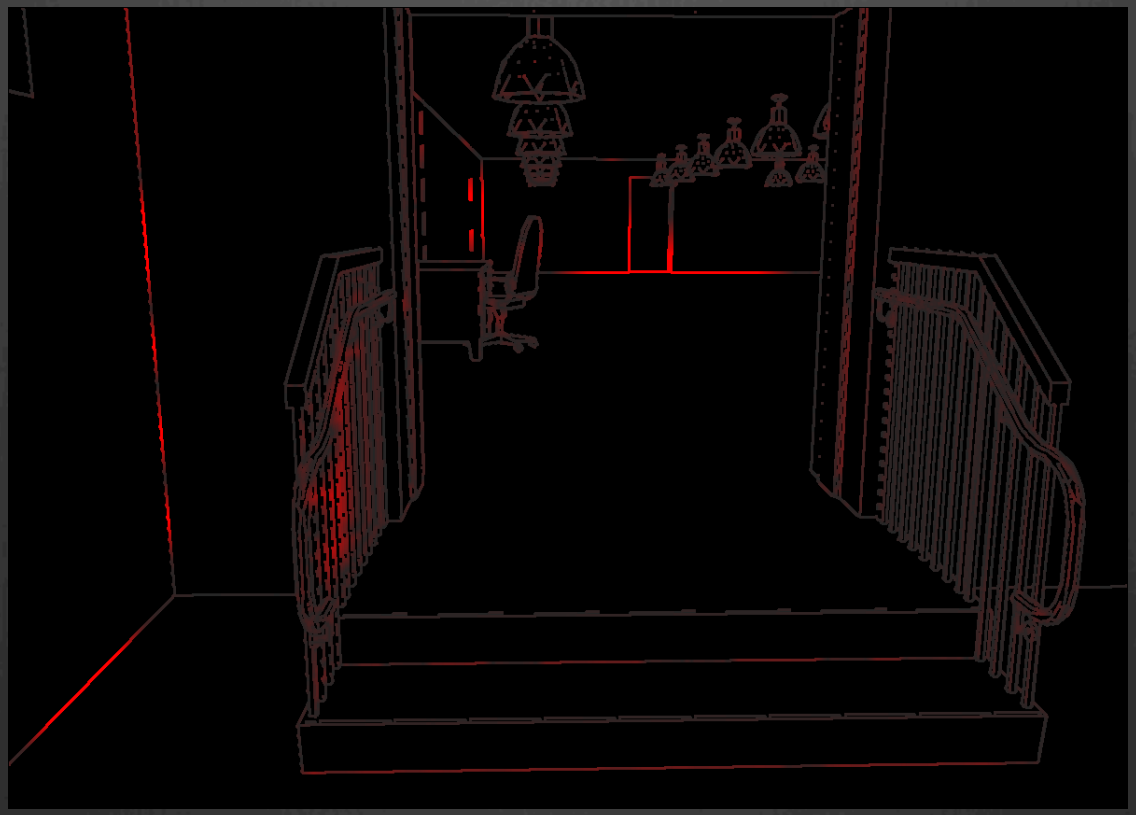


RED – edged predicted not-visible

Design Phase Tools

Add high contrast stripe on steps

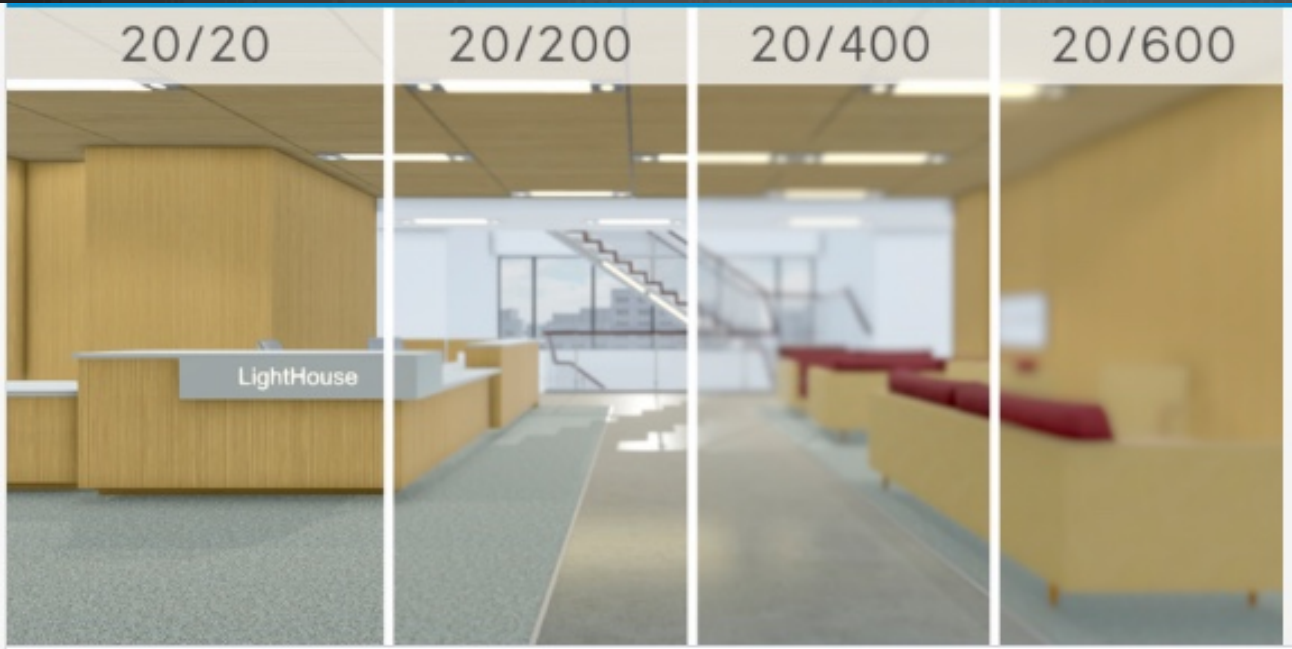
Design Phase Tools



Predicted to be Visually Accessible
for Moderate low Vision

Current Approaches to Visual Accessibility…

Excellent for **Sensitizing Designers**… **Subject Evaluation only**



MULTIPLE DATES

See Your Designs Through Someone Else's Eyes, A New Virtual Reality Experie…

by LightHouse for the Blin…

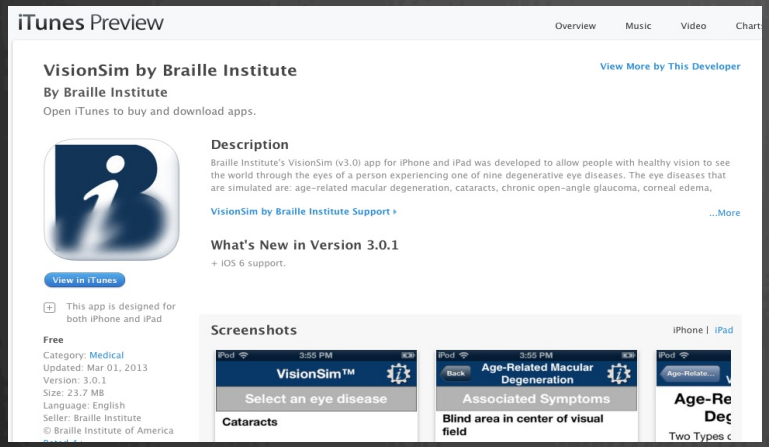
$10

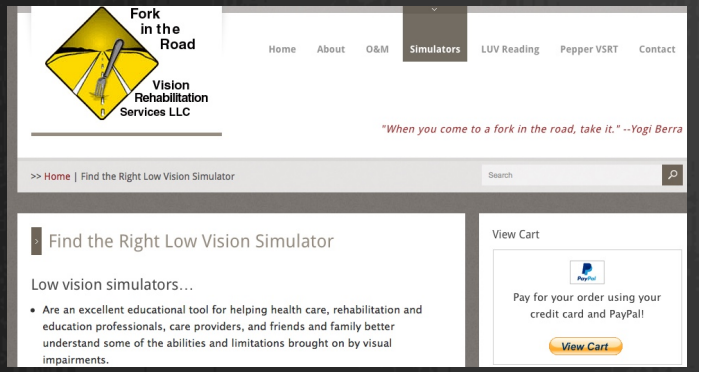
"From the subtle, gauzy effects of cataracts to the more dramatic challenges of tunnel vision… changes in vision are incredible hard to convey in words… Fully sighted designers can guess, but rarely know how to optimize their products for low vision"

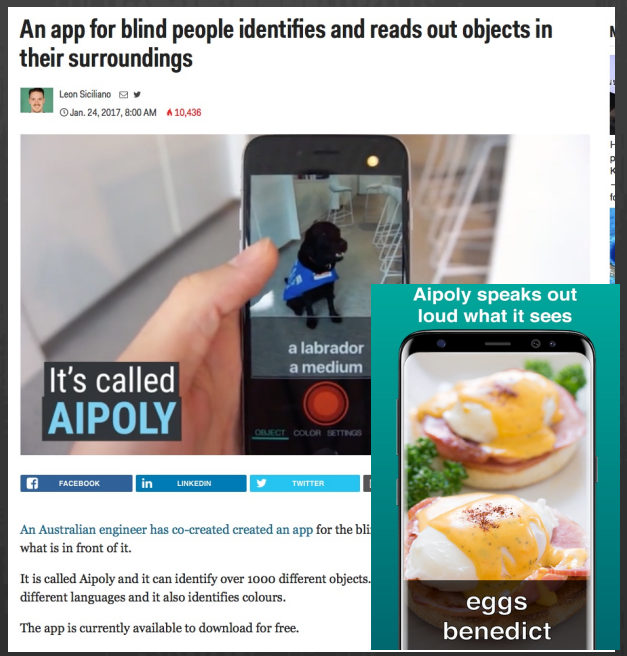
- *Theia Immersive*

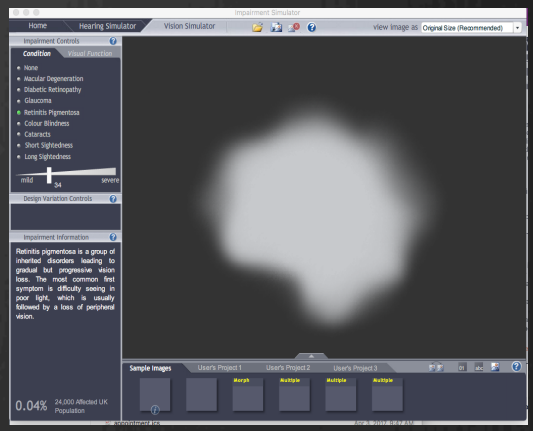
Current Approaches to Visual Accessibility…

Sensitizing tools…new aids…









many more ….

Current Approaches to Visual Accessibility…

Recommended Practices

AIA sessions

Designing Supportive Environments for People with Low Vision

Session #14
Friday, October 16, 2015
1 LU/HSW

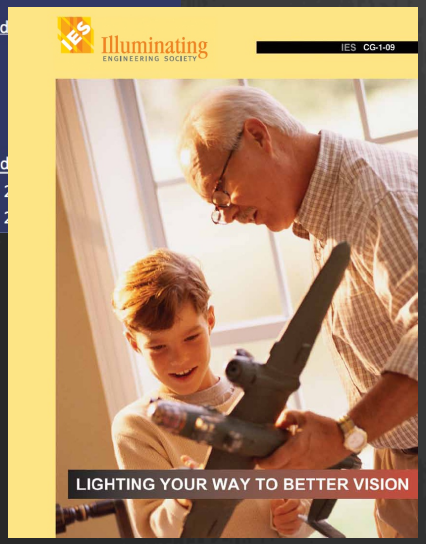
DESIGNING FOR LOW VISION

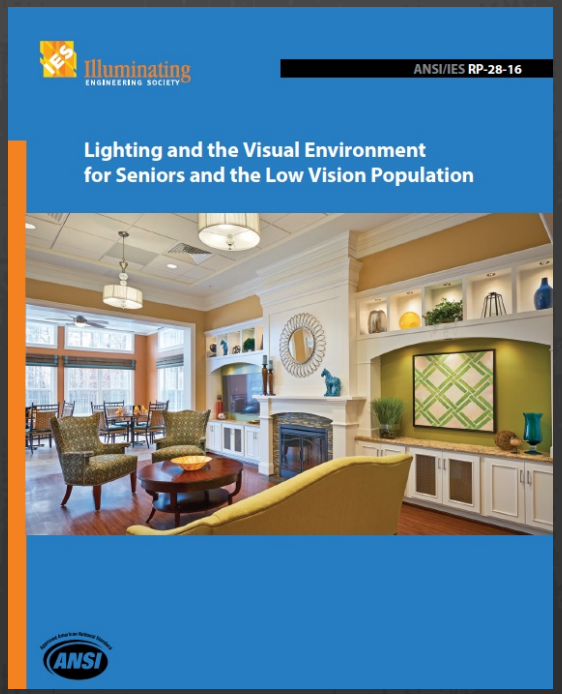
ASHRAE/IES 90.1 - 2016

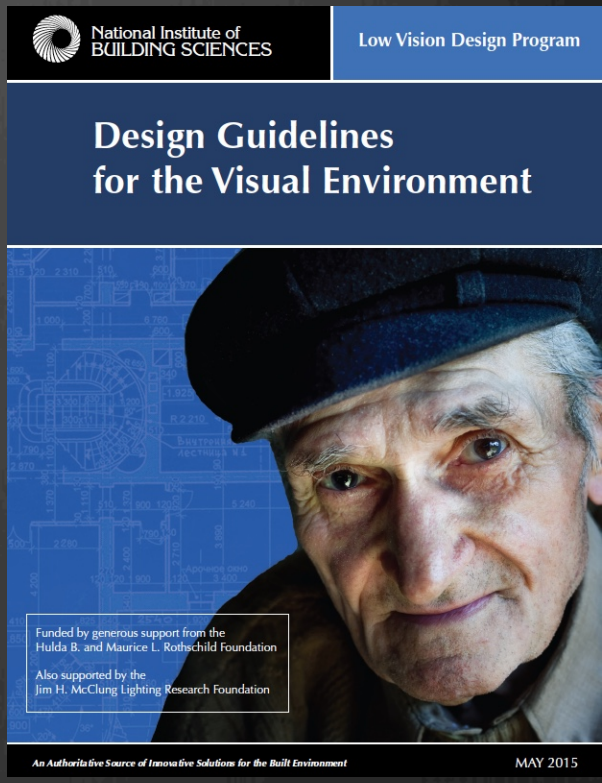
Higher LPD's provided for Visually Impaired:
Table 9.6.1 (Pages 95 – 99)

Space type:	Typical	Visually impaired
Dining/Activity Areas:	.65	2.65
Corridors:	.66	.92
Lobbies:	.90	1.80
Restrooms:	.98	1.21

Building Type	Typical	Visually Impaired
Living Room/Recreation:	.73	
Chapel	1.53	







Design Guidelines…

Now we have a tool that PREDICTS

Now we have a tool that PREDICTS

Wheelchair

20/45
LogMAR 0.35
color 75%

20/115
LogMAR 0.75
color 40%

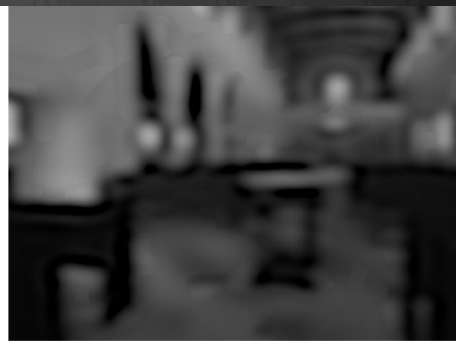
20/285
LogMAR 1.15
color 25%

20/710
LogMAR 1.55
color 0%

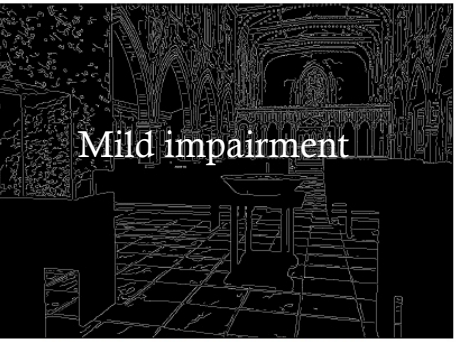
Simulation of *mild* visual impairment.

Simulation of *moderate* low vision.

Simulation of *severe* low vision.



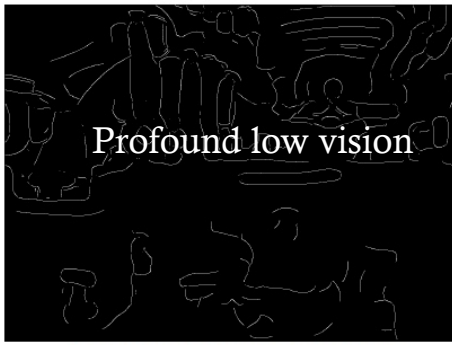
Simulation of *profound* low vision.



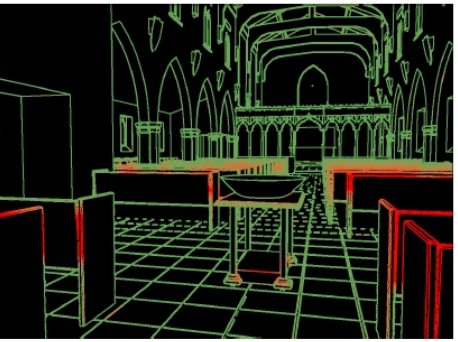
Canny edges for *mild* visual impairment.

Canny edges for *moderate* low vision.

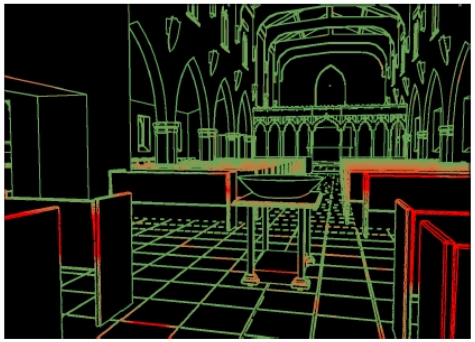
Canny edges for *severe* low vision.



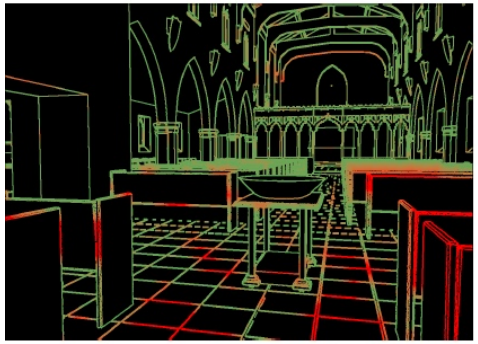
Canny edges for *profound* low vision.



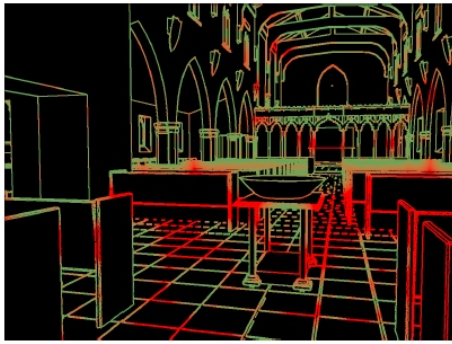
Predicted visibility of geometry under *mild* visual impairment.



Predicted visibility of geometry under *moderate* low vision.



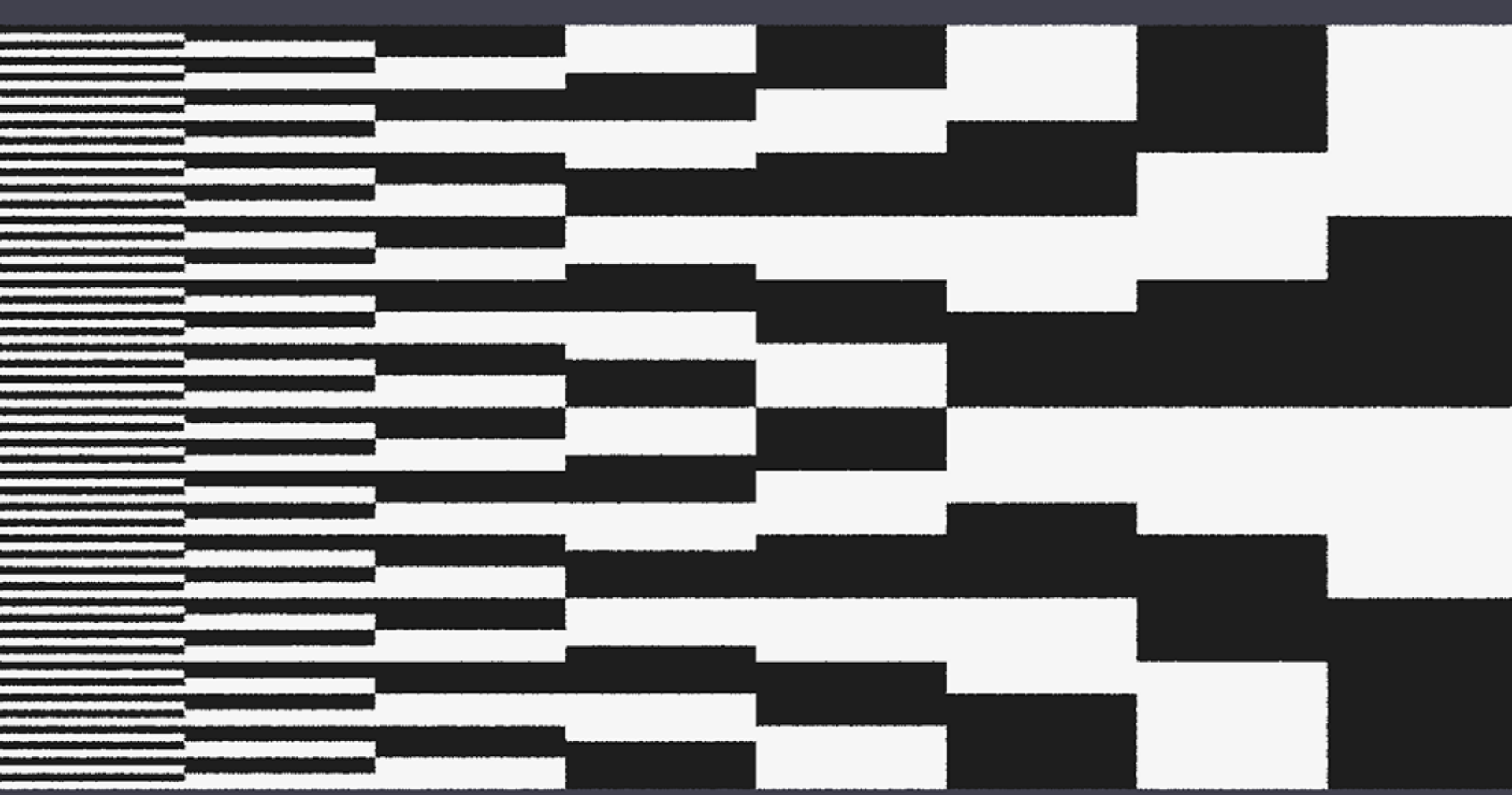
Predicted visibility of geometry under *severe* low vision



Predicted visibility of geometry under *profound* low vision

Background

Acuity and Contrast



20/20

30 cpd

Acuity

20/40

15 cpd

20/80

7.5 cpd

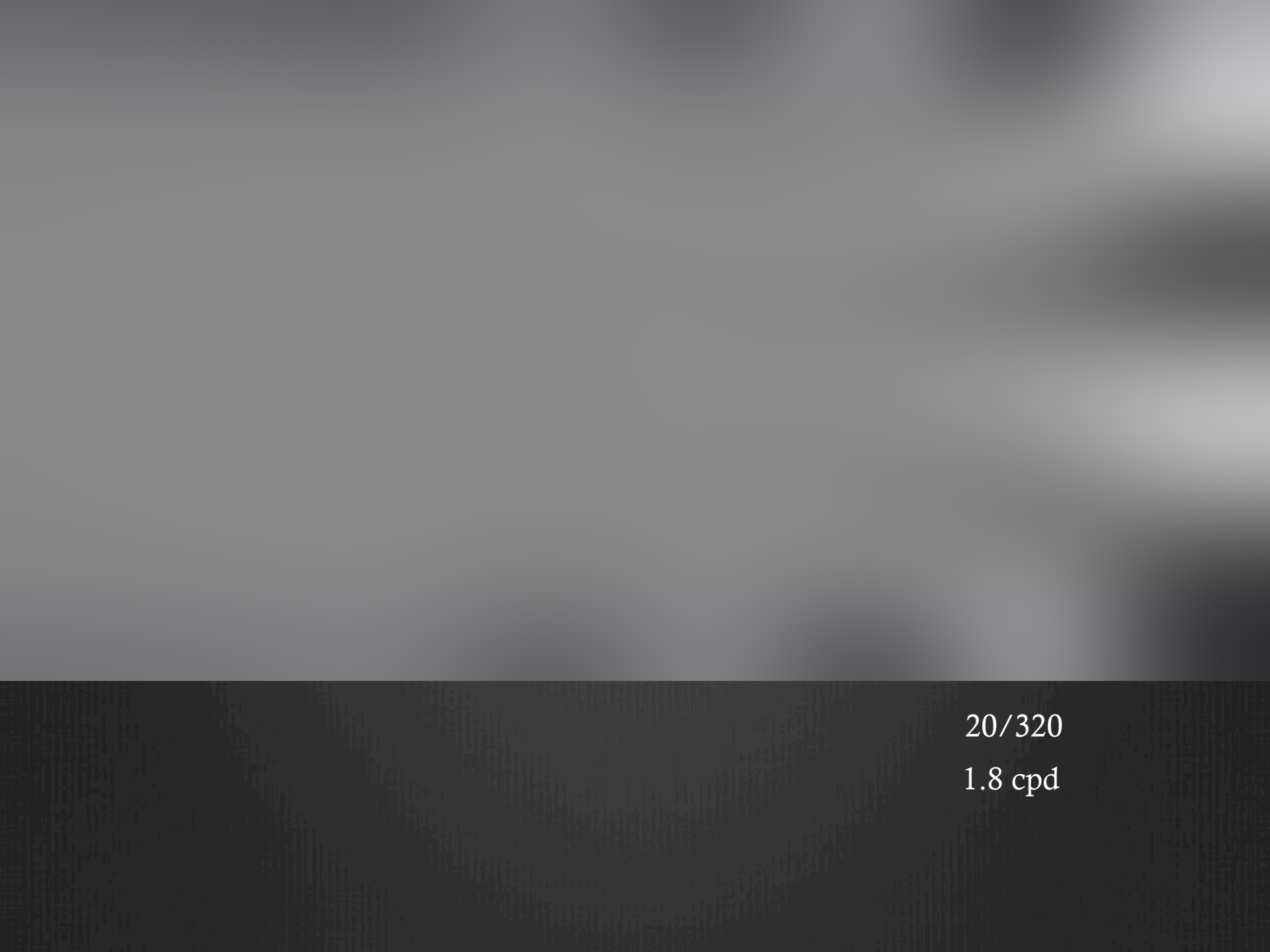
20/120

5 cpd

20/160

3.75 cpd

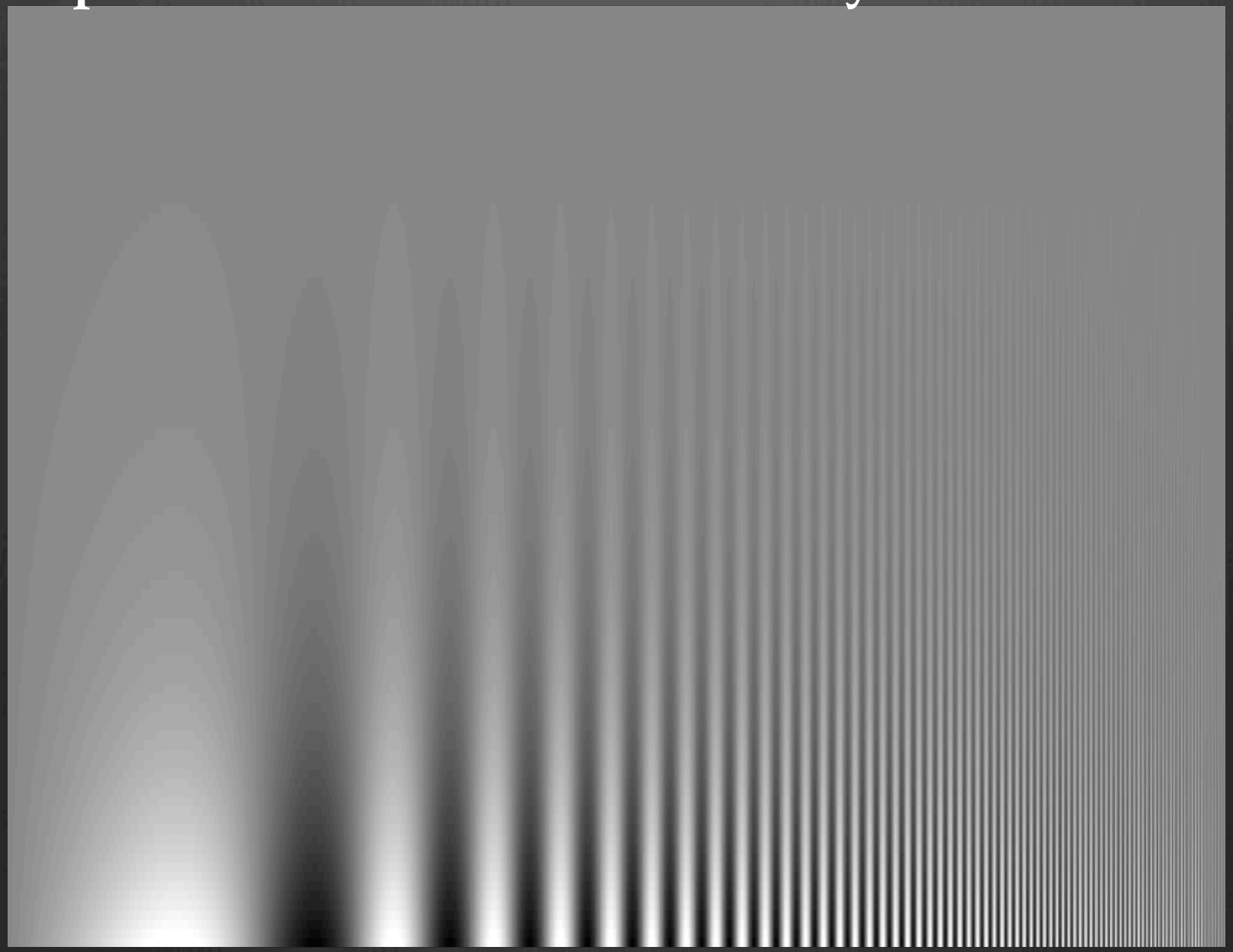

20/240
2.5 cpd


20/320
1.8 cpd

YIKES!!

VERY Low Acuity

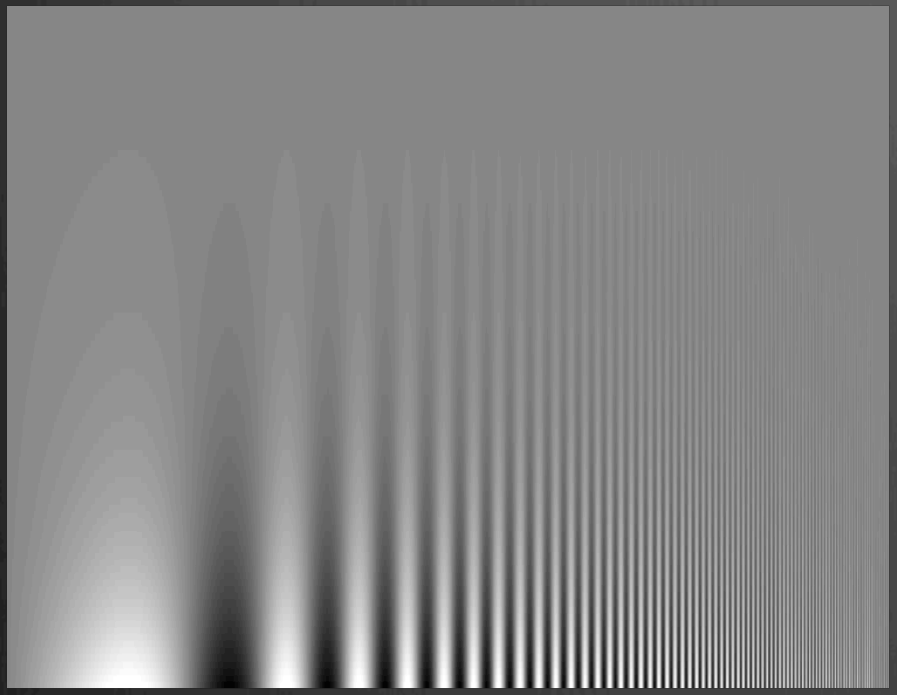
Campbell-Robson Contrast Sensitivity Function Chart

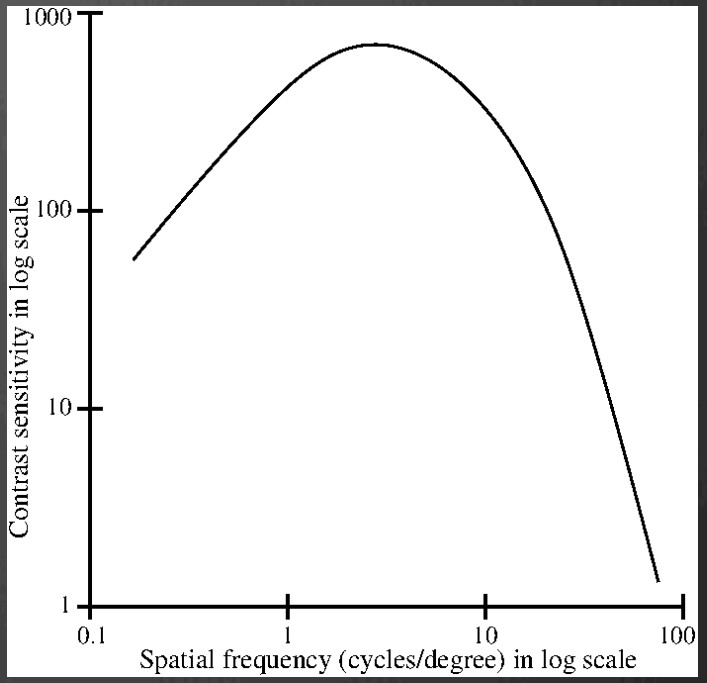


Contrast decreases from 100% to .05%

Frequency of sine wave (black to white) increases

Campbell-Robson Contrast Sensitivity Function Chart

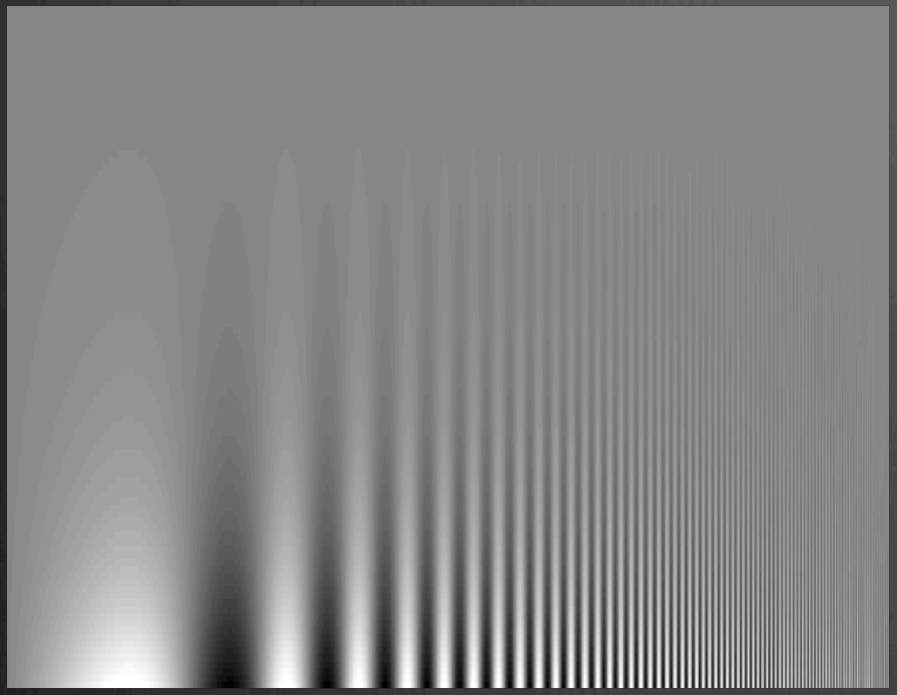


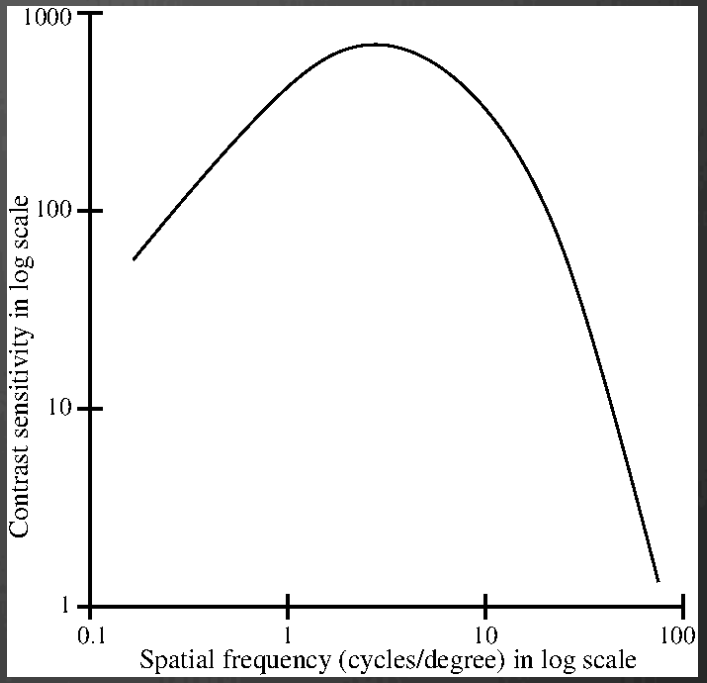


Courtesy of William Thompson

The inverted "U" shape is not in the image.. It reflects the property of your visual system .

Campbell-Robson Contrast Sensitivity Function Chart



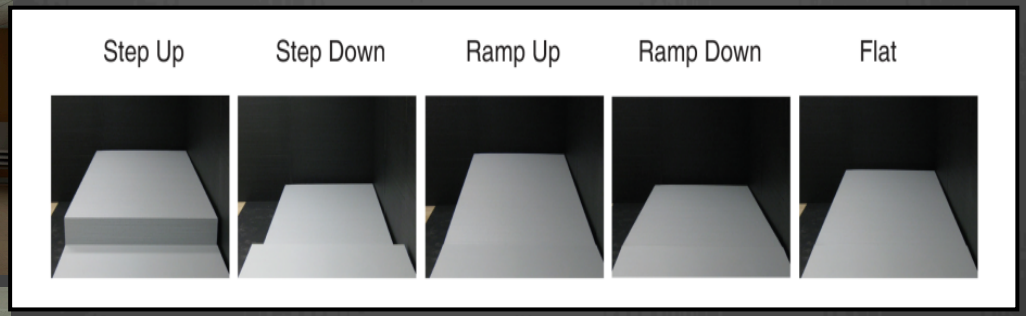


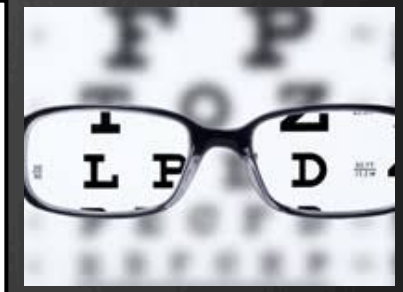
If detection of contrast is dictated solely by image contrast, the bars would appear to have equal height across the image.

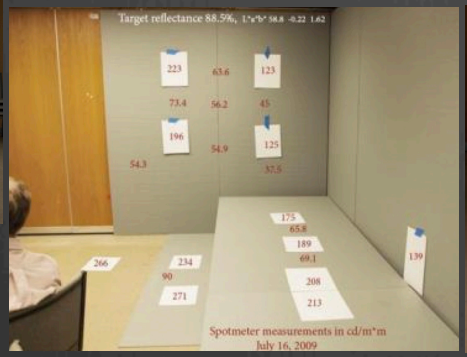
The function of size of image features = the spatial frequency

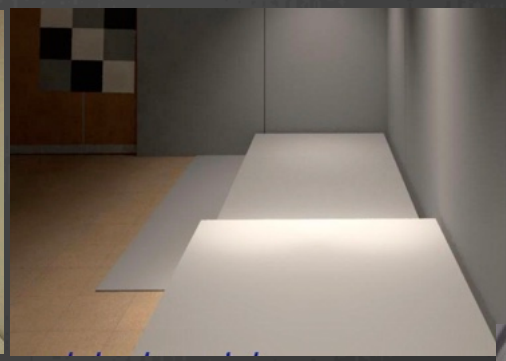
Almost a decade of human studies to explore low vision

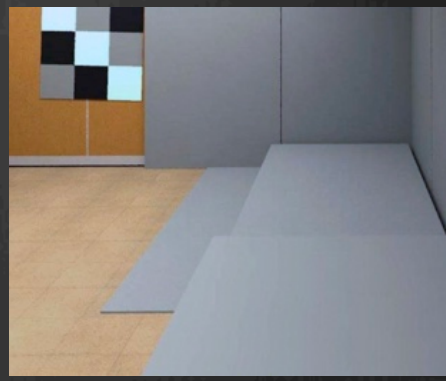
Hazard Detection & Navigation

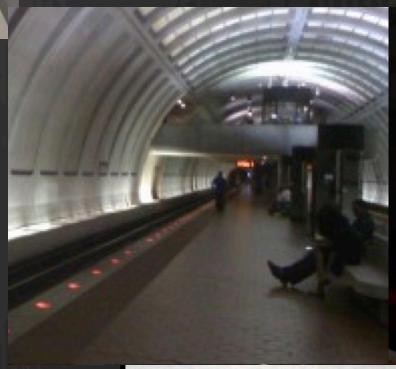












So how does the Visibility Prediction Tool work? …

Our approach builds on the work of Eli Peli, who described a method for transforming an image to simulate the visibility associated with a particular Contrast Sensitivity Function (CSF).

An explanation of the approach in laymen's terms..

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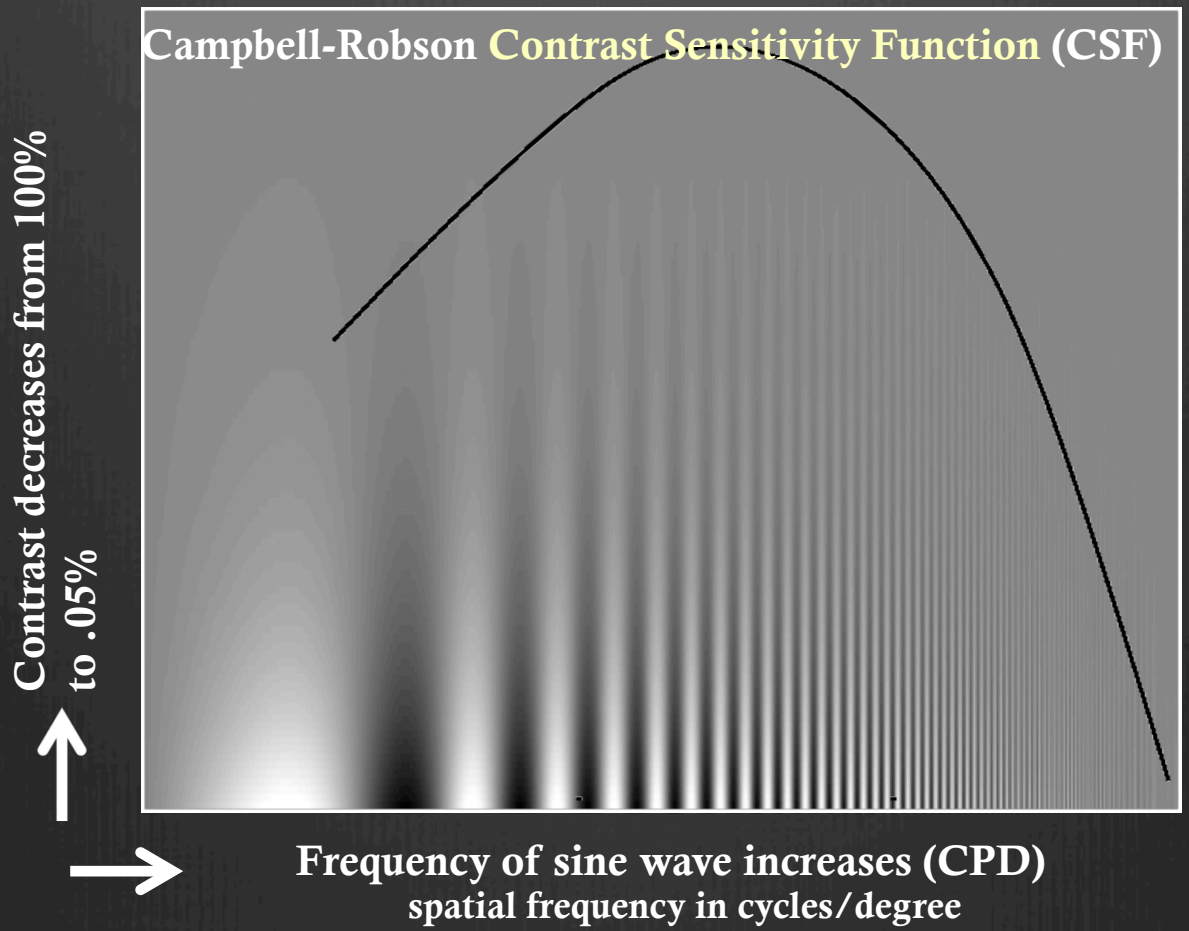

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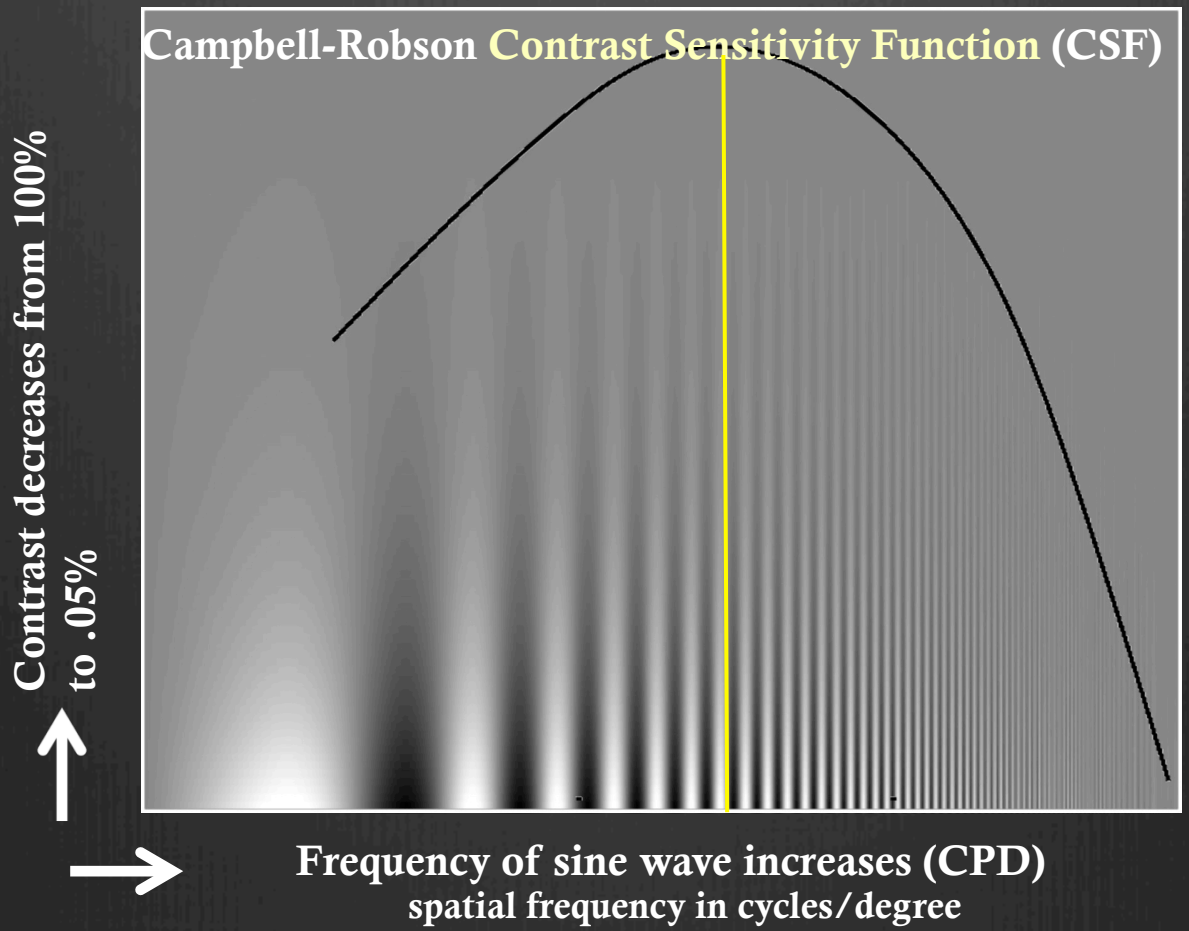

CS peaks at 2 CPD for normal 20/20

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- Several functional forms of the CSF in modeling human vision
- we chose the only one that has been shown to fit empirical data from a group of low-vision subjects. (Chung and Legge: 2016)

Slide left for reduced Acuity – Slide down for reduced Contrast Sensitivity

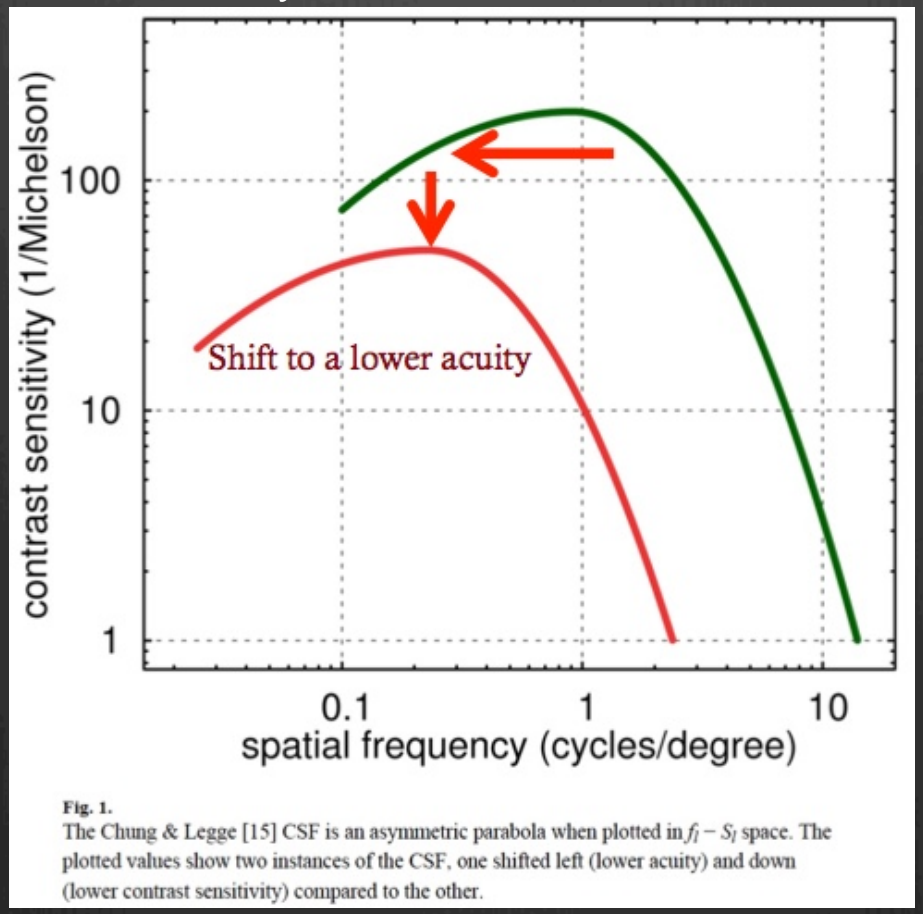

Fig. 1.
The Chung & Legge [15] CSF is an asymmetric parabola when plotted in $f_l - S_l$ space. The plotted values show two instances of the CSF, one shifted left (lower acuity) and down (lower contrast sensitivity) compared to the other.

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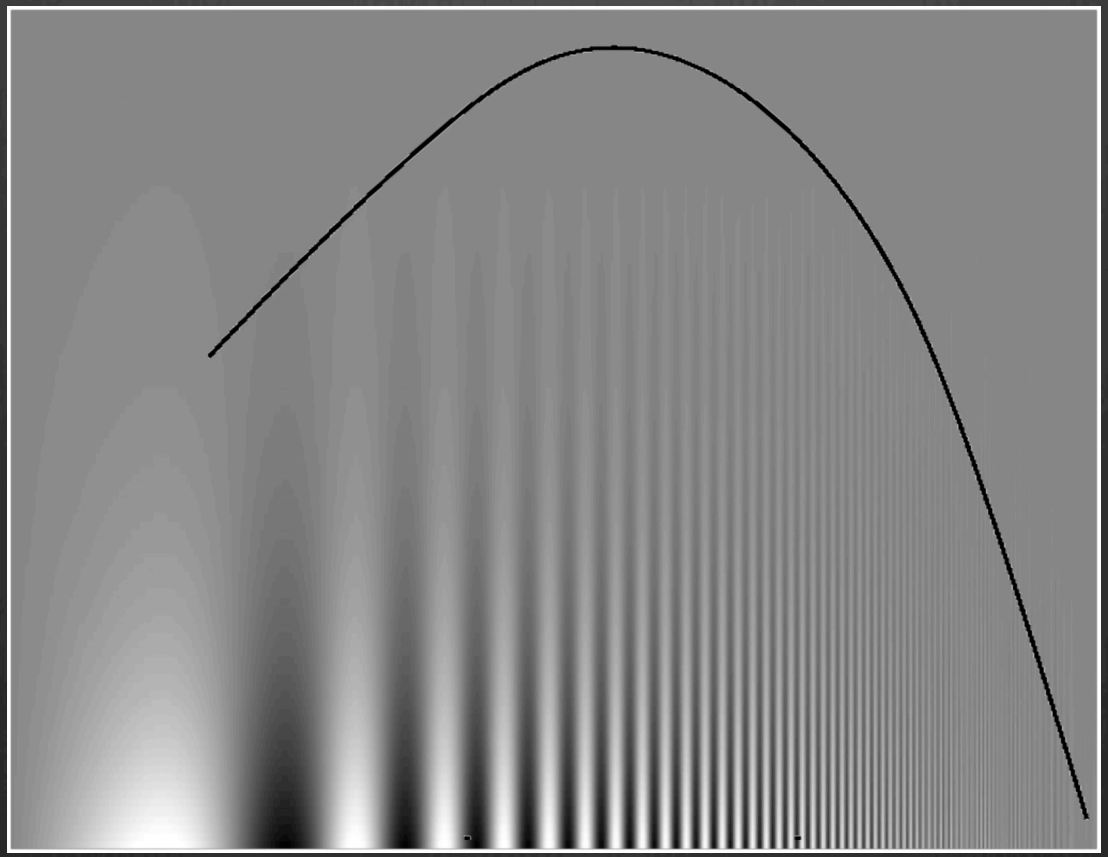

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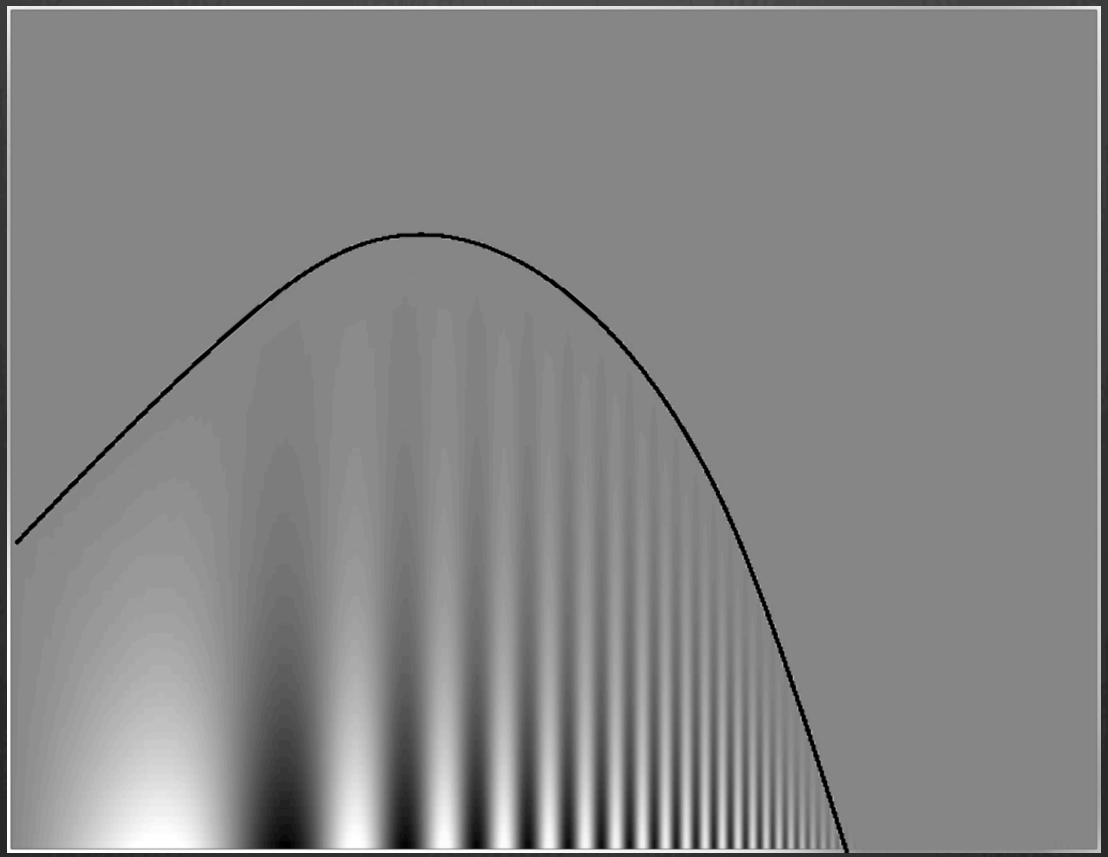

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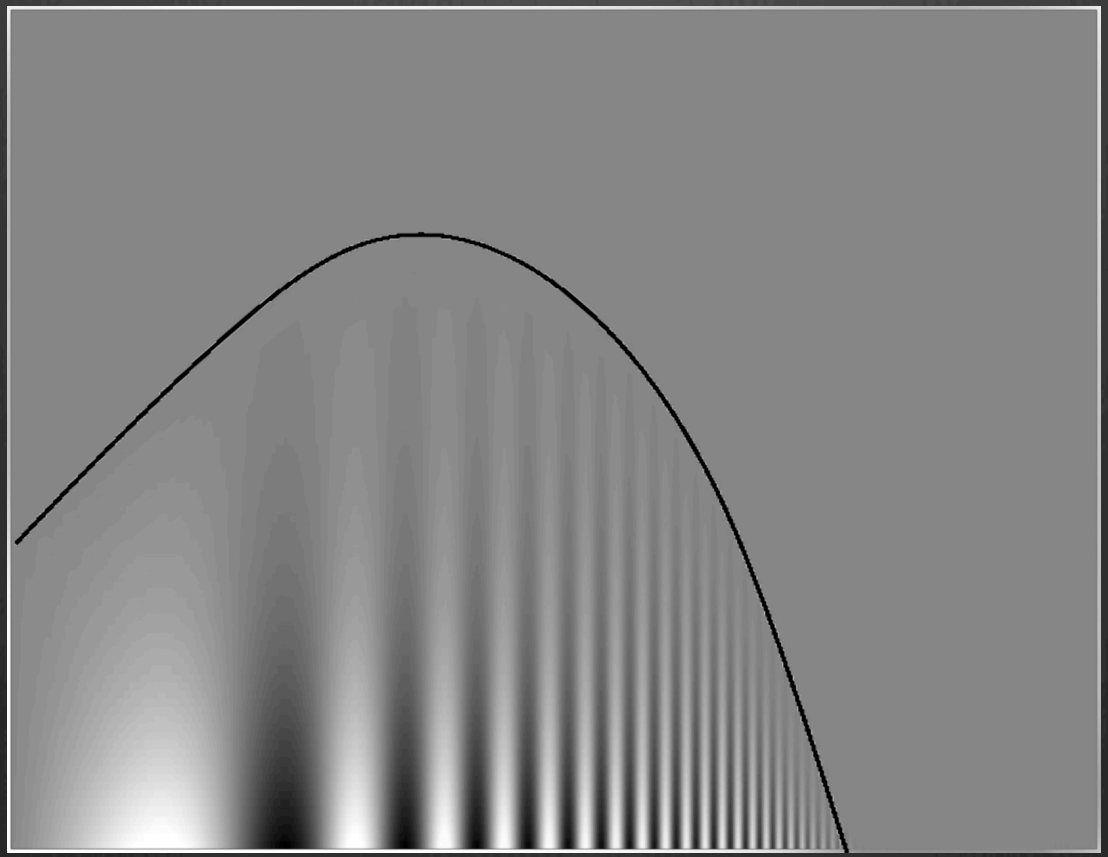
-An image is first transformed into a set of bandpass images, each representing an unnormalized contrast measure over a narrow range of spatial scales.



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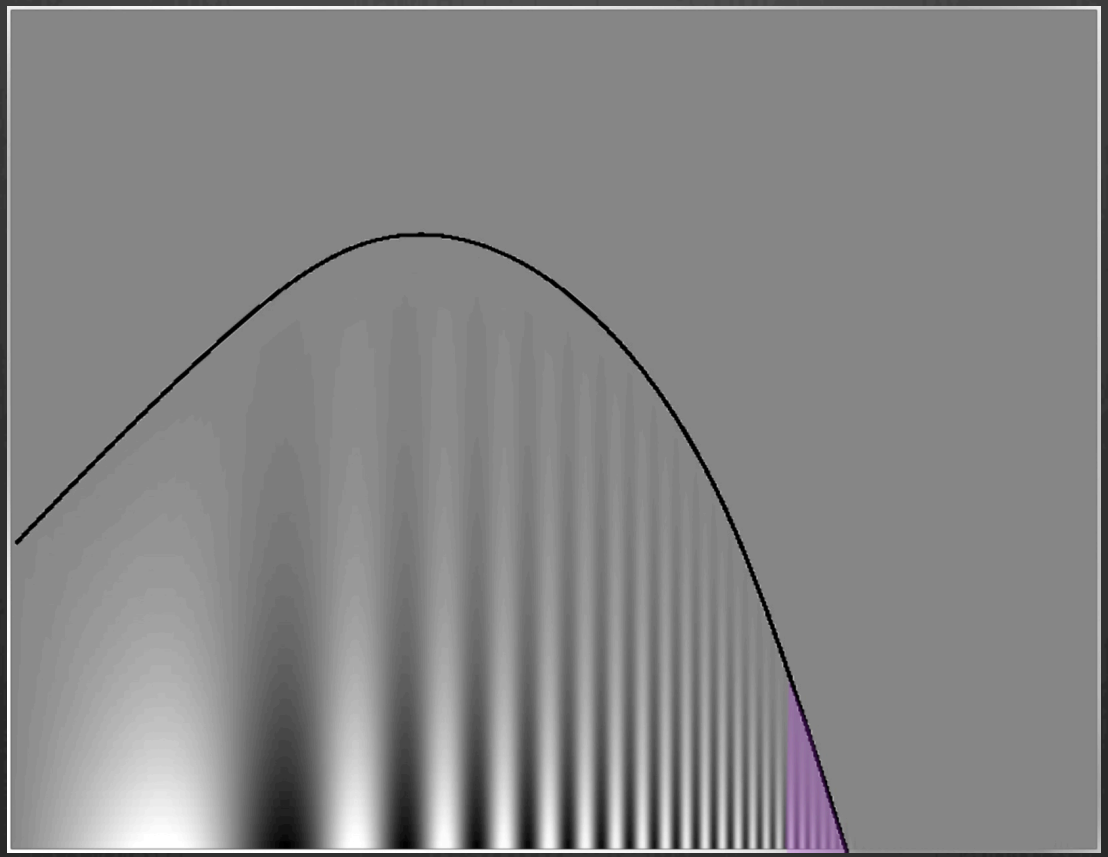

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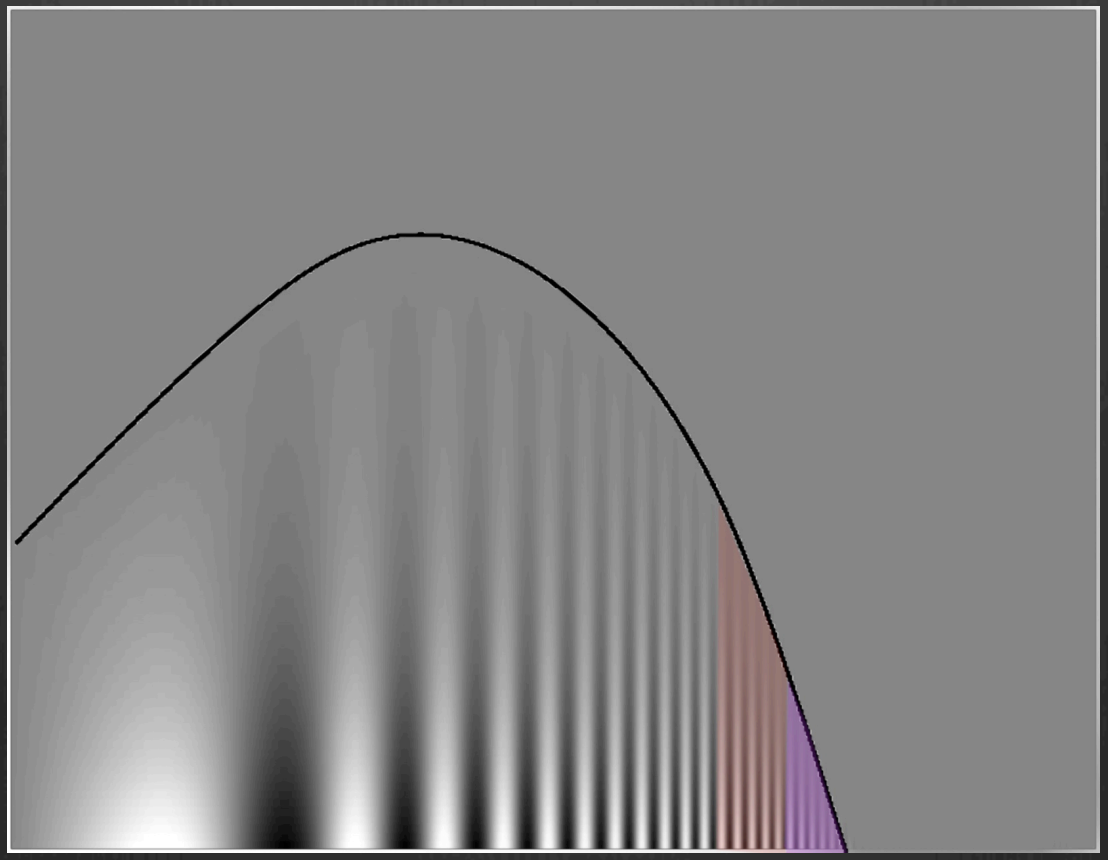

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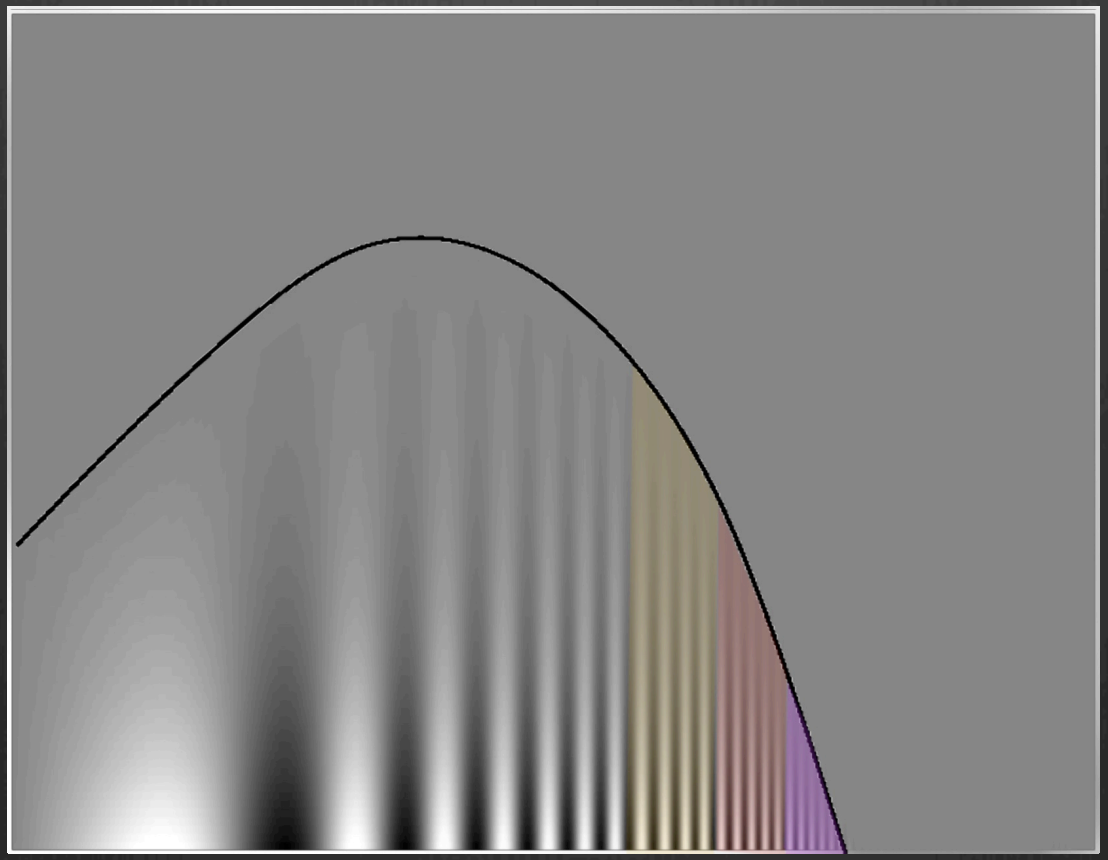

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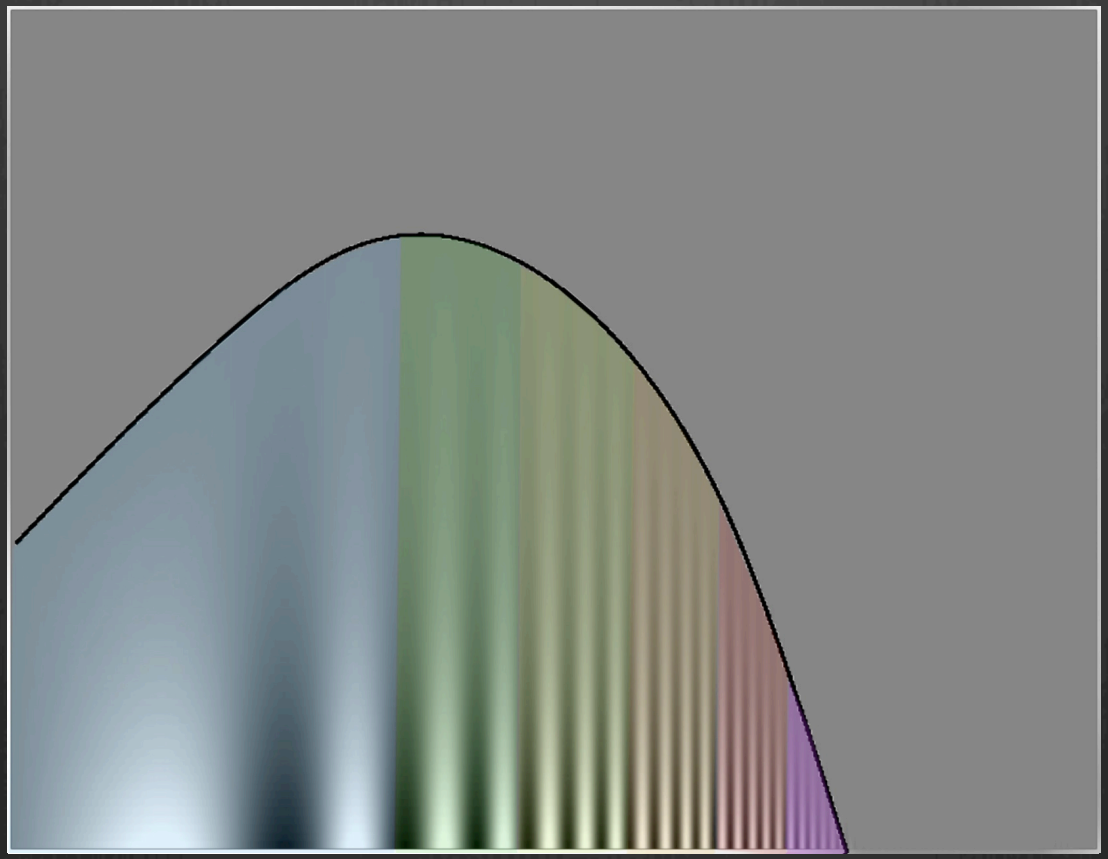
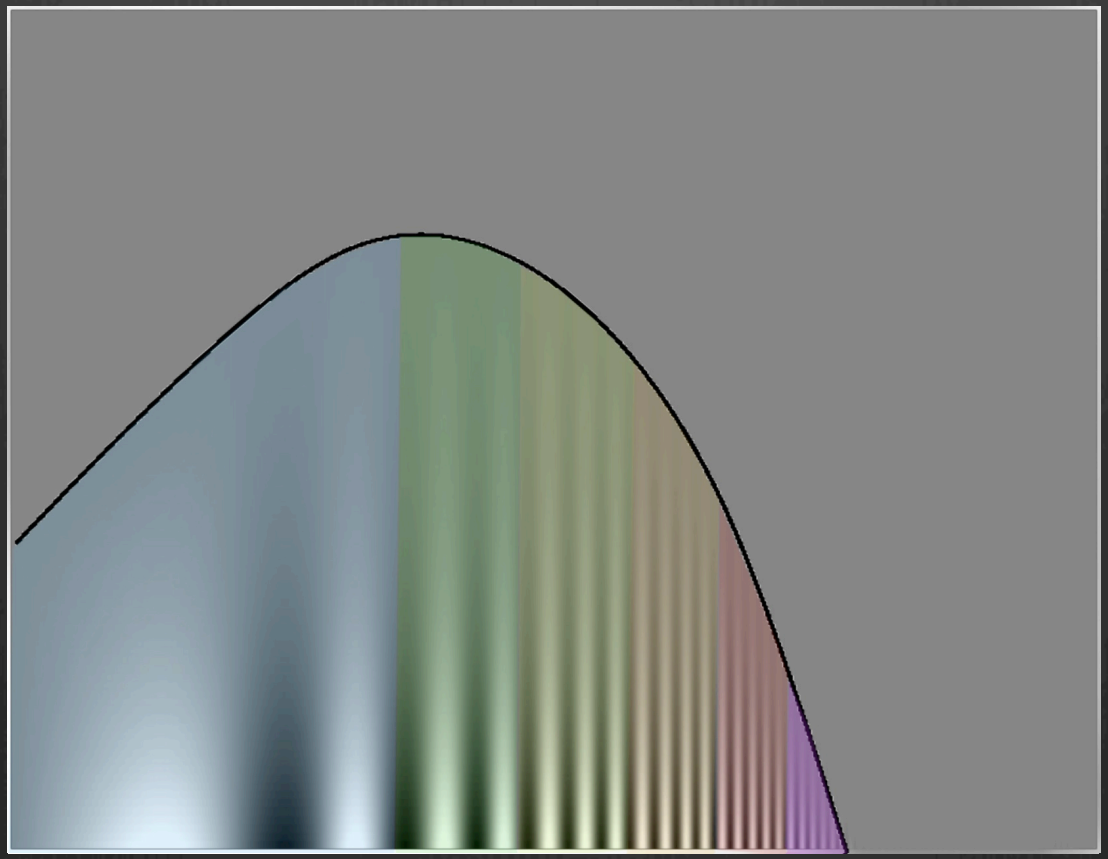


-Each pixel in each band is processed to provide a measure of local contrast.

-Then thresholded on a criterion that compares local contrast values to the peak sensitivity frequency of the band filter.

-The thresholded contrast bands are reassembled to produce an output image.



Advantages over a linear filtering including:

1. Contrast that is below the specified CSF is **removed**, rather than being attenuated. This reduces variability related to viewer/viewing conditions.
2. Contrast above the CSF threshold is left intact.
3. This spatially localized approach takes into account local luminance, which has a strong effect on contrast perception.

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Together, these properties:

remove image details predicted to be not visible,
while leaving intact, details predicted to BE visible.

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Together, these properties:

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while leaving intact, details predicted to BE visible.

Our most significant contribution is that we calibrated the parameterized simulation using human subject studies as little is known about the relationship between contrast sensitivity and letter charts, as used in specifying the degree of visual degradation.

J Opt Soc Am A Opt Image Sci Vis. 2017 April 1 *Thompson et al*

Subjects judged the readability of letters presented in various simulated acuities and contrast values.

The resulting data was integrated into the filter

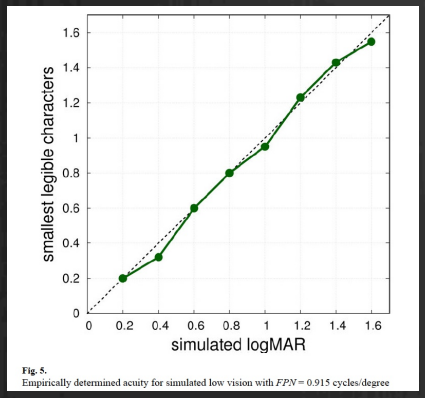


Fig. 5.
Empirically determined acuity for simulated low vision with *FPN* = 0.915 cycles/degree

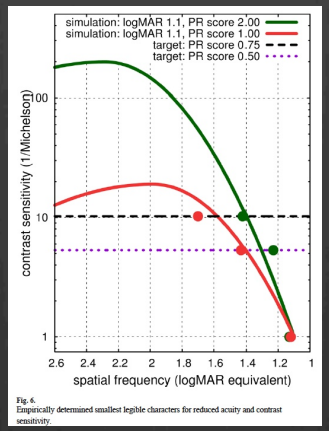


Fig. 6.
Empirically determined smallest legible characters for reduced acuity and contrast sensitivity.

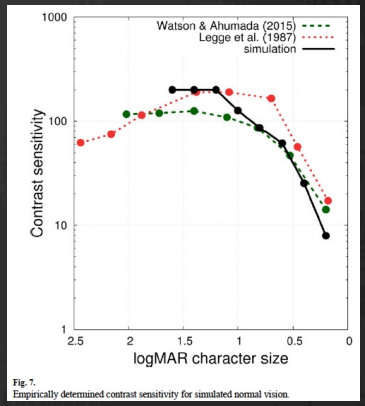


Fig. 7.
Empirically determined contrast sensitivity for simulated normal vision.

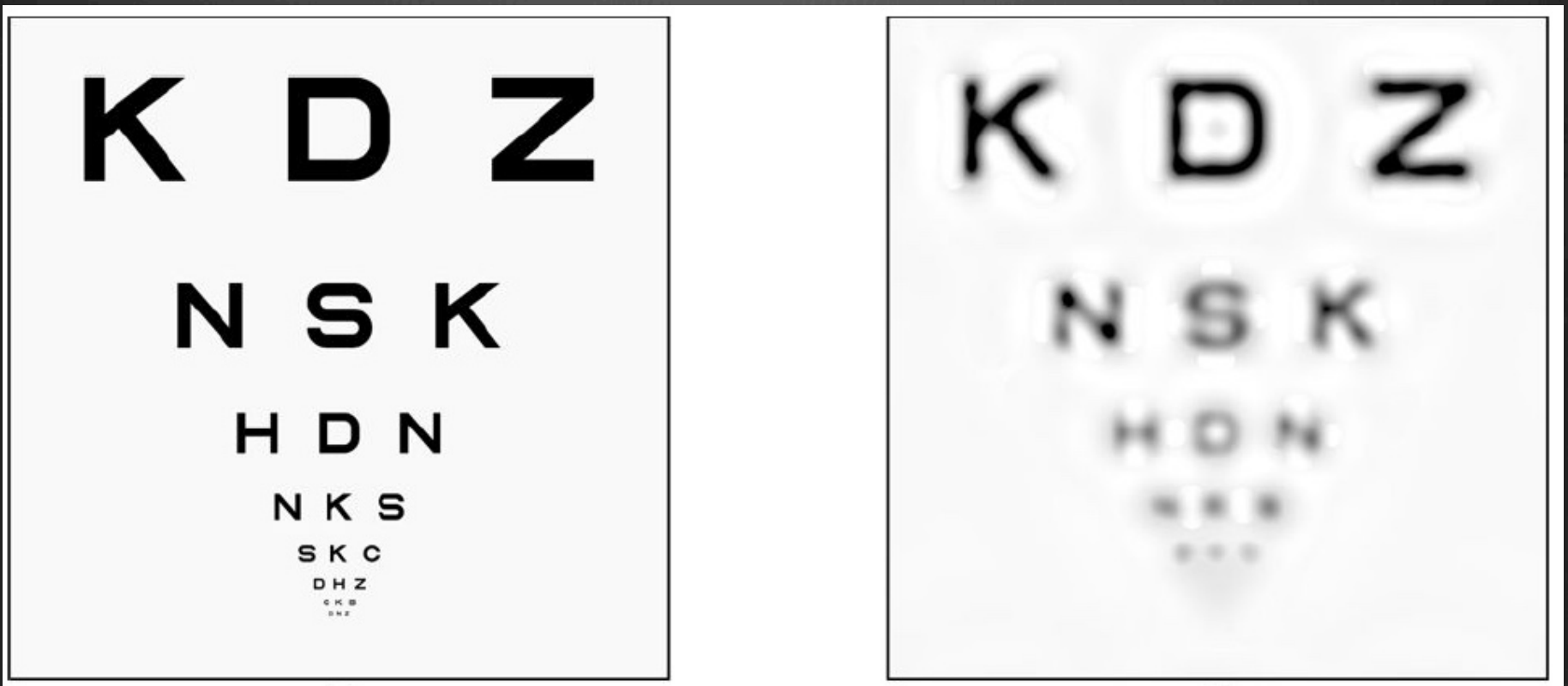
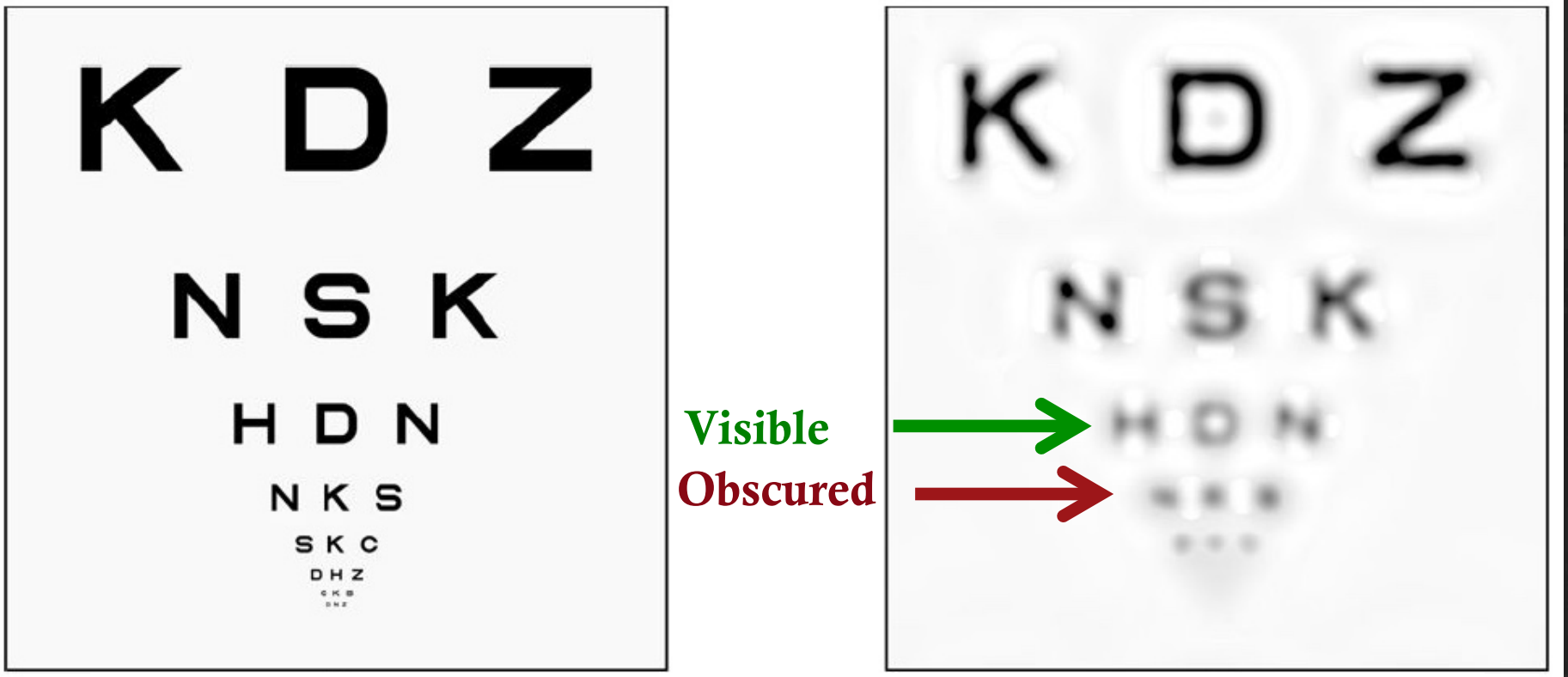


Fig. 8.
(a) Original logMAR chart, with third line from top corresponding to logMAR 1.1 and the fourth line from the top corresponding to logMAR 0.9. For correct character size, view the chart from a distance equivalent to 3.33 times the width of the chart image. (b) Original logMAR chart, filtered to simulate an acuity of logMAR 1.0. The third line is readable, the fourth line is not.

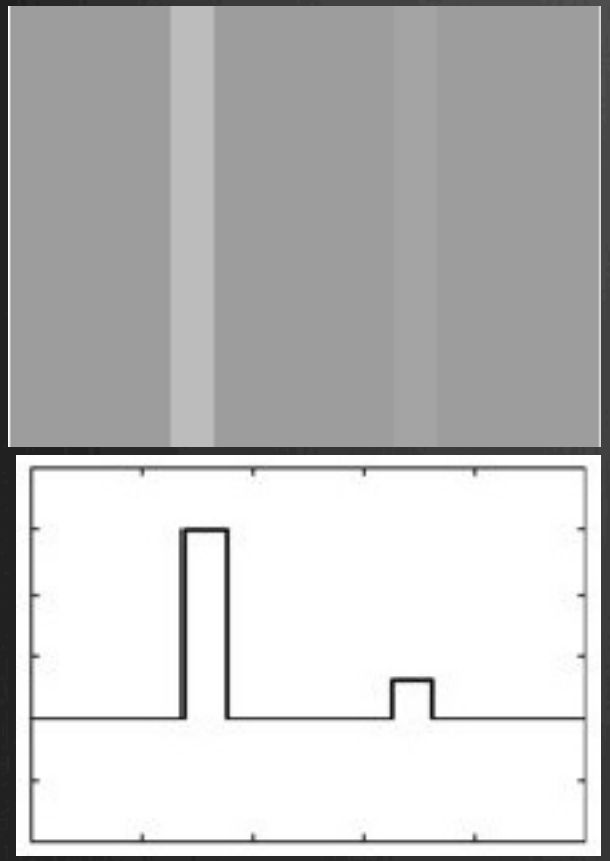


(Legal Blindness: 20/200 or less with best possible correction)

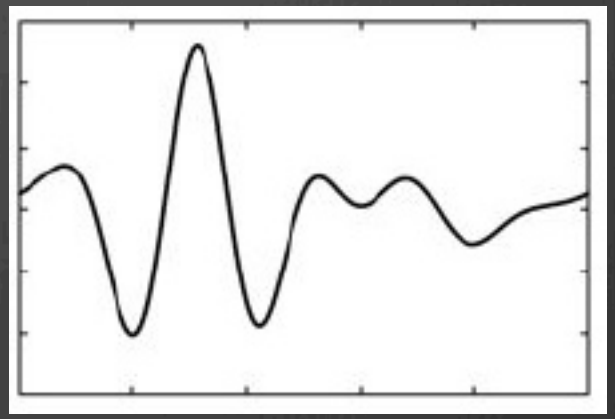
Fig. 8.

(a) Original logMAR chart, with third line from top corresponding to logMAR 1.1 and the fourth line from the top corresponding to logMAR 0.9. For correct character size, view the chart from a distance equivalent to 3.33 times the width of the chart image. (b) Original logMAR chart, filtered to simulate an acuity of logMAR 1.0. The third line is readable, the fourth line is not.

Reducing banding and artifacts in the simulations built on HDR images

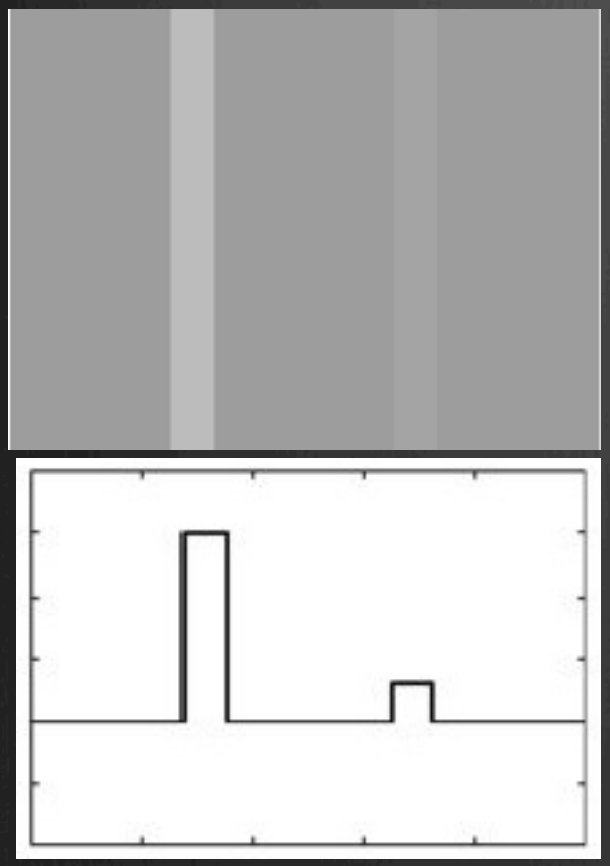


Luminance profile

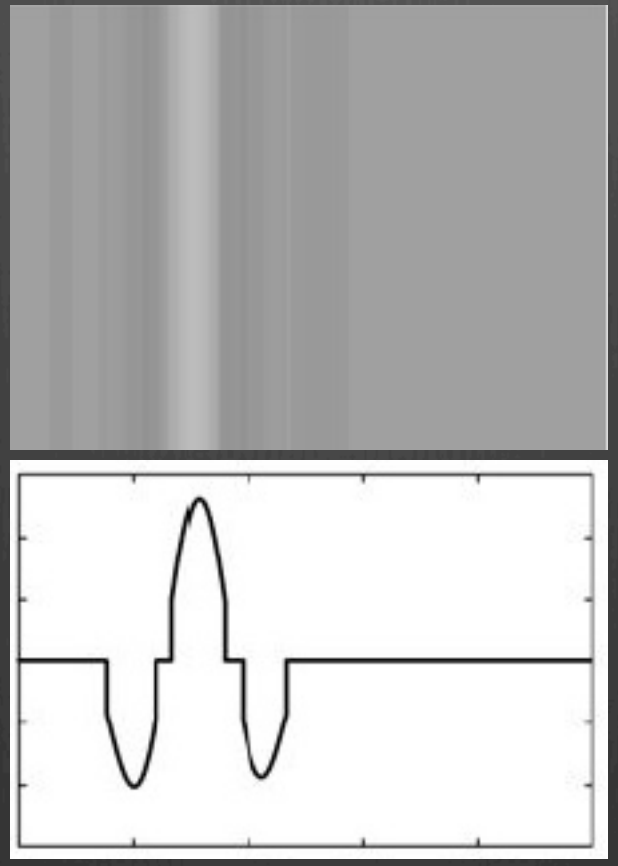


Bands produced by low vision simulation filter

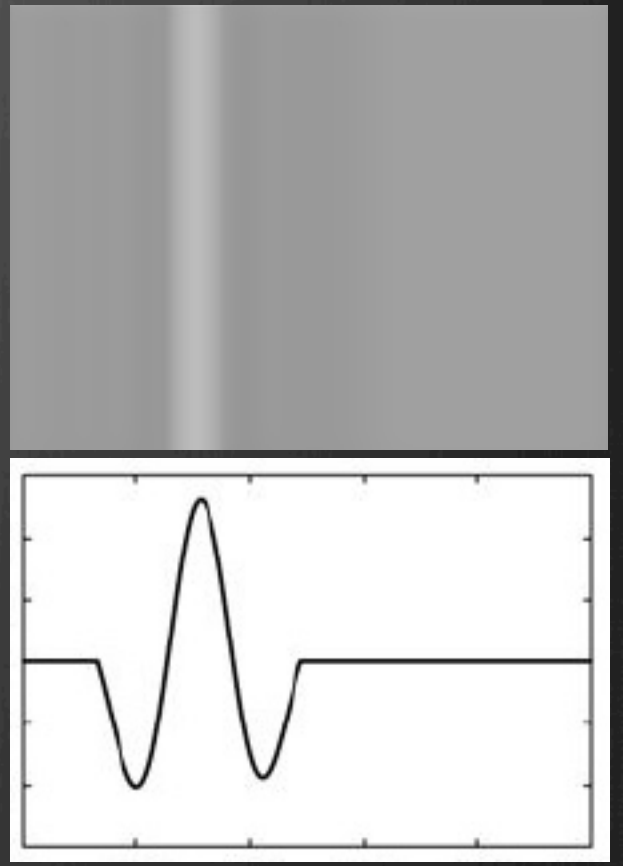
J Opt Soc Am A Opt Image Sci Vis. 2017 April 1 *Thompson et al*



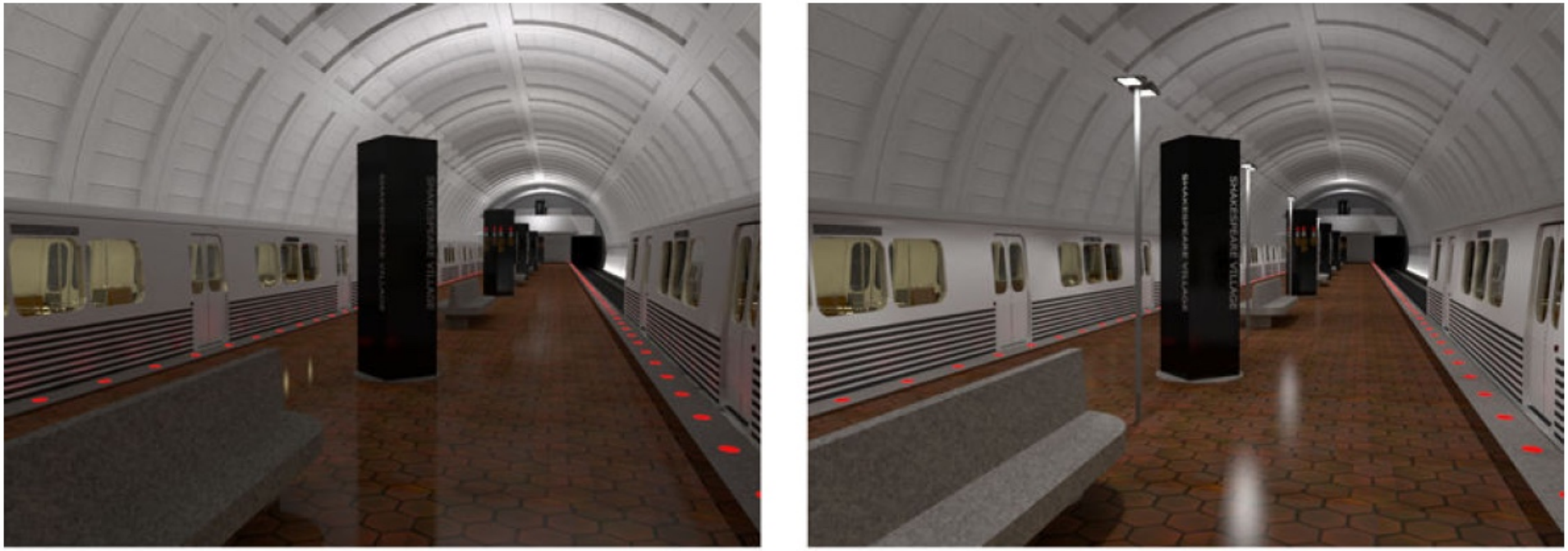
Luminance profile



thresholding of band



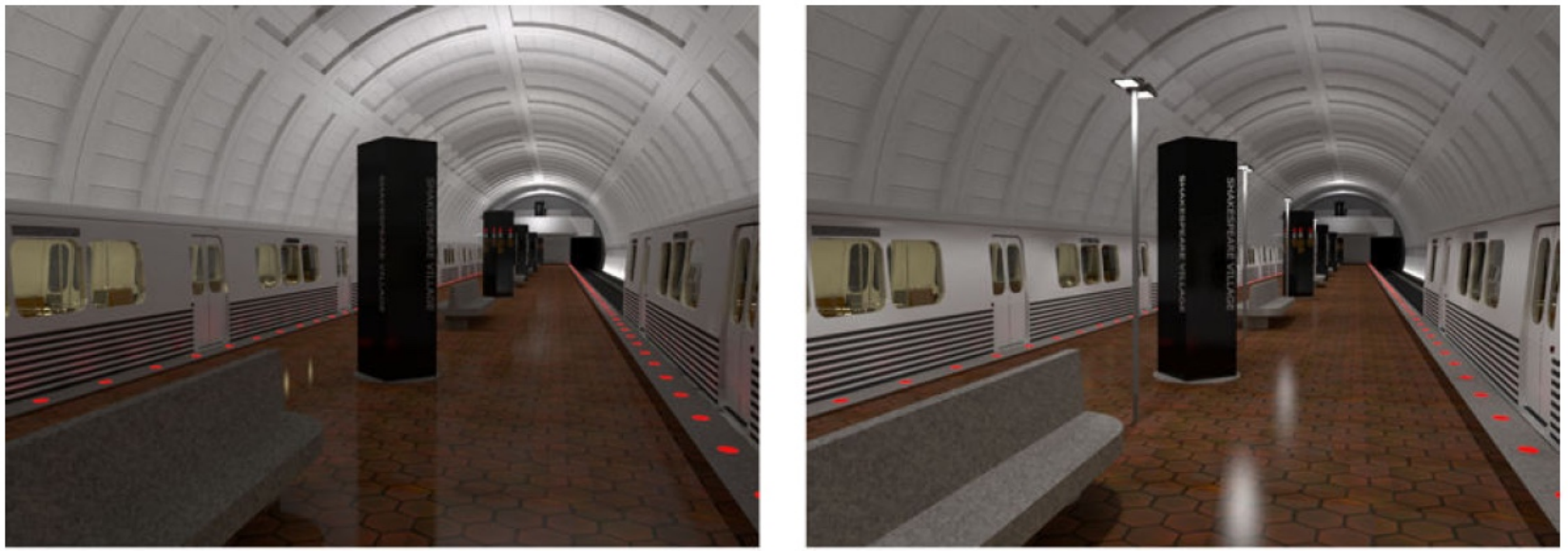
improved thresholding



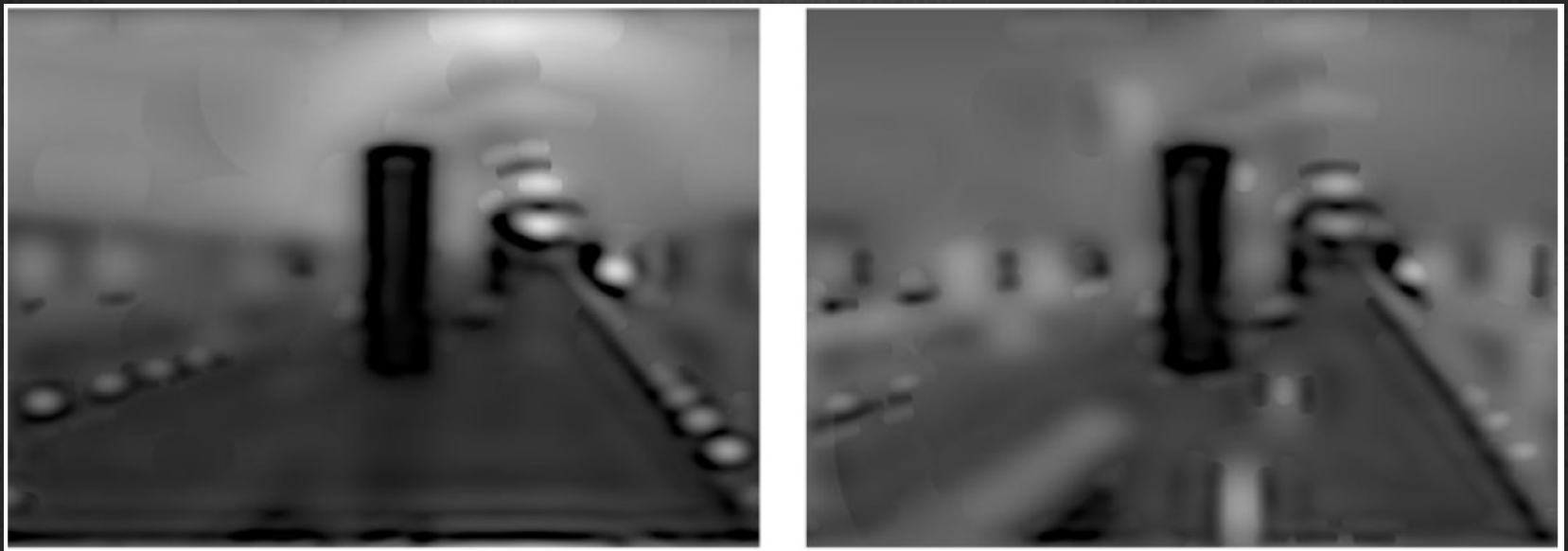
Original RADIANCE renderings.

Original filtered to simulate moderate low vision.

Original filtered to simulate severe low vision.



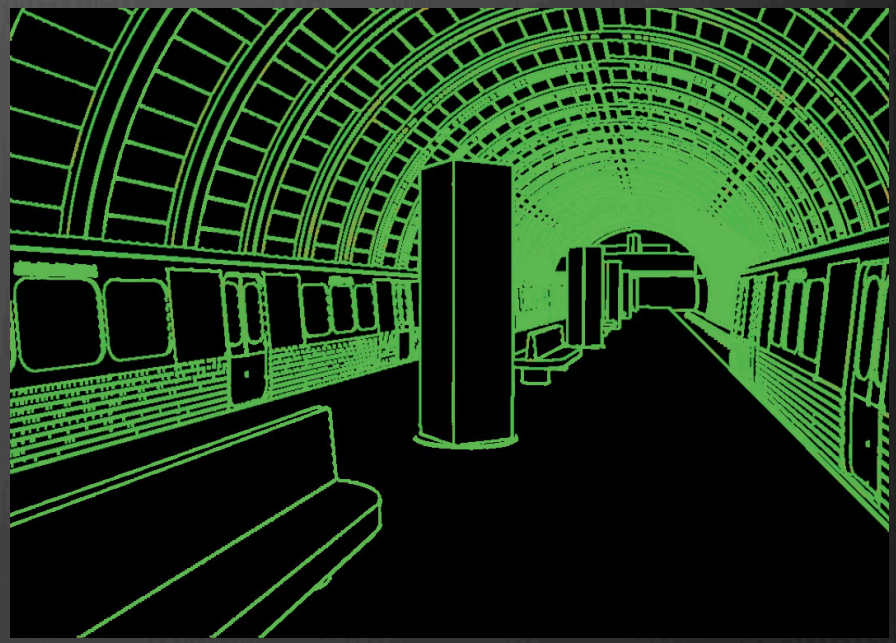
Original RADIANCE renderings.



Original filtered to simulate severe low vision.

How do we predict visible edges once we have an image, filtered to obscure non-visible parts of the scene?

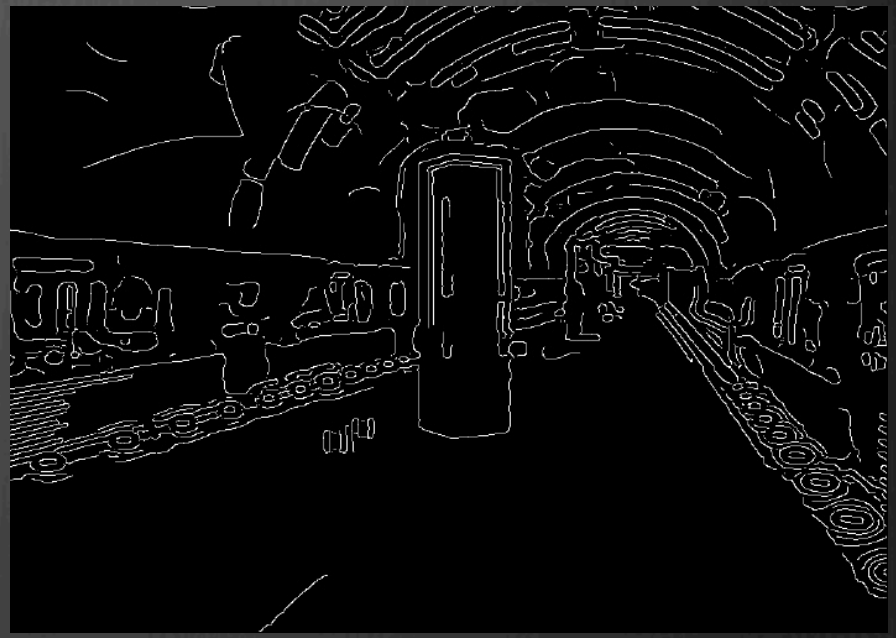
Visibility Filter



Radiance Data Set → Ground Truth Edges

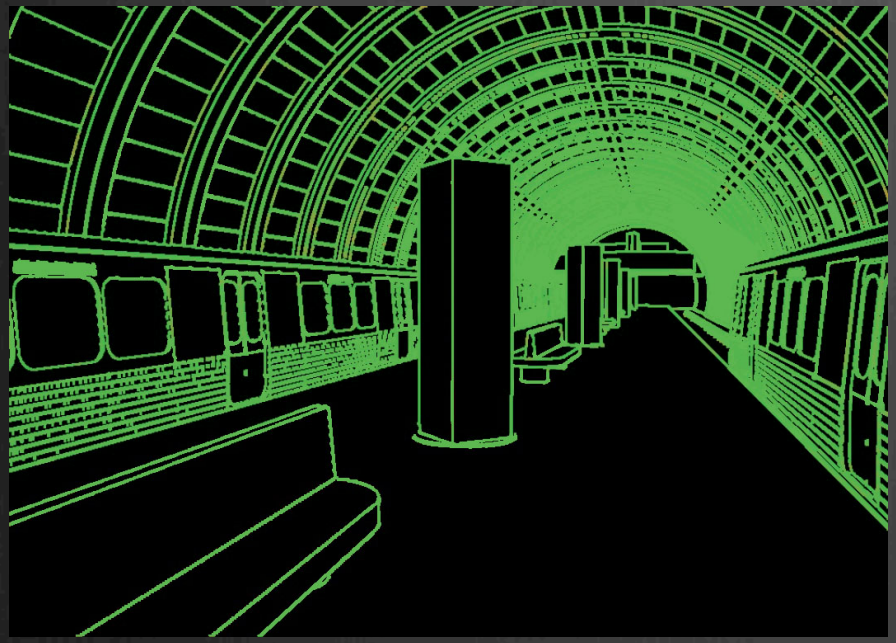
```
### *.hdr image  input to vwrays and rtrace  then process results to establish Ground Truth Edges
## create normal at surface text file
                                    set  norflnm = $bfnm"nor"$t
                                    vwrays -fd $dirhdrfnm | rtrace -fda `vwrays -d $dirhdrfnm` -on $octree >  $subd/$norflnm &
## create distance to surface text file
                                    set  dstflnm = $bfnm"dst"$t
                                    vwrays -fd $dirhdrfnm | rtrace -fda `vwrays -d $dirhdrfnm` -oL $octree >  $subd/$dstflnm &
## create surface coordinate text file
                                    set  dstflnm = $bfnm"xyz"$t
                                    vwrays -fd $dirhdrfnm | rtrace -fda `vwrays -d $dirhdrfnm` -op $octree >  $subd/$dstflnm &
```

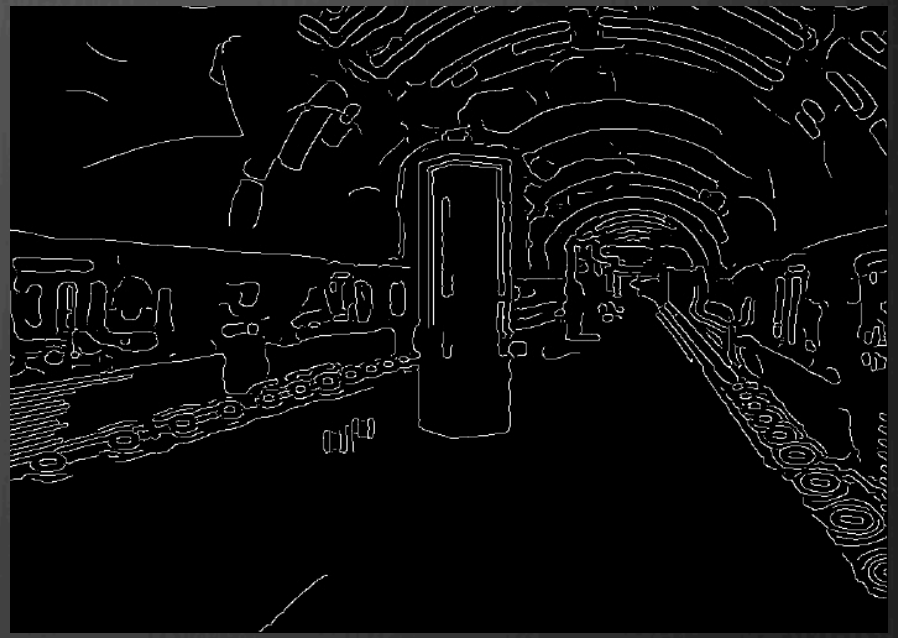
Visibility Filter



Severe Low Vision → Edge Detection of HDR Image
(luminance boundary "canny" edges)

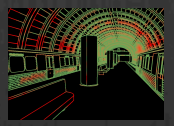
Visibility Filter



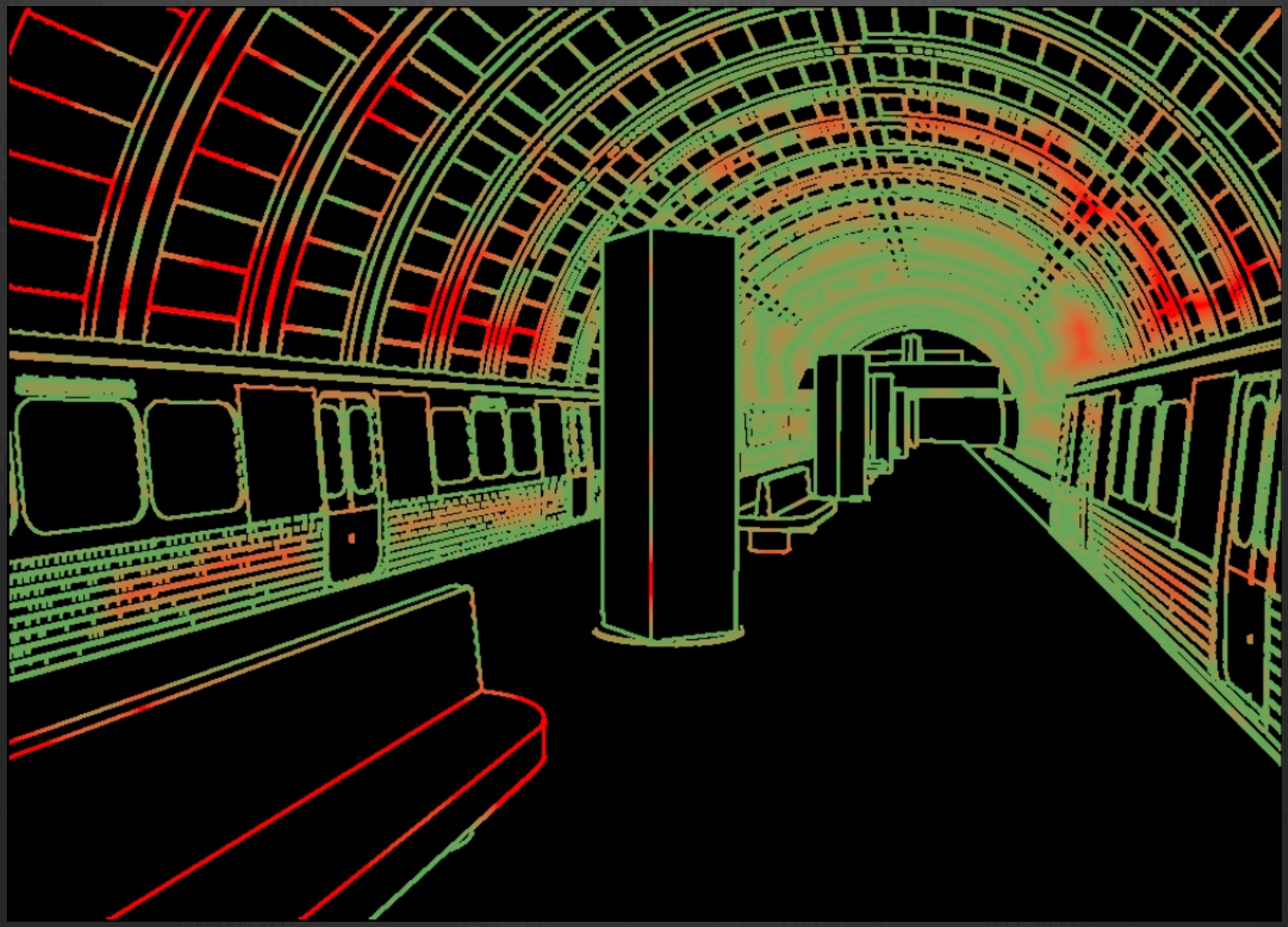


Ground Truth Edges

Edge Detection of HDR Image

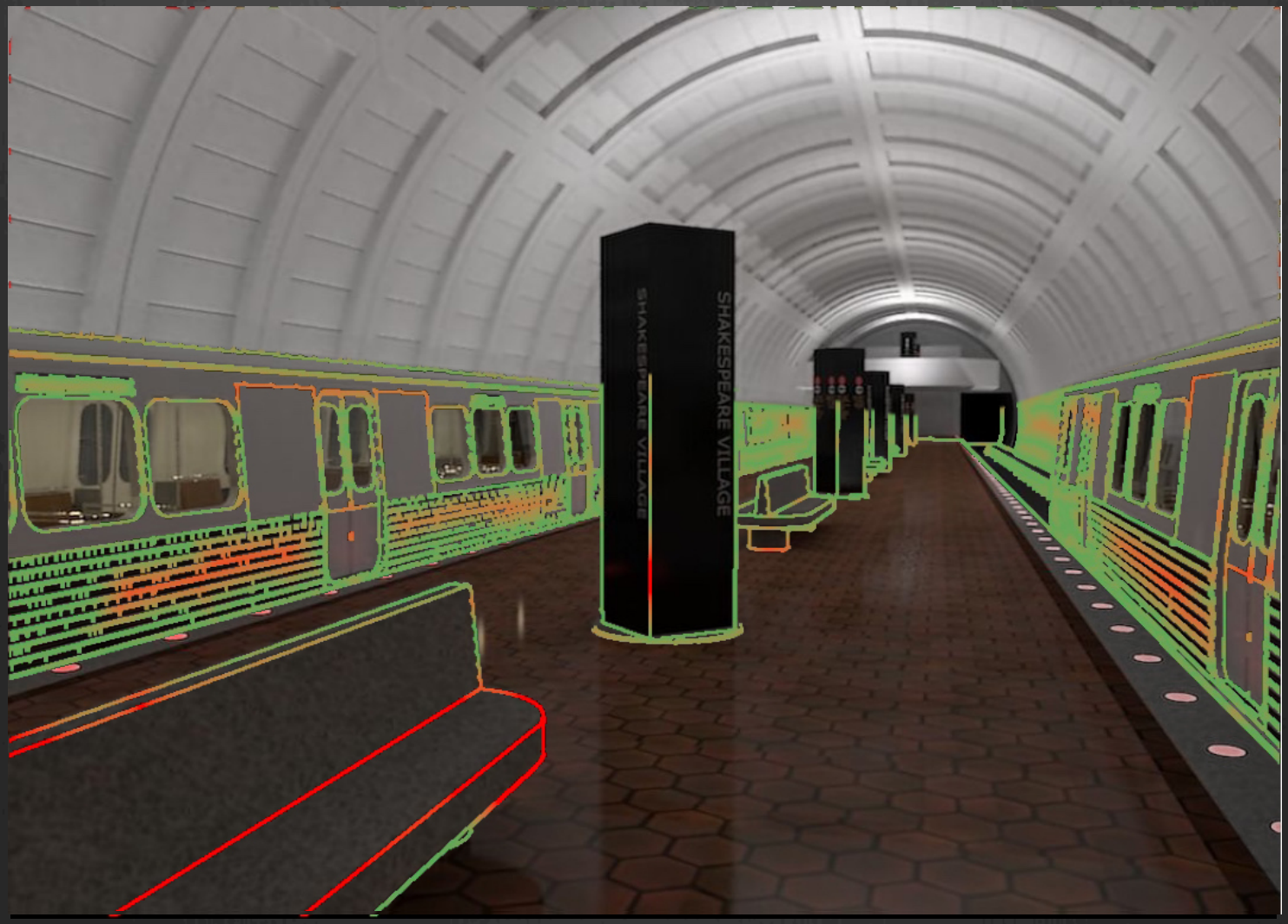


Visibility Filter



RED edges predicted NOT to be visible

Visibility Filter

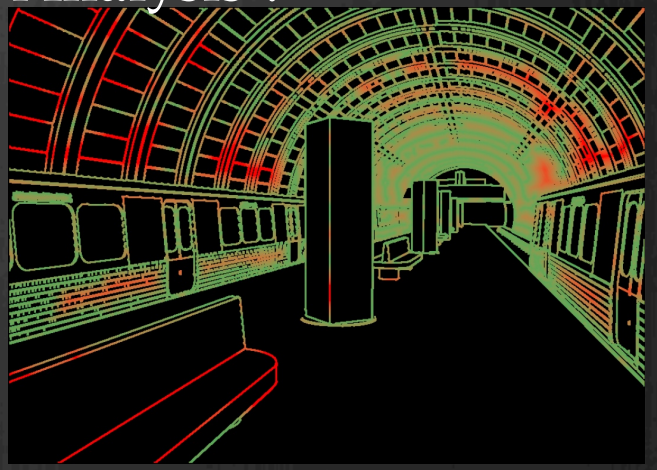


RED edges predicted NOT to be visible

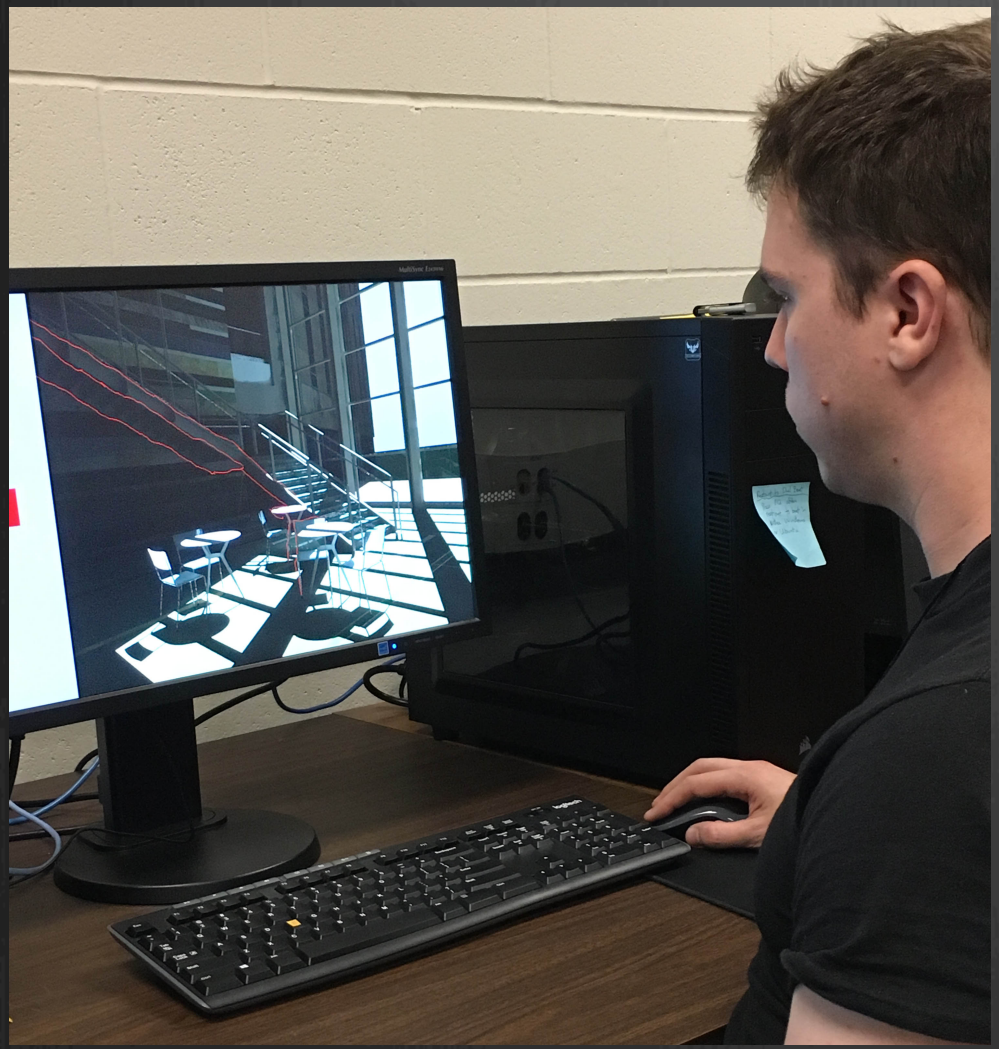
Subjective or Objective

Guess at what is likely not visible ?

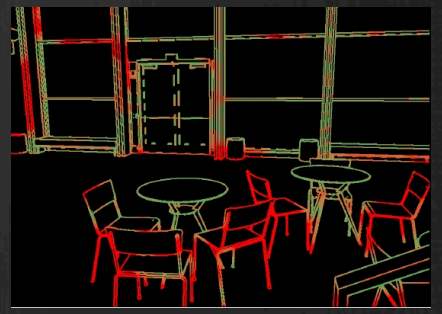
Automated visibility Analysis ?

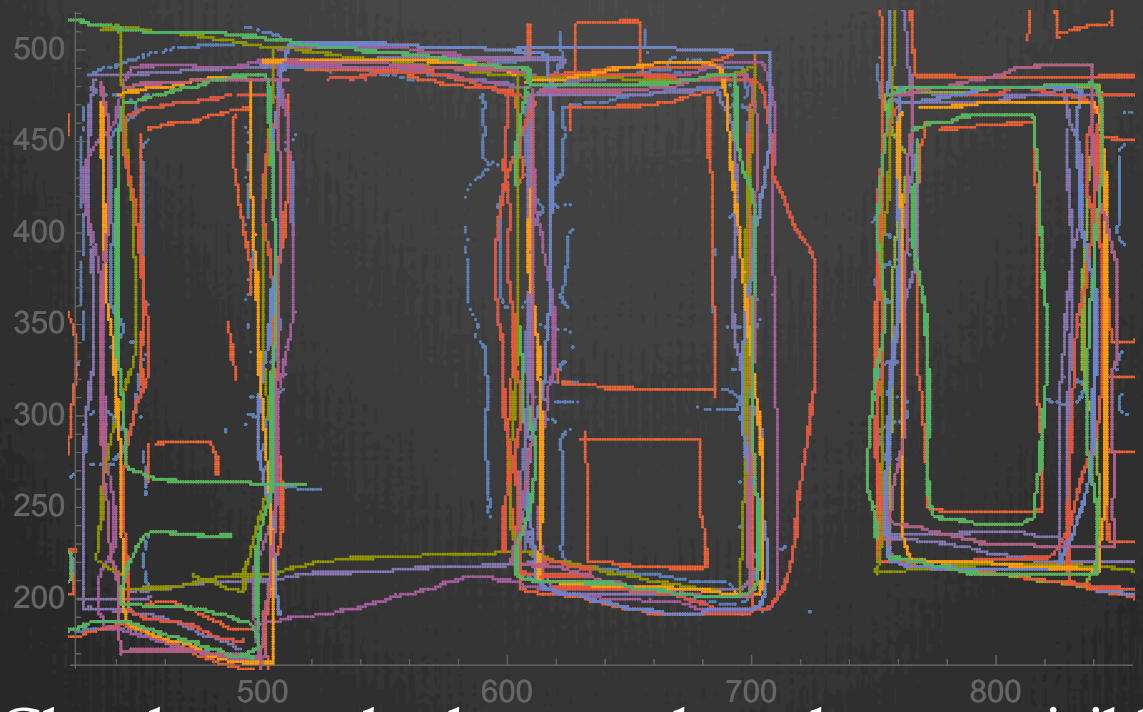


Validation



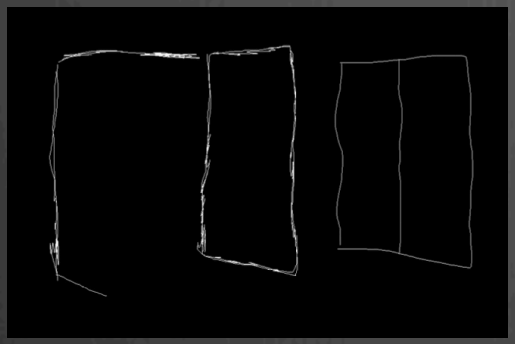
Validation studies included “edge labeling” on images: normal and processed with the Low Vision Filter.

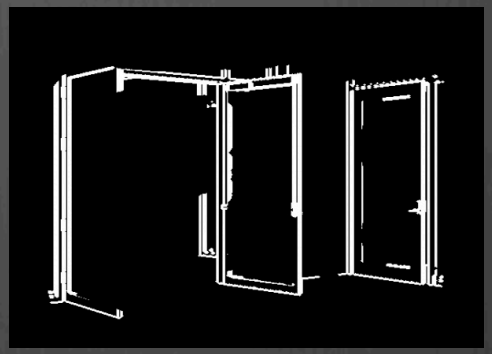




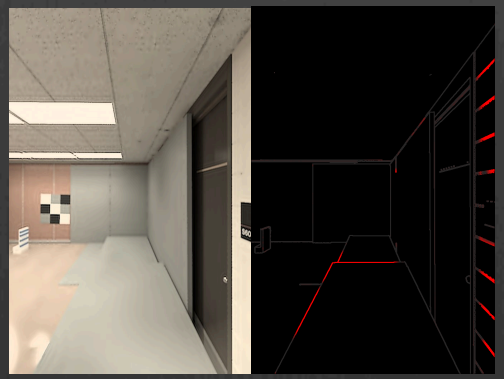
Closely traced relevant edges that are visible

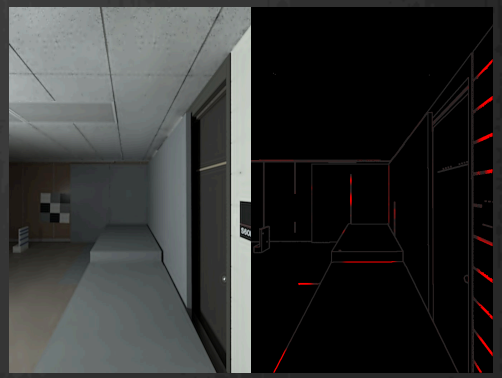
There is a high correlation between automated edge visibility and user detected geometry over a wide range of images.





Similar correlations result between the ramps and steps studies and automated edge visibility of the same scenes.





Statically afirming results will be forthcoming

The visibility prediction process in action:

Required input:

RadianceImage.hdr

First intersection coordinates xyz.txt

first intersection distance dist.txt

first intersection normal norm.txt

Output:

Visibility filtered image.hdr

Visibility prediction image.png

The visibility prediction process in action:

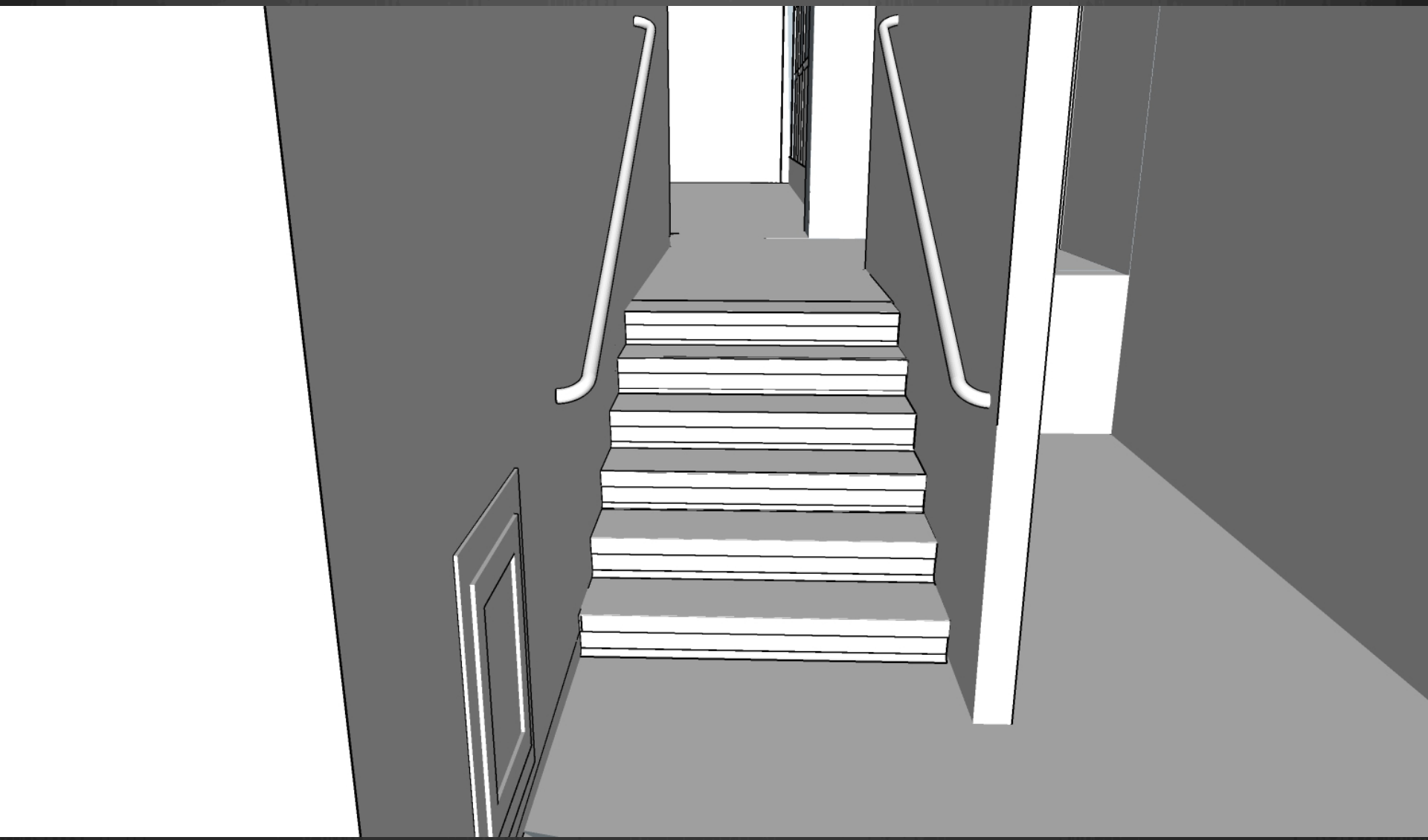
make-coordinates-file units radiance-file.hdr coordinates-file

```
deva-visibility --mild|--moderate|--severe|--profound [--margin=<value>]
        [--red-gray|--red-green]
        [--Gaussian=<sigma>|--reciprocal=<scale>|--linear=<max>]
        [--luminanceboundaries=<filename.png>]
        [--geometryboundaries=<filename.png>]
        input.hdr coordinates xyz.txt dist.txt nor.txt
        simulated-view.hdr hazards.png
                        or
deva-visibility [--snellen|--logMAR] [--sensitivity-ratio|--pelli-robson]
        [--autoclip|--clip=<level>] [--color|--grayscale|saturation=<value>]
        [--margin=<value>] [--verbose] [--version] [--presets]
        [--red-gray|--red-green]
        [--Gaussian=<sigma>|--reciprocal=<scale>|--linear=<max>]
        [--luminanceboundaries=<filename.png>]
        [--geometryboundaries=<filename.png>]
                acuity contrast input.hdr coordinates xyz.txt dist.txt
                nor.txt simulated-view.hdr hazards.png
```

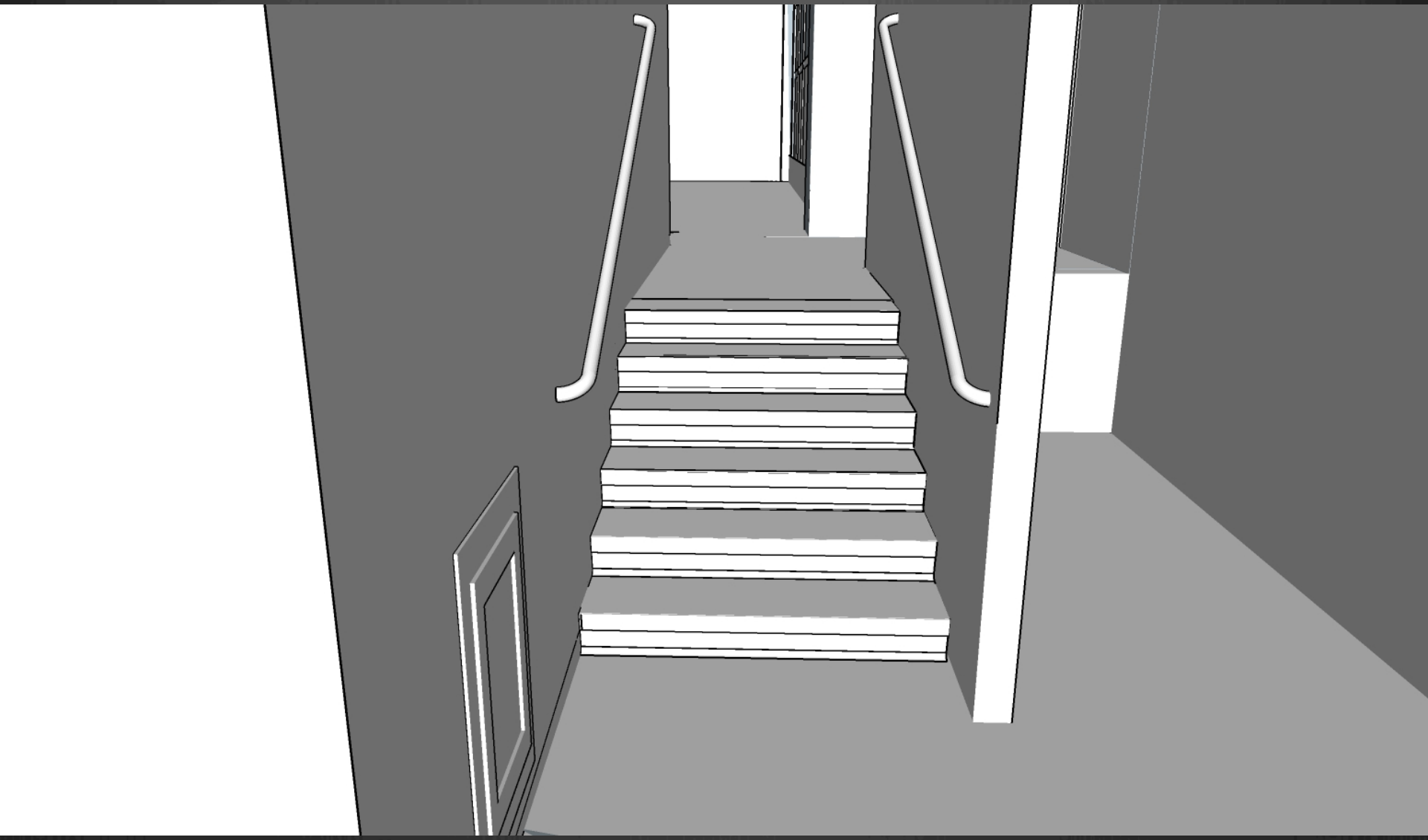
deva-run.csh

Switch to terminal…

Any HDR image can be processed to remove non-visible details… models provide ground truth necessary for automated visibility analysis



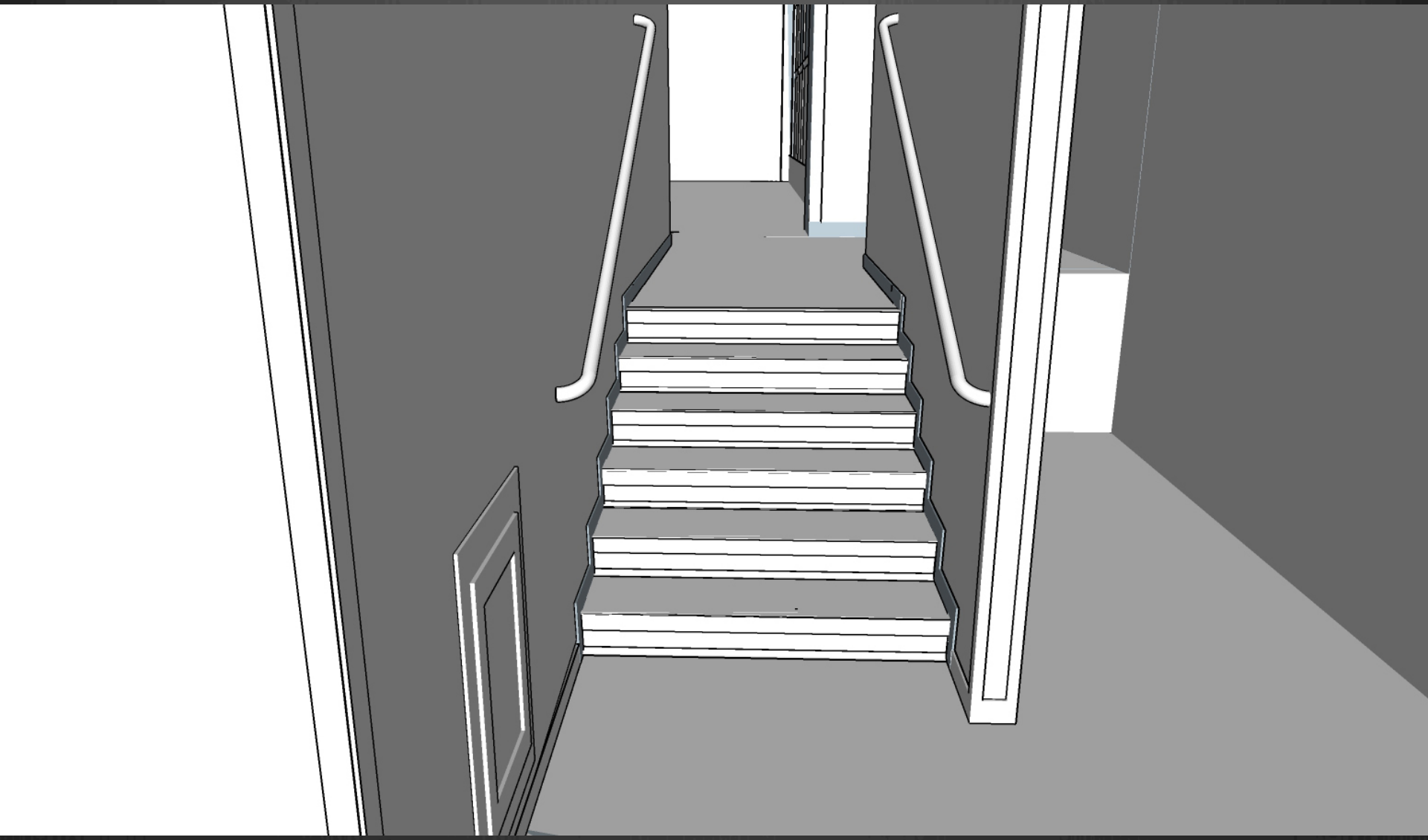
Workflow: REVIT > GROUNDHOG (add photometry and accurate materials) > RADIANCE



No baseboard contrast, no tread stripes

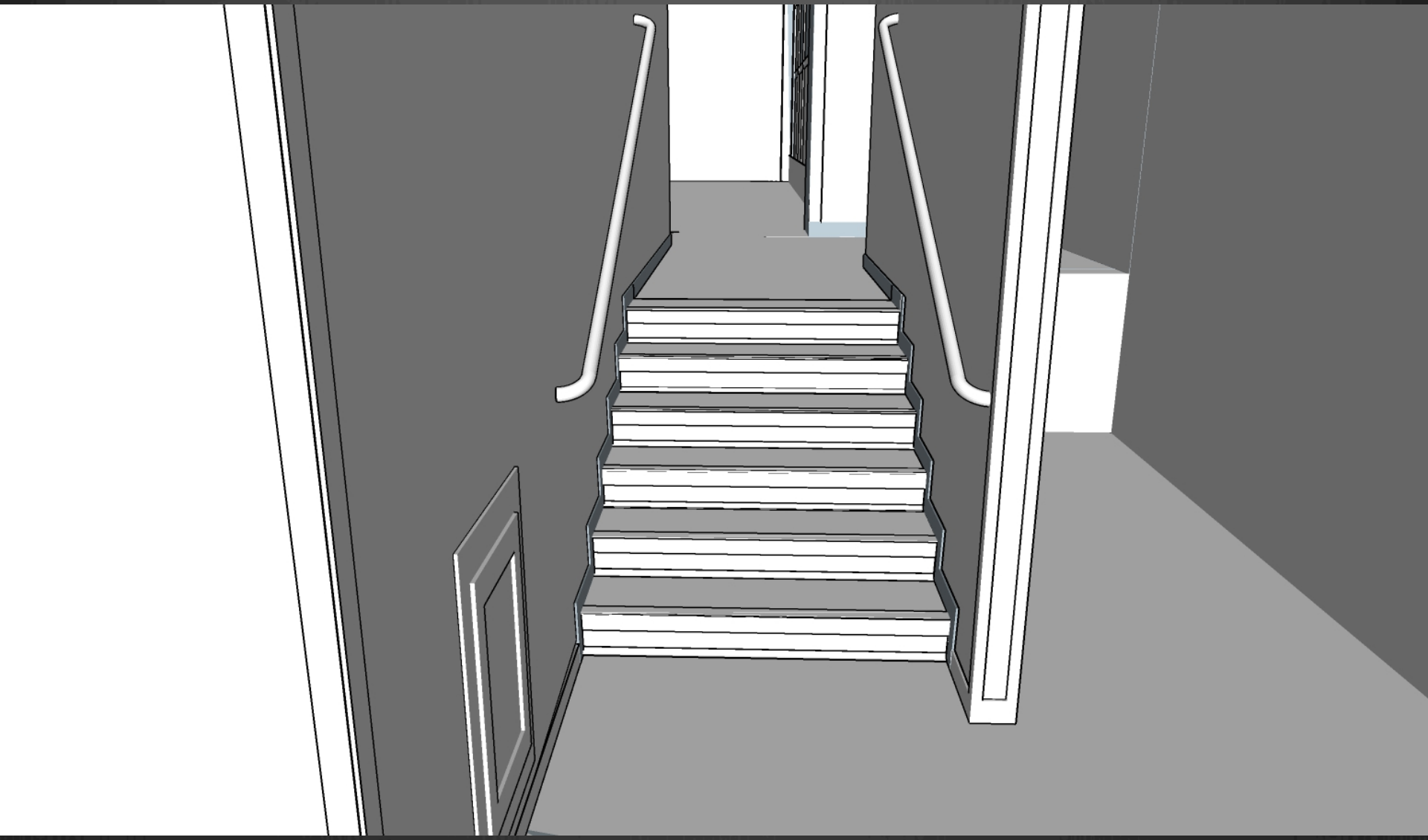
No baseboard contrast, no tread stripes: Severe

Darken the floor and railings : Severe



Add contrasting side baseboards: Severe

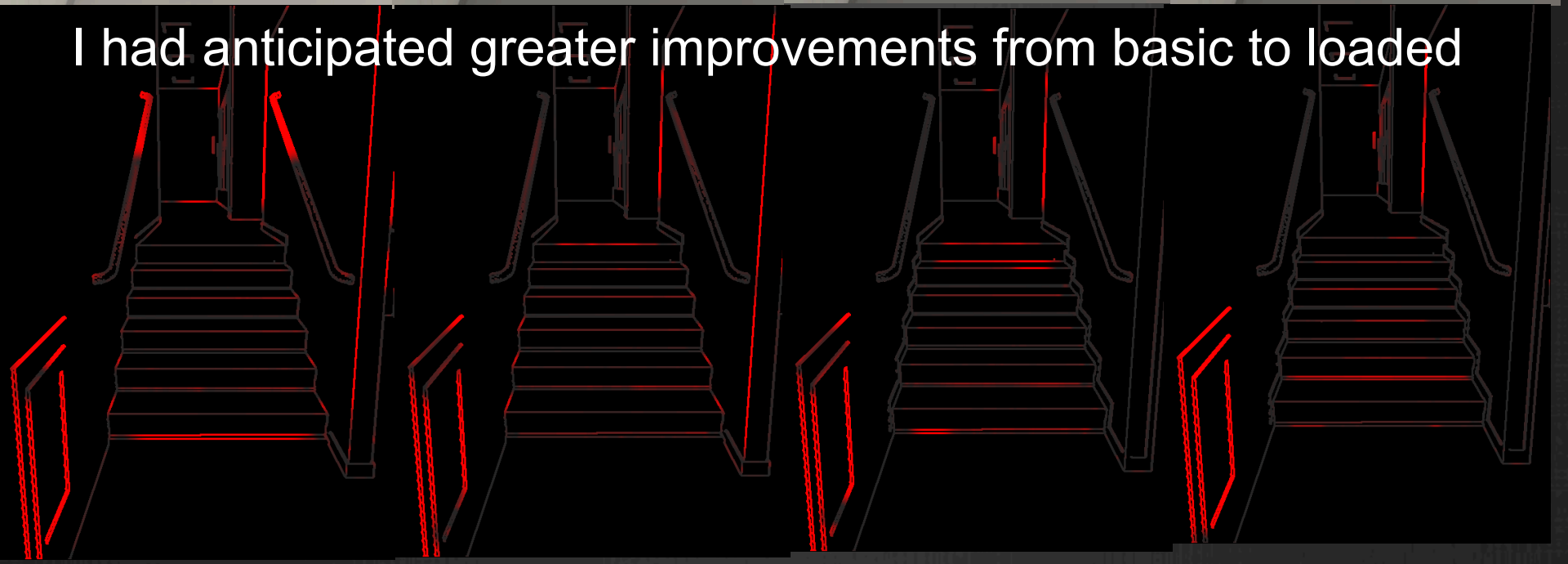
Add contrasting side baseboards: Severe



Contrasting baseboards and stripes

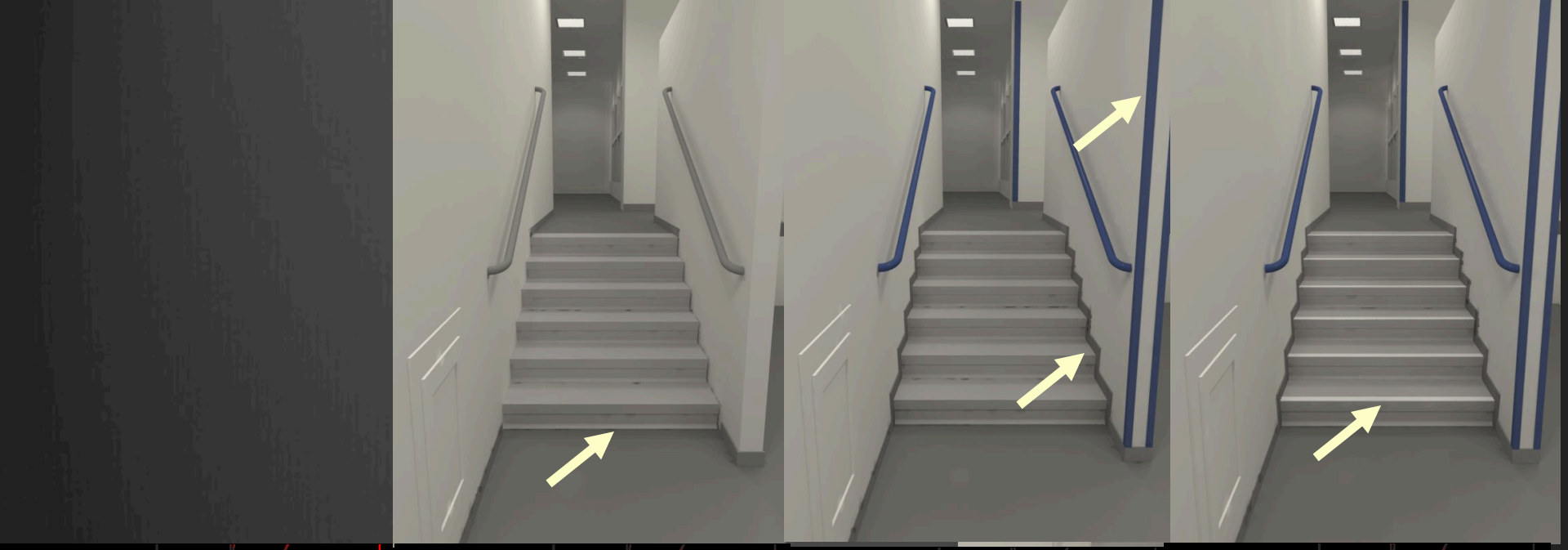
Contrasting side baseboards and stripes: Severe

I had anticipated greater improvements from basic to loaded

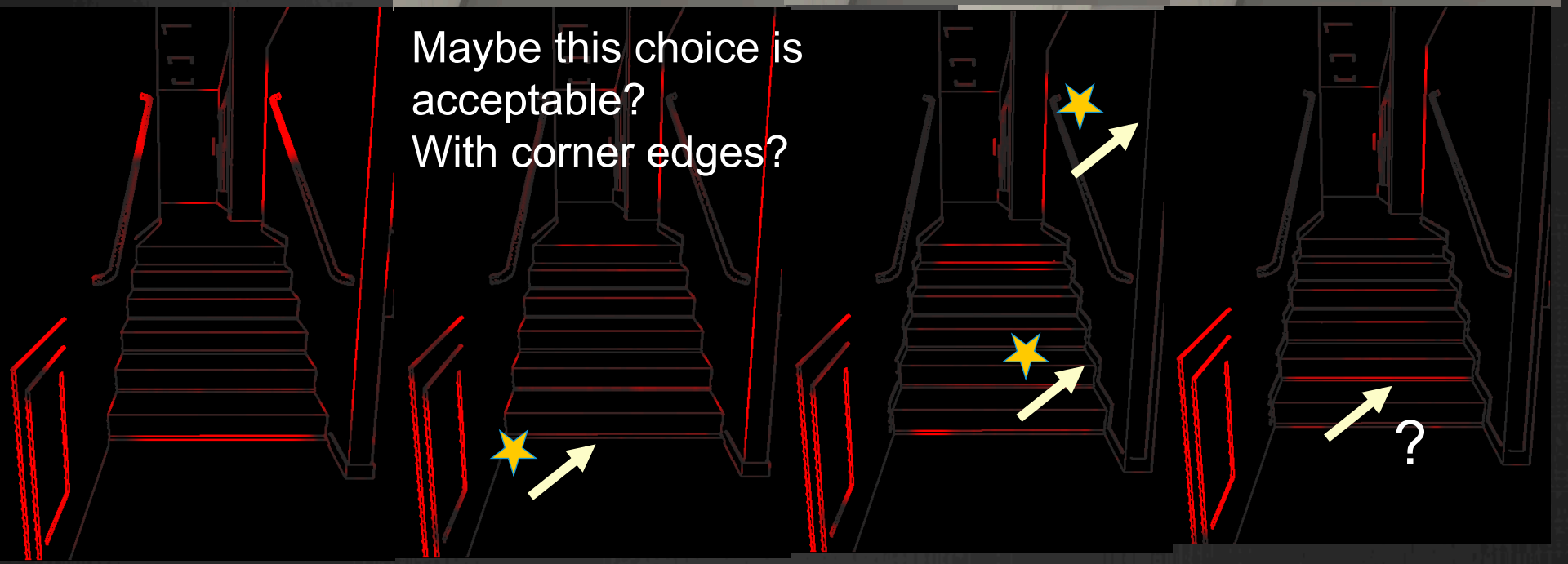


Compare Severe….

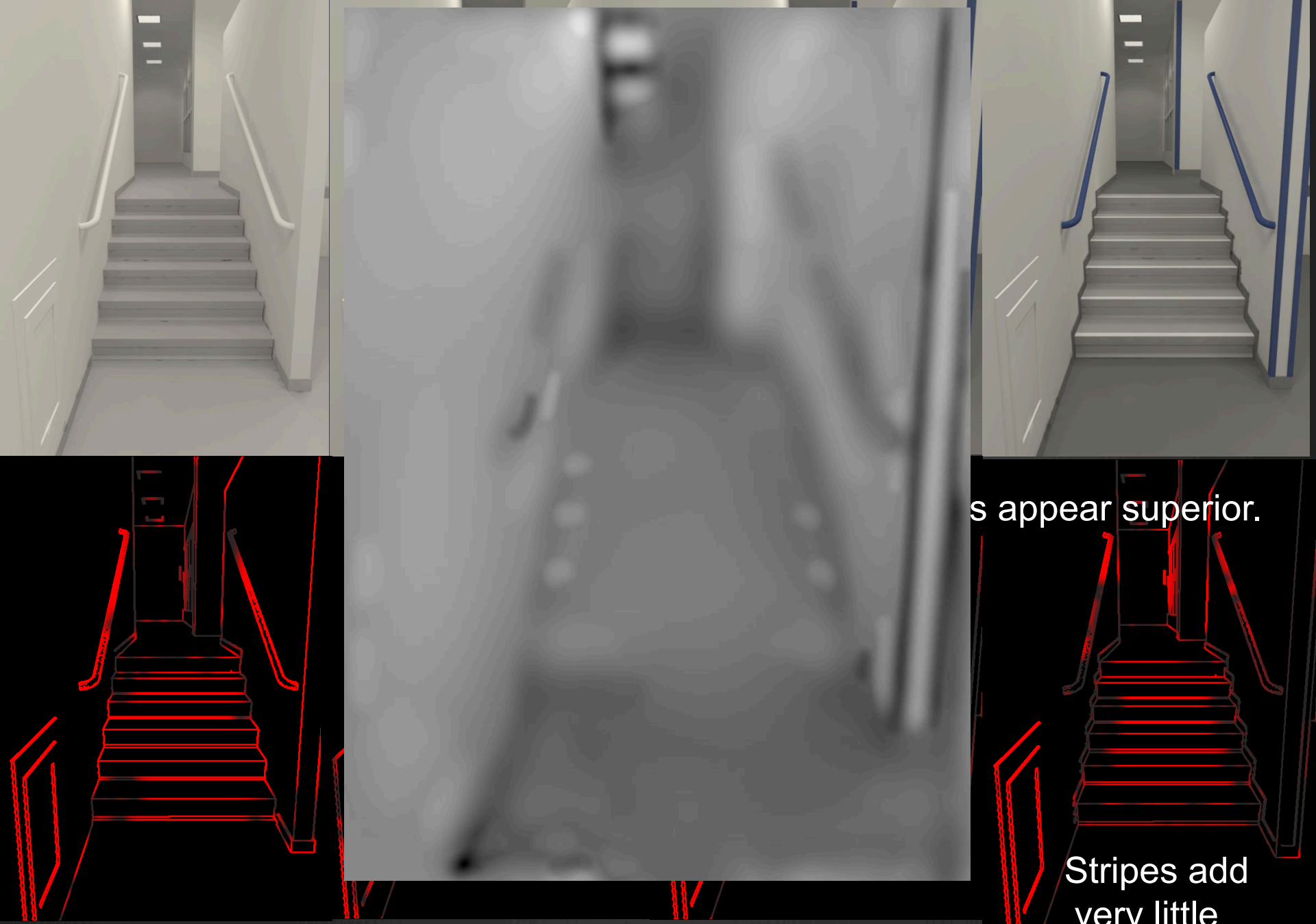
Compare Severe….



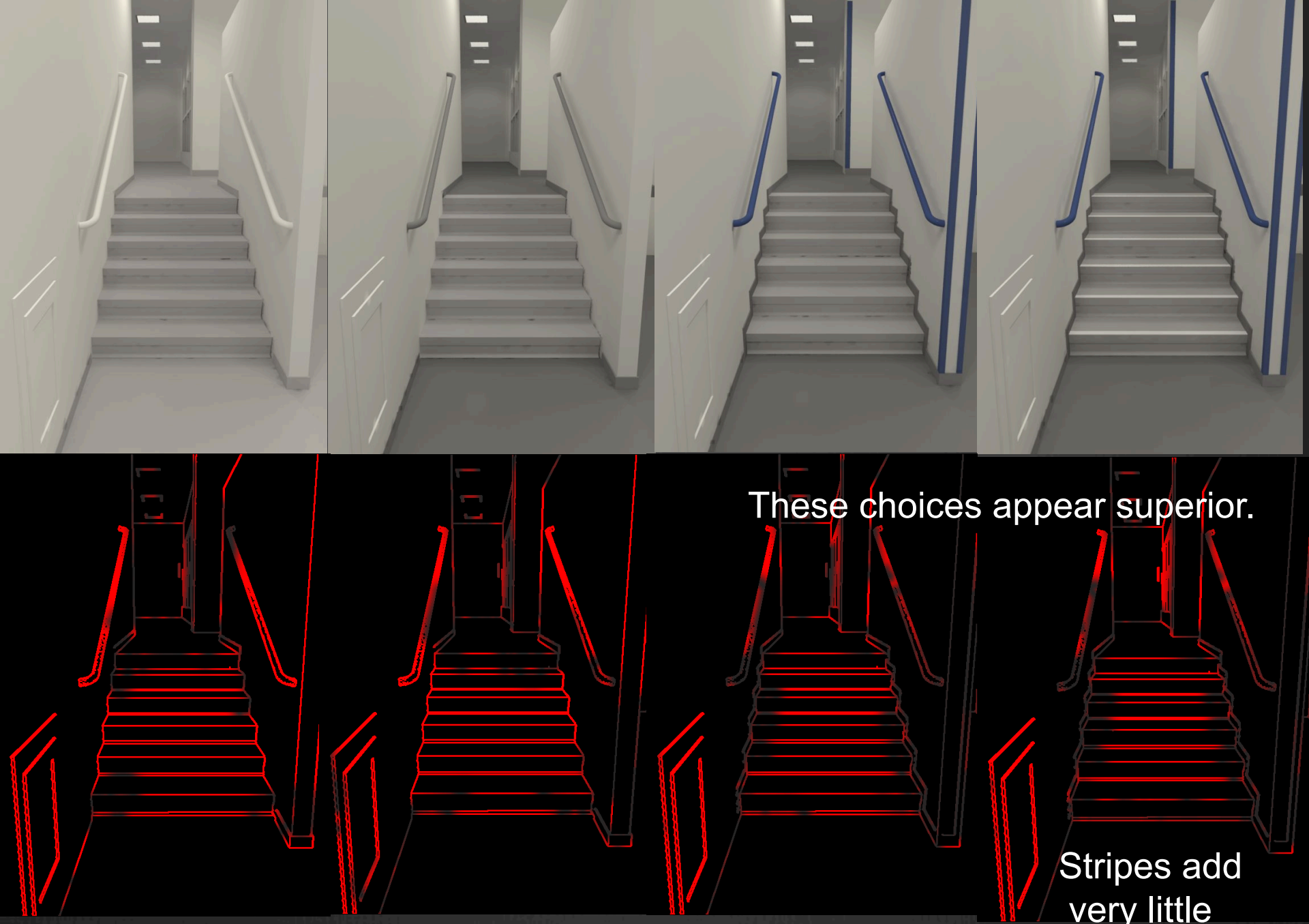
Maybe this choice is acceptable?
With corner edges?



Compare Severe….

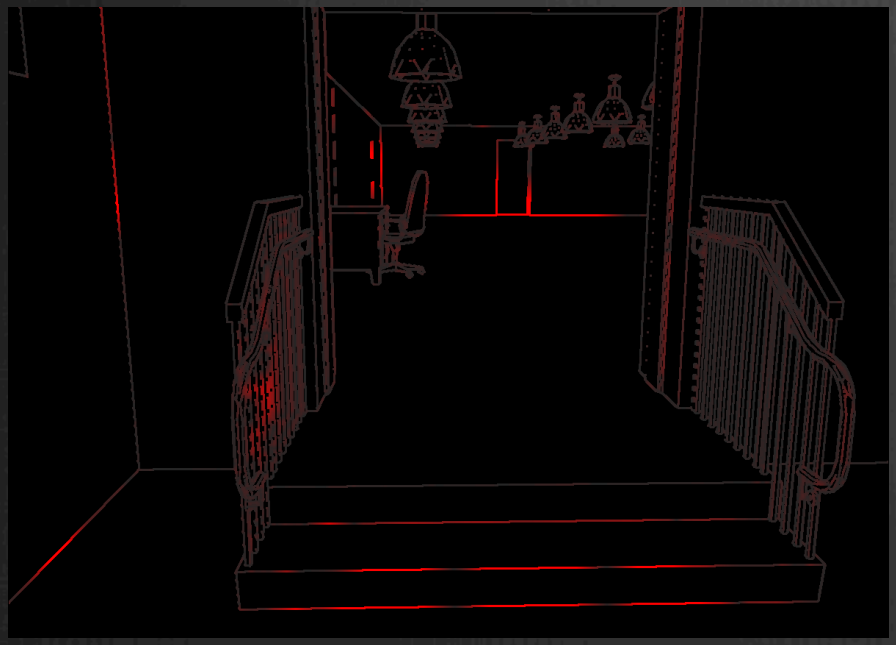


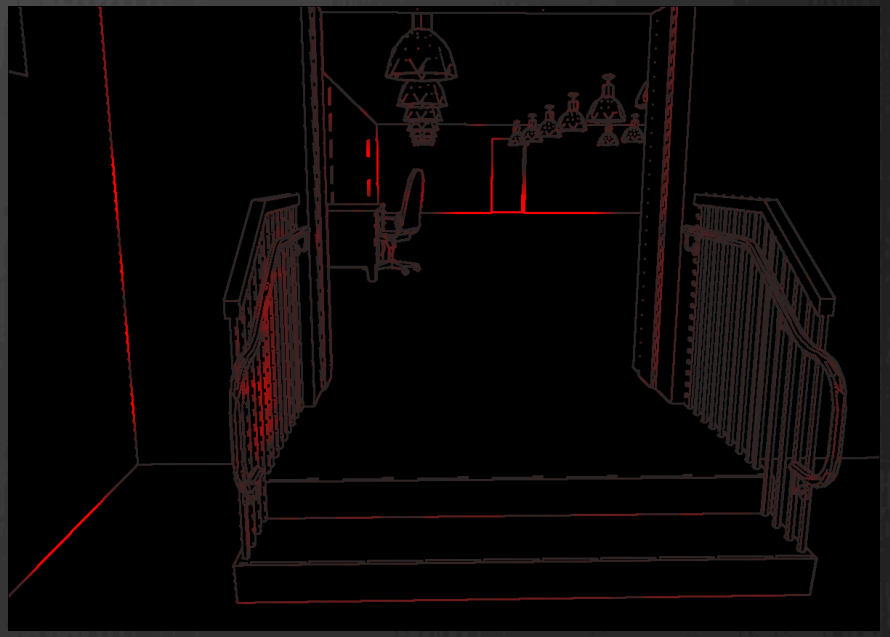
Compare Profound….



Compare Profound….

Unlike this study where stripes made a significant difference.





Now to evaluate the other direction… tomorrow!

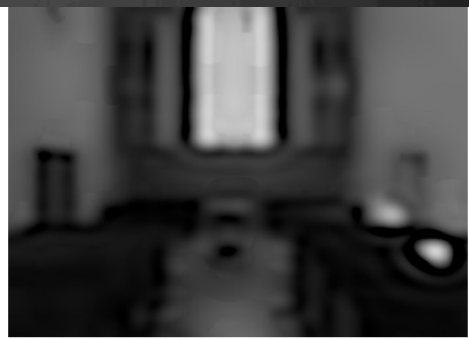
Visibility Prediction studies

Visibility Prediction studies

Simulation of *mild* visual impairment.

Simulation of *moderate* low vision.

Simulation of *severe* low vision.

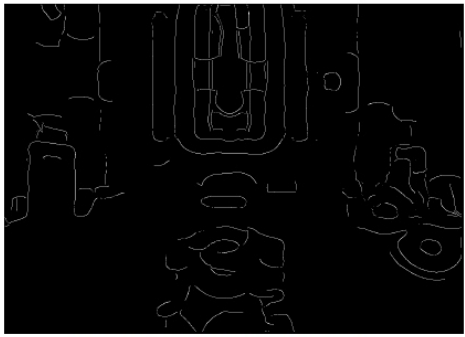


Simulation of *profound* low vision.

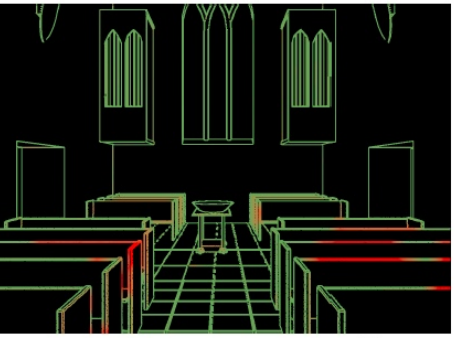
Canny edges for *mild* visual impairment.

Canny edges for *moderate* low vision.

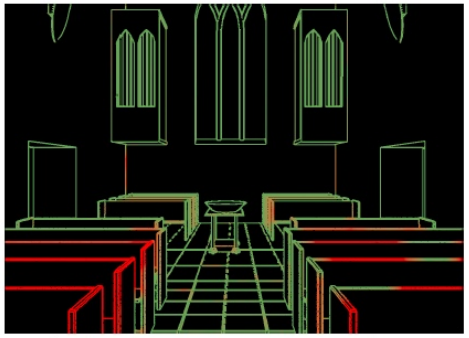
Canny edges for *severe* low vision.



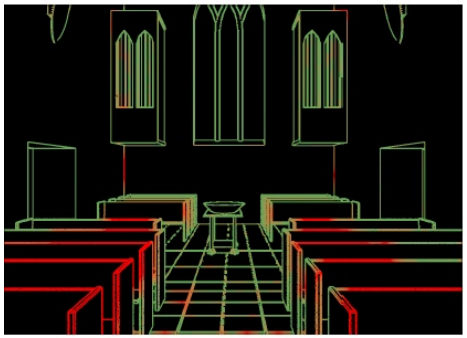
Canny edges for *profound* low vision.



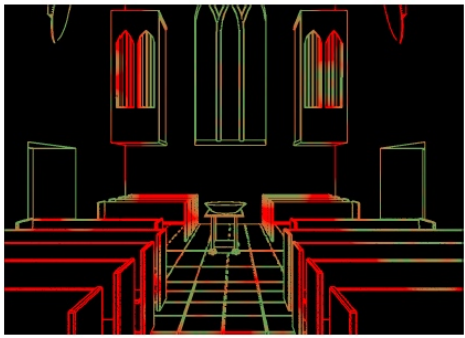
Predicted visibility of geometry under *mild* visual impairment.



Predicted visibility of geometry under *moderate* low vision.



Predicted visibility of geometry under *severe* low vision.

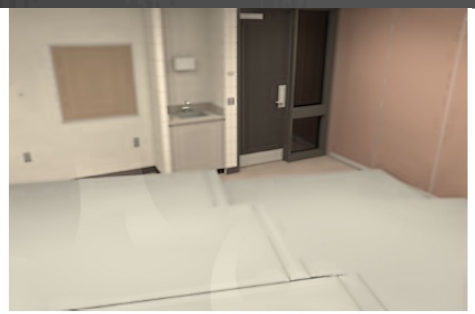


Predicted visibility of geometry under *profound* low vision.

Visibility Prediction studies

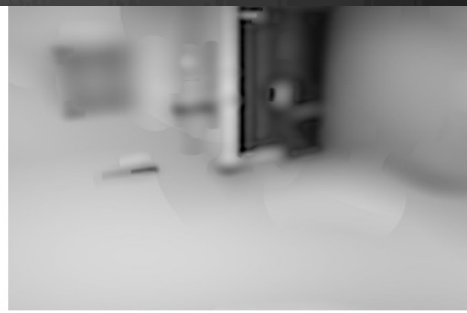
Visibility Prediction studies

Simulation of *mild* visual impairment.

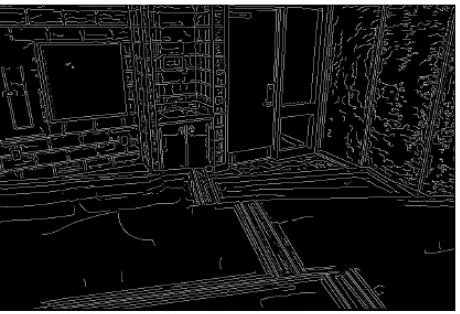


Simulation of *moderate* low vision.

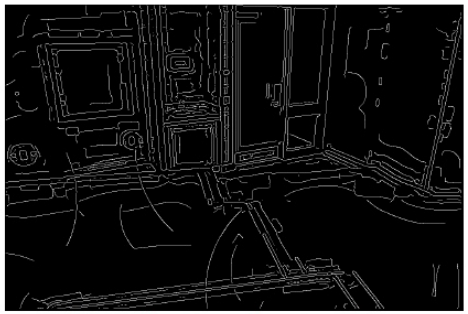
Simulation of *severe* low vision.



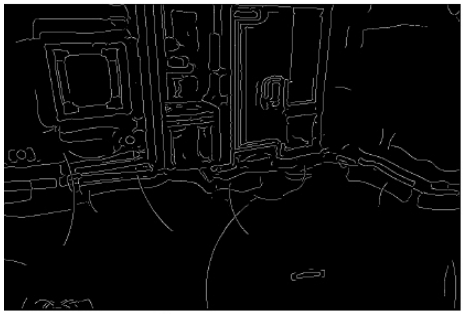
Simulation of *profound* low vision.



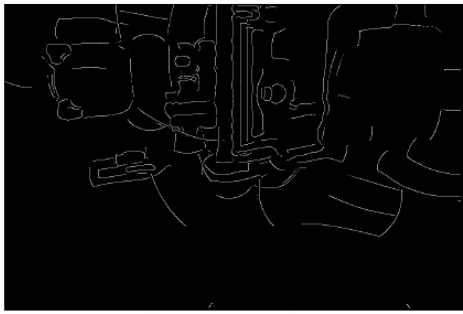
Canny edges for *mild* visual impairment.



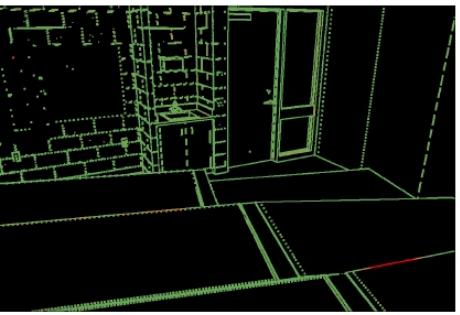
Canny edges for *moderate* low vision.



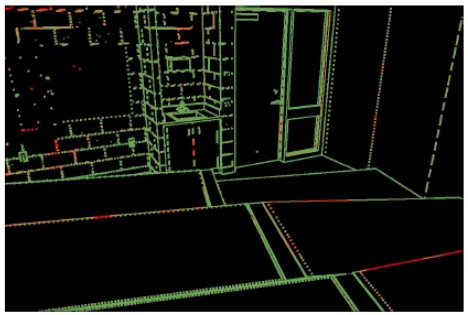
Canny edges for *severe* low vision.



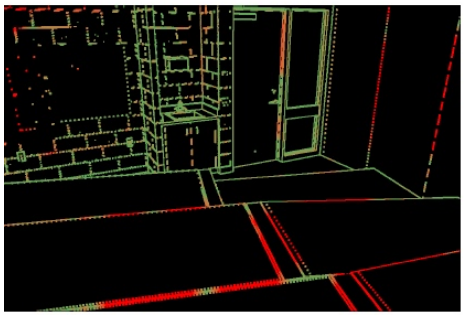
Canny edges for *profound* low vision.



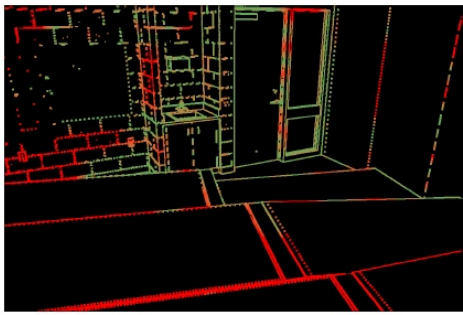
Predicted visibility of geometry under *mild* visual impairment.



Predicted visibility of geometry under *moderate* low vision.

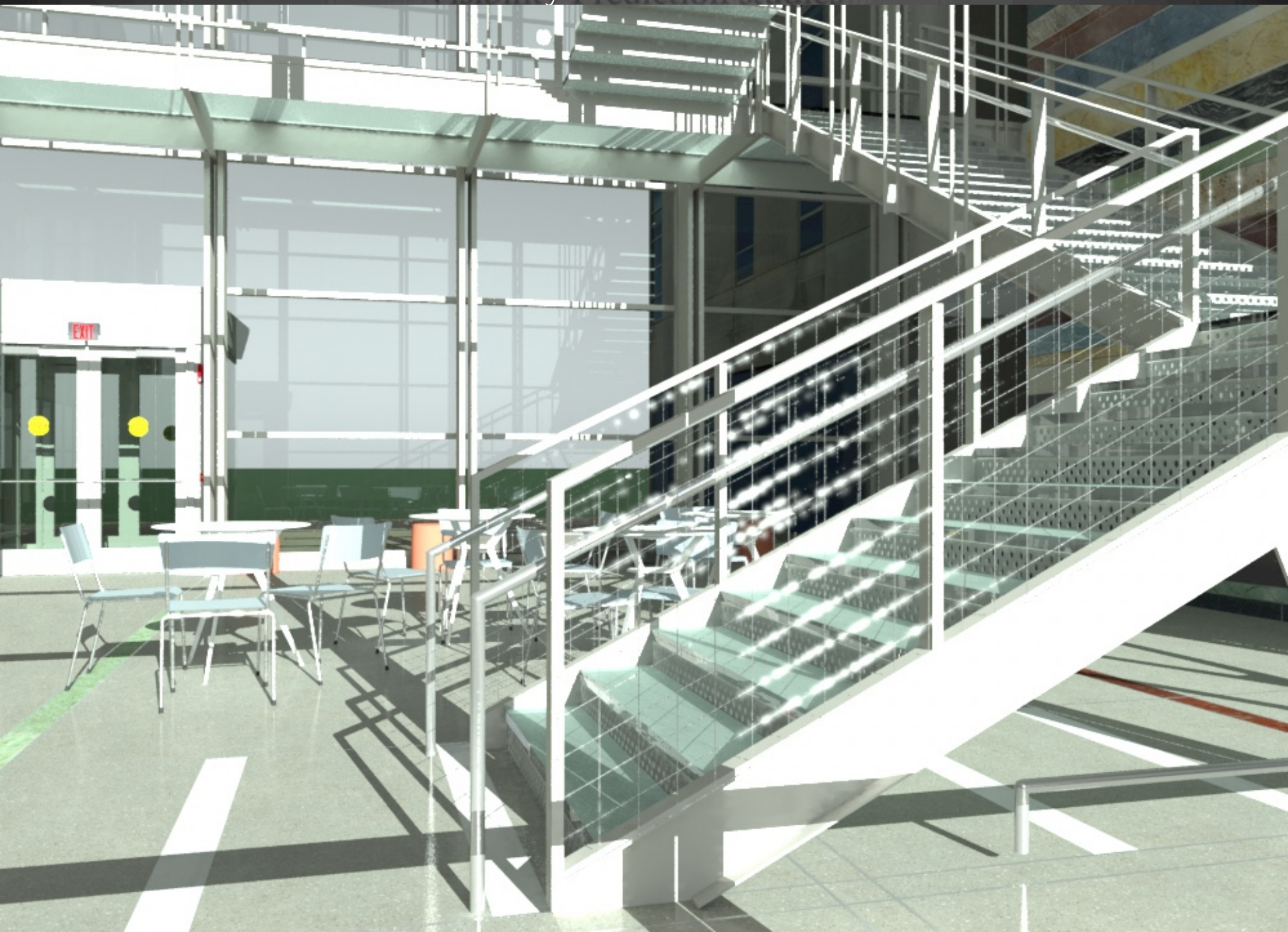


Predicted visibility of geometry under *severe* low vision.

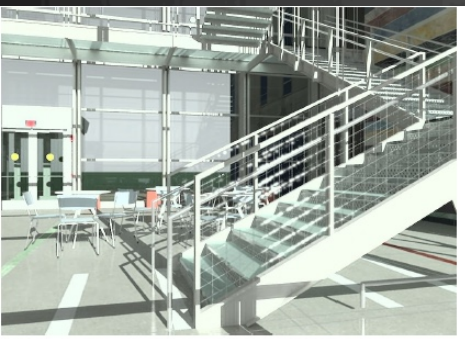


Predicted visibility of geometry under *profound* low vision.

Visibility Prediction studies



Visibility Prediction studies

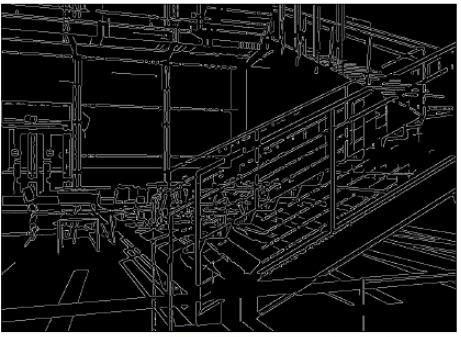


Simulation of *mild* visual impairment.

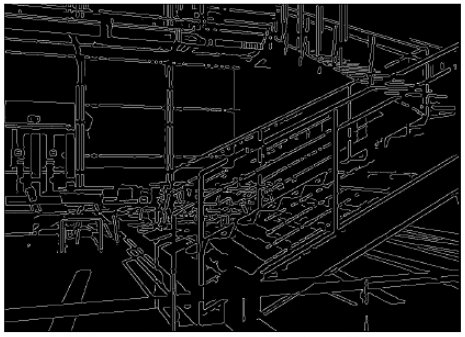
Simulation of *moderate* low vision.

Simulation of *severe* low vision.

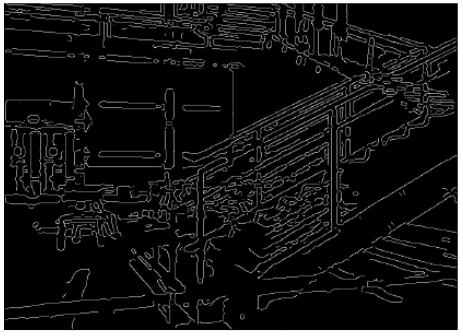
Simulation of *profound* low vision.



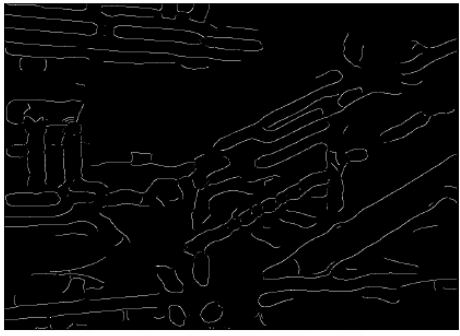
Canny edges for *mild* visual impairment.



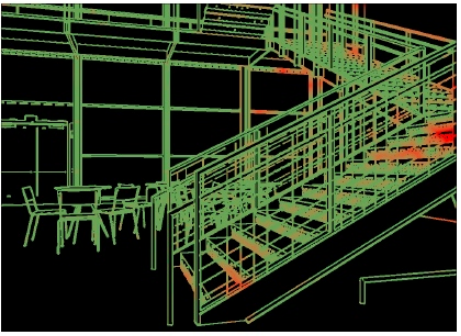
Canny edges for *moderate* low vision.



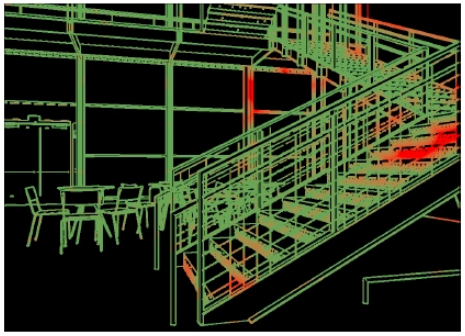
Canny edges for *severe* low vision.



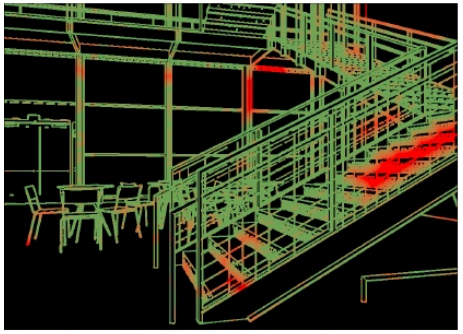
Canny edges for *profound* low vision.



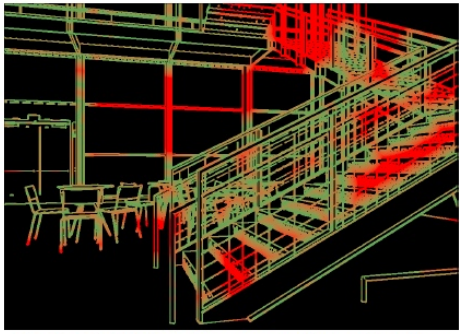
Predicted visibility of geometry under *mild* visual impairment.



Predicted visibility of geometry under *moderate* low vision.



Predicted visibility of geometry under *severe* low vision.

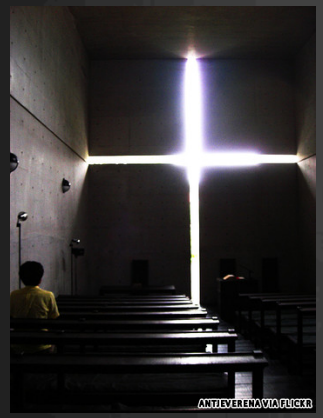


Predicted visibility of geometry under *profound* low vision.

Note that the visibility filter can operate on any HDR image...

Evaluation of an existing site prior to and/or post renovation?

.



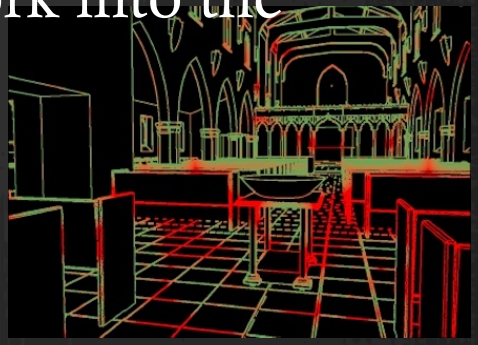
Future work

Glare: This is a challenging topic that needs to be addressed in regards to low vision

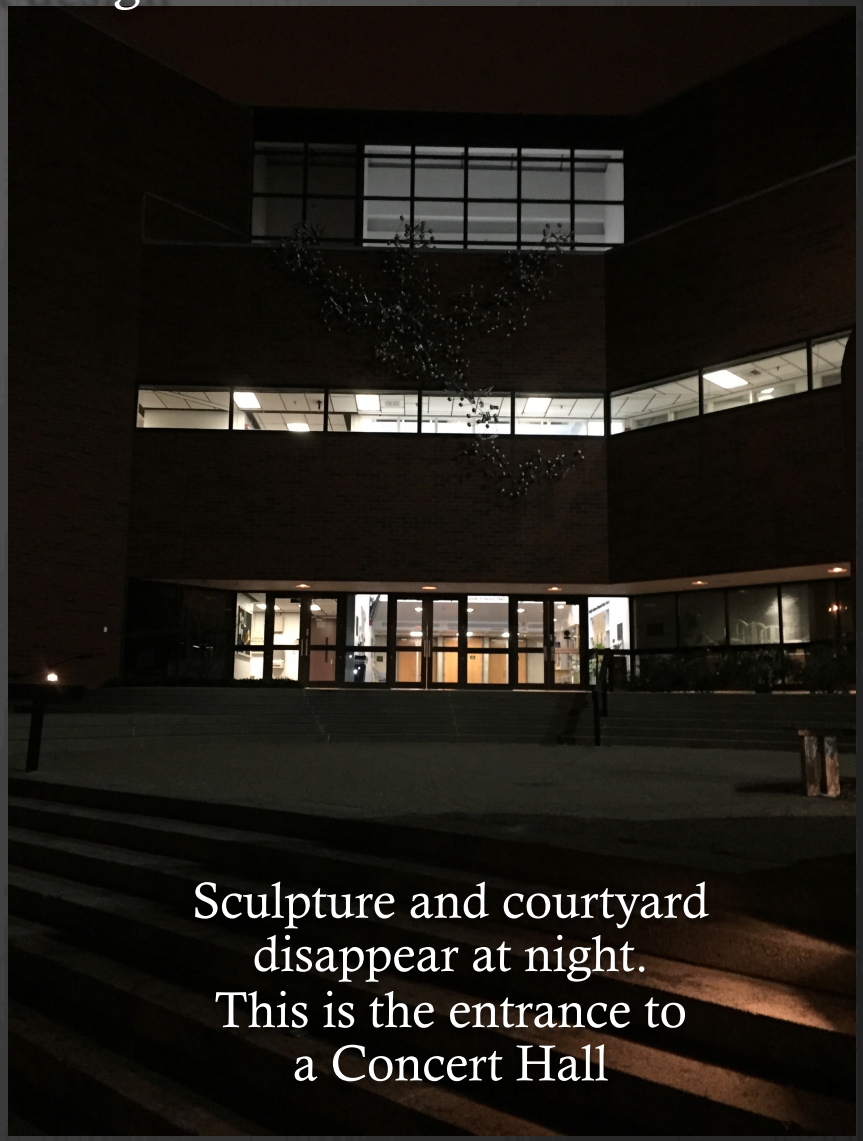
Remove non-trip surface features less that 1/2” high wide from the walking planes in the Ground Truth edge analysis

Add binocular and eye movement influences, currently underway.

IDENTIFY DEVELOPERS to integrate this work into the tools such as REVIT, making it accessible to the architectural design professions



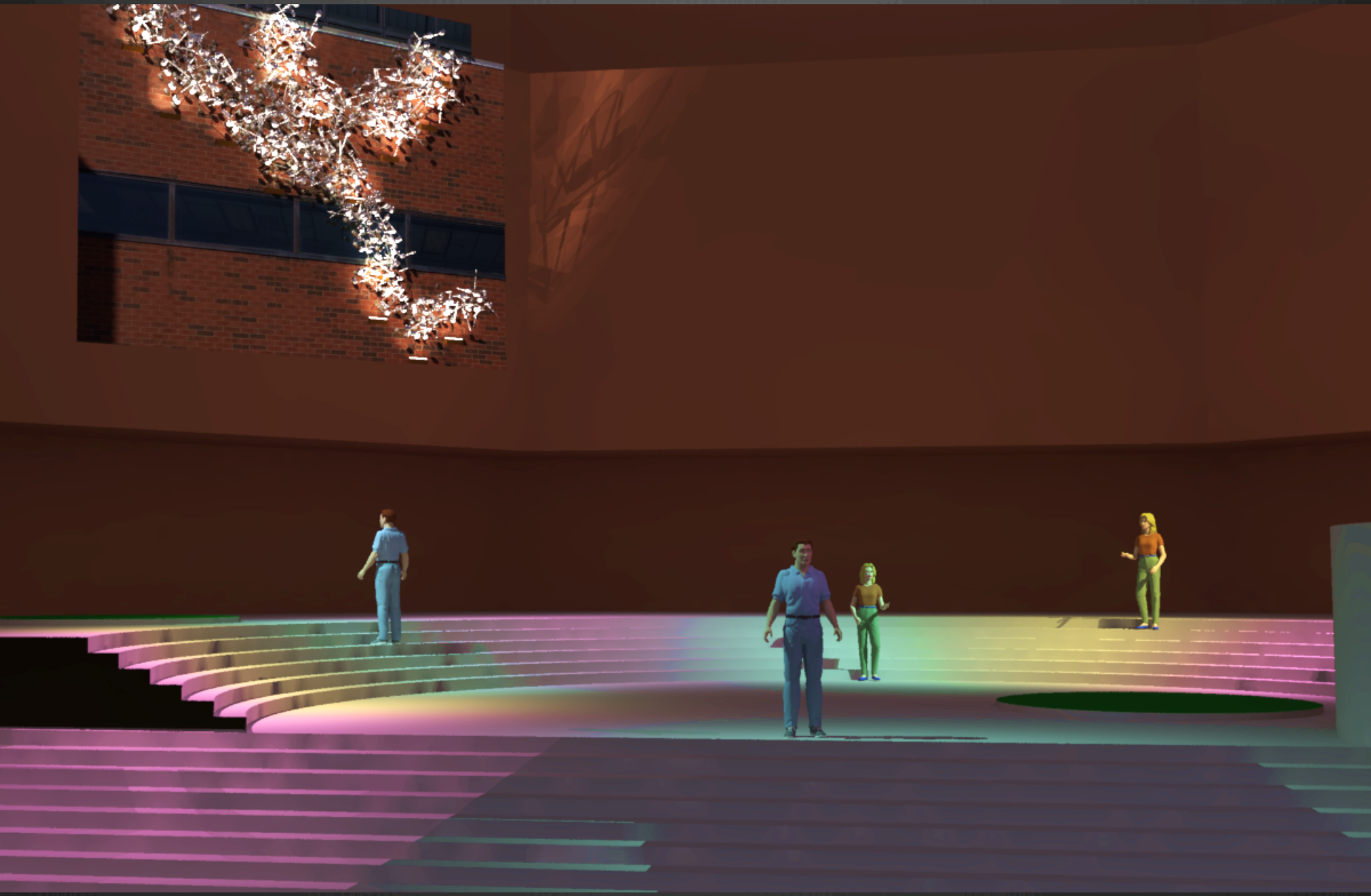
+ my latest design



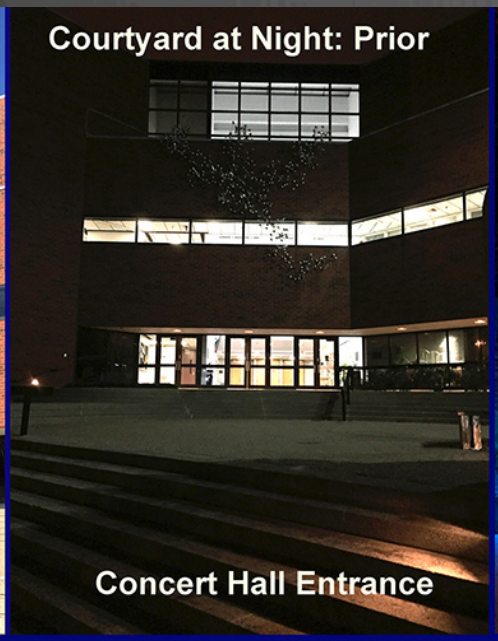
Sculpture and courtyard
disappear at night.
This is the entrance to
a Concert Hall

University of Louisville, School of Music courtyard

Quickie Concept Image for *CORONA*




School of Music
“Effervescence” Sculpture


Courtyard at Night: Prior
Concert Hall Entrance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17th Annual International Radiance Workshop

Predicting Visibility during the Design Phase+

Thank You!

Designing Visually Accessible Spaces
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Rob Shakespeare
Indiana University PI

Other research team members from:
University of Minnesota, Low Vision Lab & Computational Vision
University of Utah, Computer Science & Visual Perception & Spatial Cognition