Designing Visually Accessible Spaces (DeVAS): Visibility prediction tools and introducing the Hazard Visibility Score

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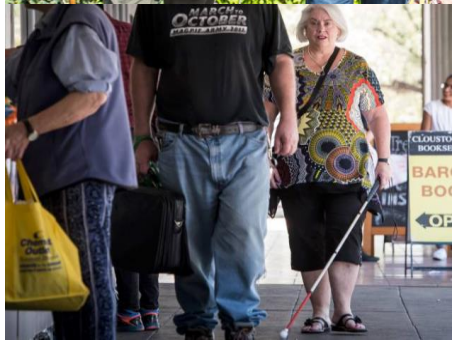
… tools for use in the architect's design workflow

Daylight Symposium
VELUX Days in Paris, October 9, 2019

Why is Visibility Prediction Important?

Fully sighted acuity	20/20	6/6
Low Vision USA	20/40	6/12
Low vision (WHO)	20/60	6/18
Legal blindness threshold (US)	20/200	6/60
Blindness threshold (WHO)	20/400	6/120

	Europe(Geographic)	World
Population	~738 mil	~7.7 bil
Low vision	**~26 mil**	~164 mil
Completely blind	**~3.2 mil**	~55 mil



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Low Vision Community has visual ability BUT we do not yet design environments enabling then to navigate spaces safely.

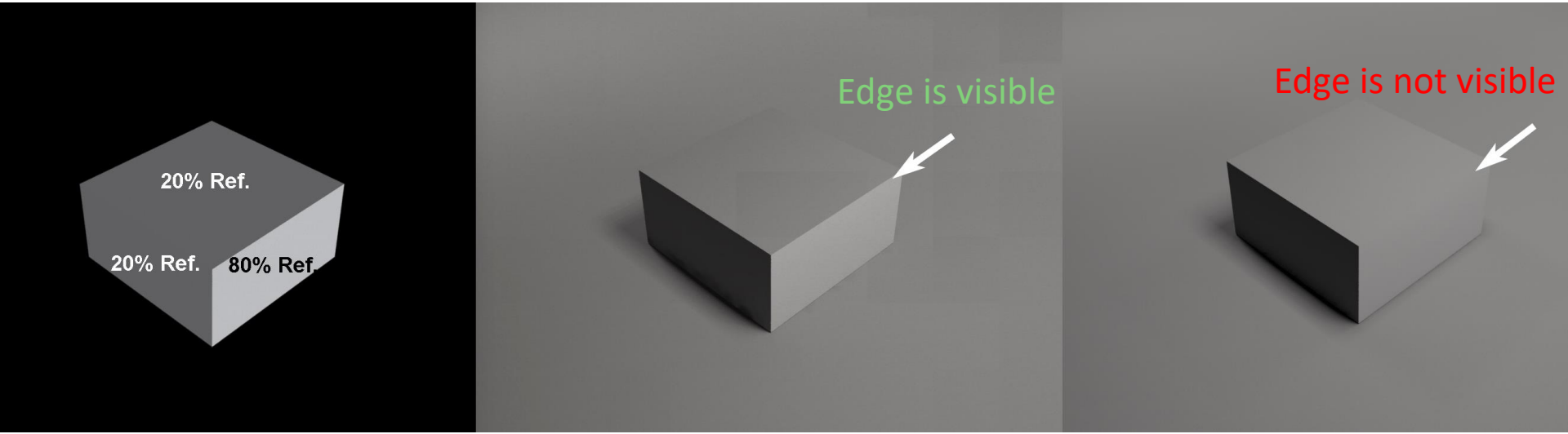
What is a Visual Hazard?

Unseen edges within the path or route of a traveller can become a hazard

"the Potential to Cause Harm"

…benches,
steps,
ramps,
protruding corners,
columns,
the edge of a subway platform…

DeVAS What current lighting analyses tools miss….



A shift in luminaire location obliterates a 60% difference in the reflectivity of these materials. Note how the edge disappears, in the right image, by moving the luminaire ~ 60cm…

WOULD BE MISSED using typical illumination calculations and analyses.

Design by luminance, not by illumination and material contrast specifications,

IS DESIGN BY WHAT WE SEE

Acuity and Contrast

DeVAS Filter

J Opt Soc Am A Opt Image Sci Vis. 2017 April 1

(Thompson, Legge, Kersten, Shakespeare, Lei)

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).

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

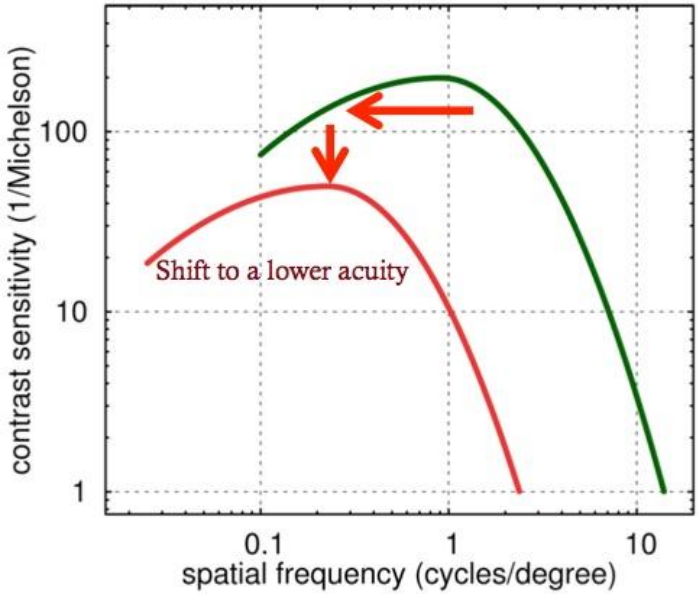
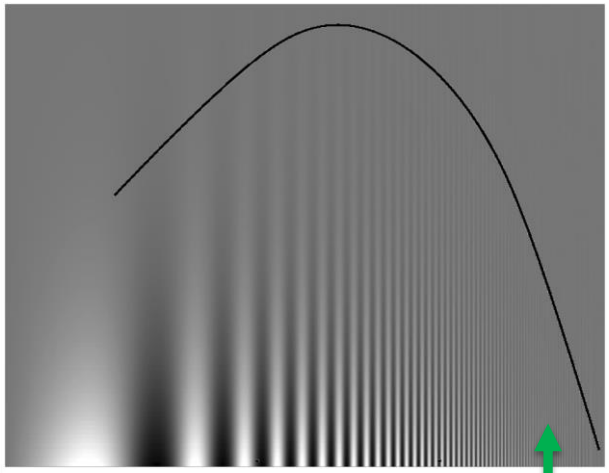
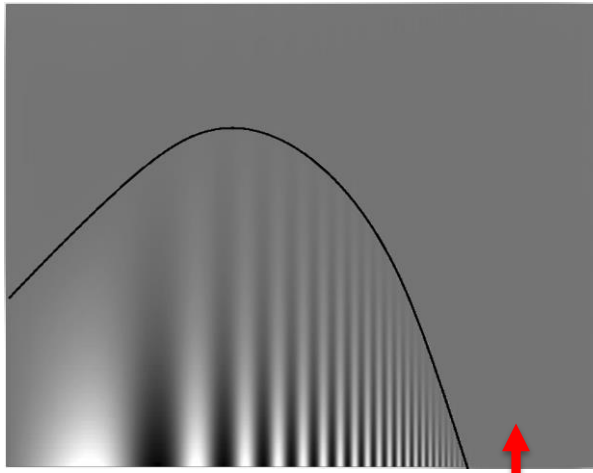


Fig. 1.
The Chung & Legge [15] CSF is an asymmetric parabola when plotted in $f_l - S_l$ space. The plotted values show two instances of the CSF, one shifted left (lower acuity) and down (lower contrast sensitivity) compared to the other.



Normal Vision CFS

Fine detail visible

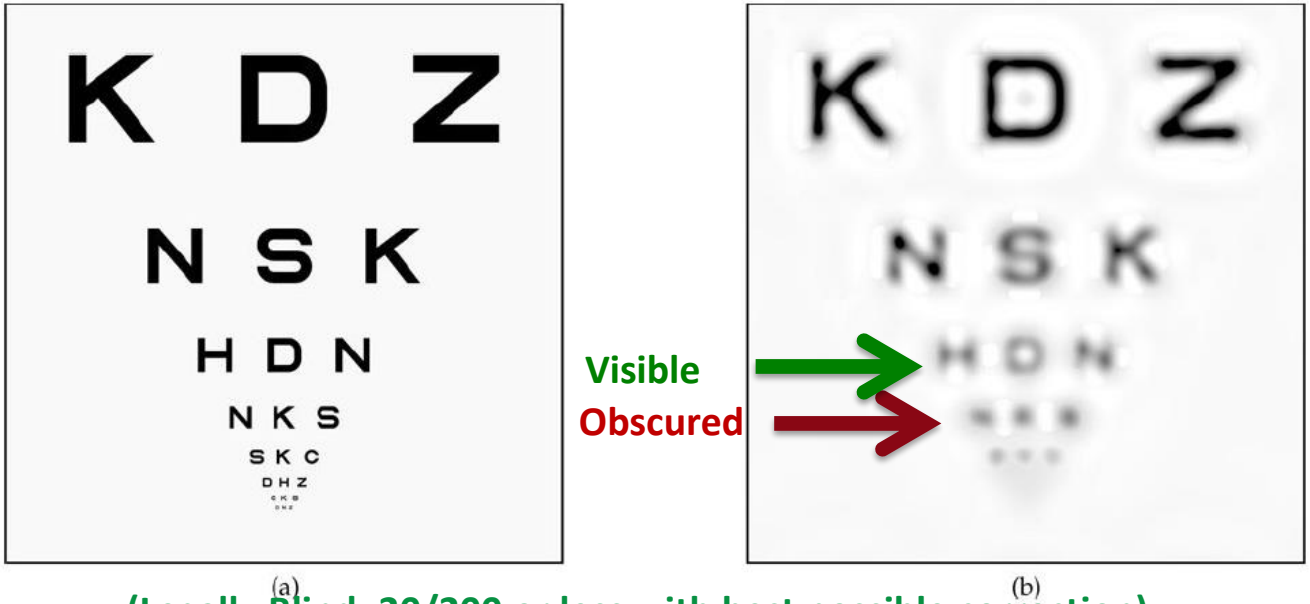


A Low Vision CSF

Fine detail invisible

DeVAS Filter

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



(Legally Blind: 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.

DeVAS-Visibility:

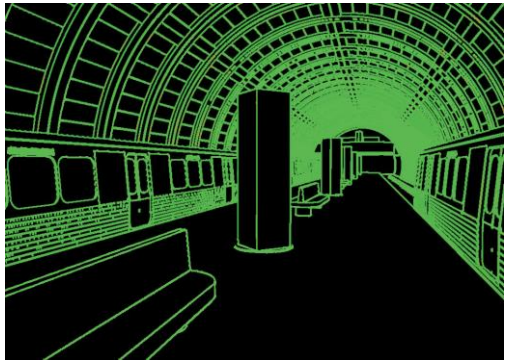
The **application tool**,

built upon **DeVAS-Filter**,

that **predicts visibility**.

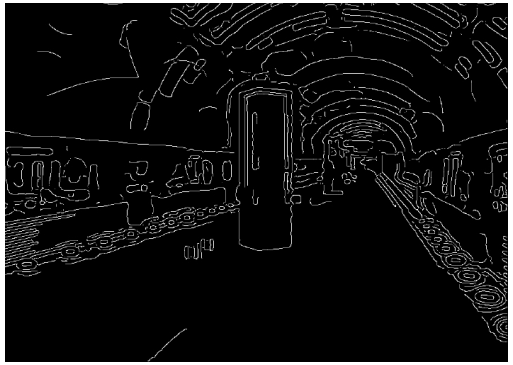
DeVAS-Visibility: Automated Visibility Prediction Application

Radiance Rendering plus Geometry Data
New: **rtpict**



Ground Truth Edges

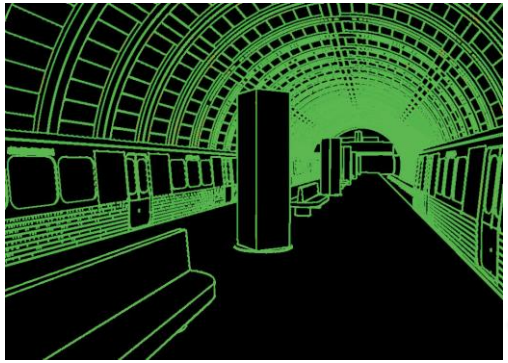
DeVAS-Filter:
Severe Low Vision



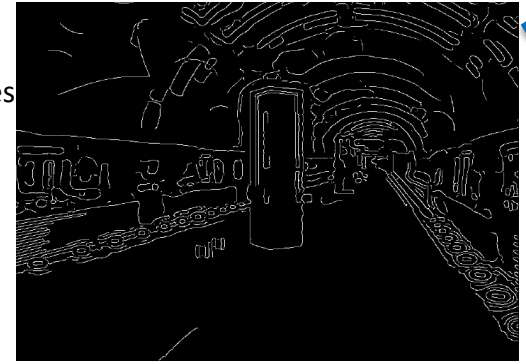
Luminance Boundaries:
Canny Edges

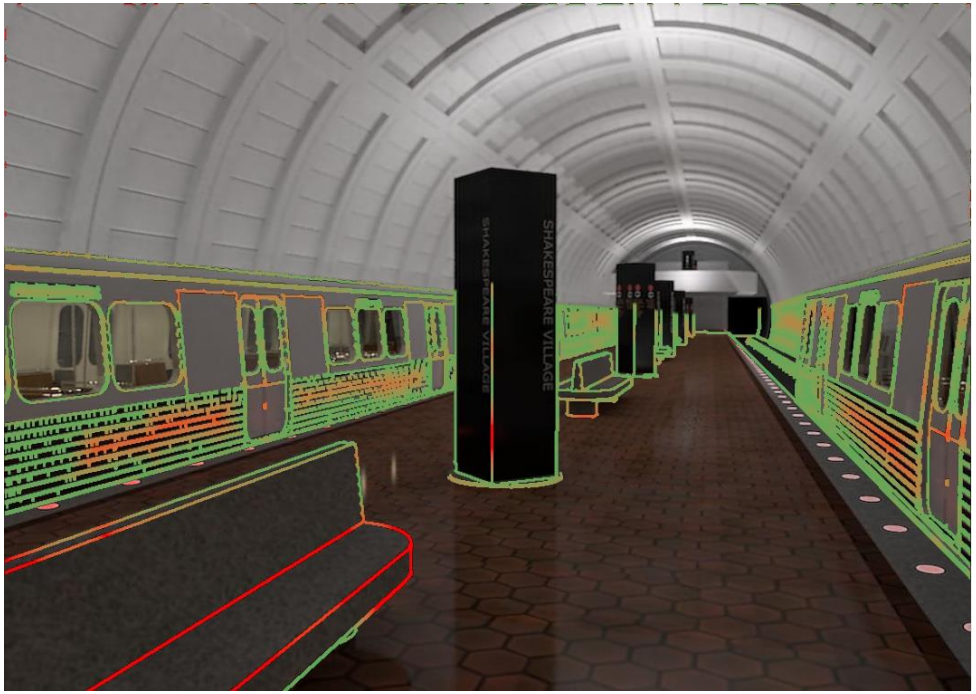
DeVAS Visibility

Ground Truth Edges



Luminance Boundaries
Severe Low Vision



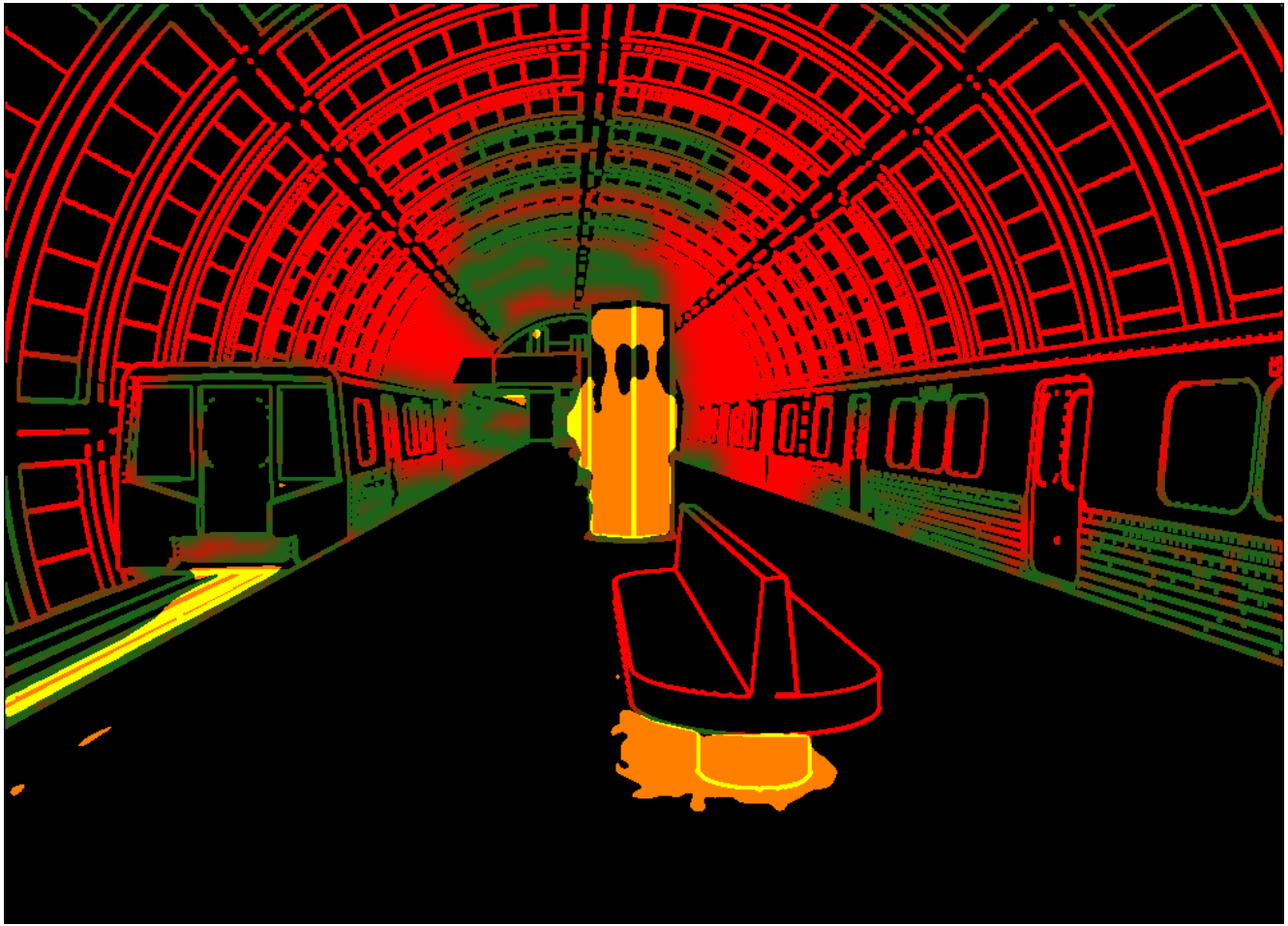


RED edges predicted **NOT** to be **visible**
Green edges predicted **visible** for Severe LV

DeVAS Visibility

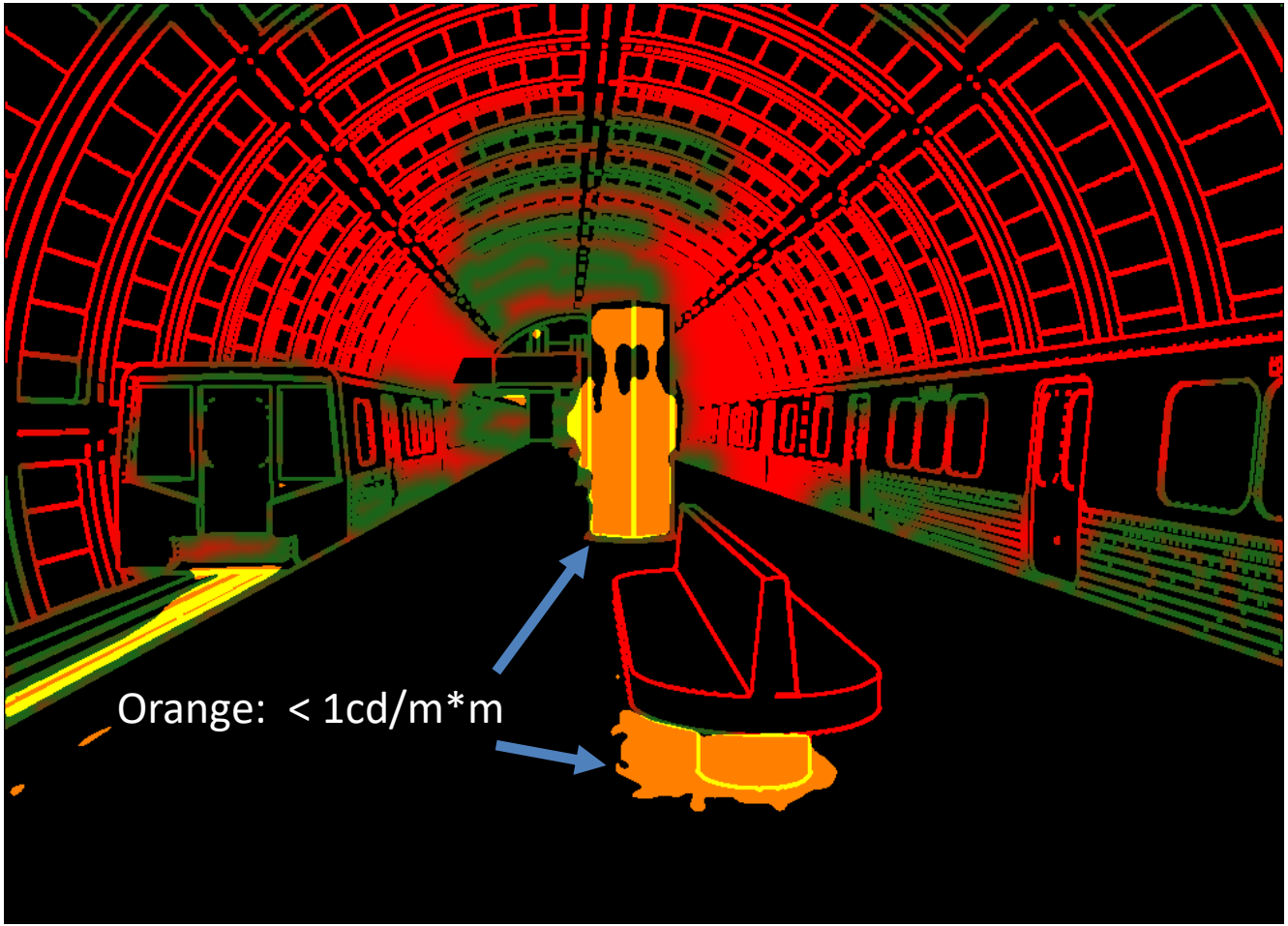
DeVAS Visibility Workflow Examples

DeVAS Visibility



Low Vision: Severe

DeVAS Visibility

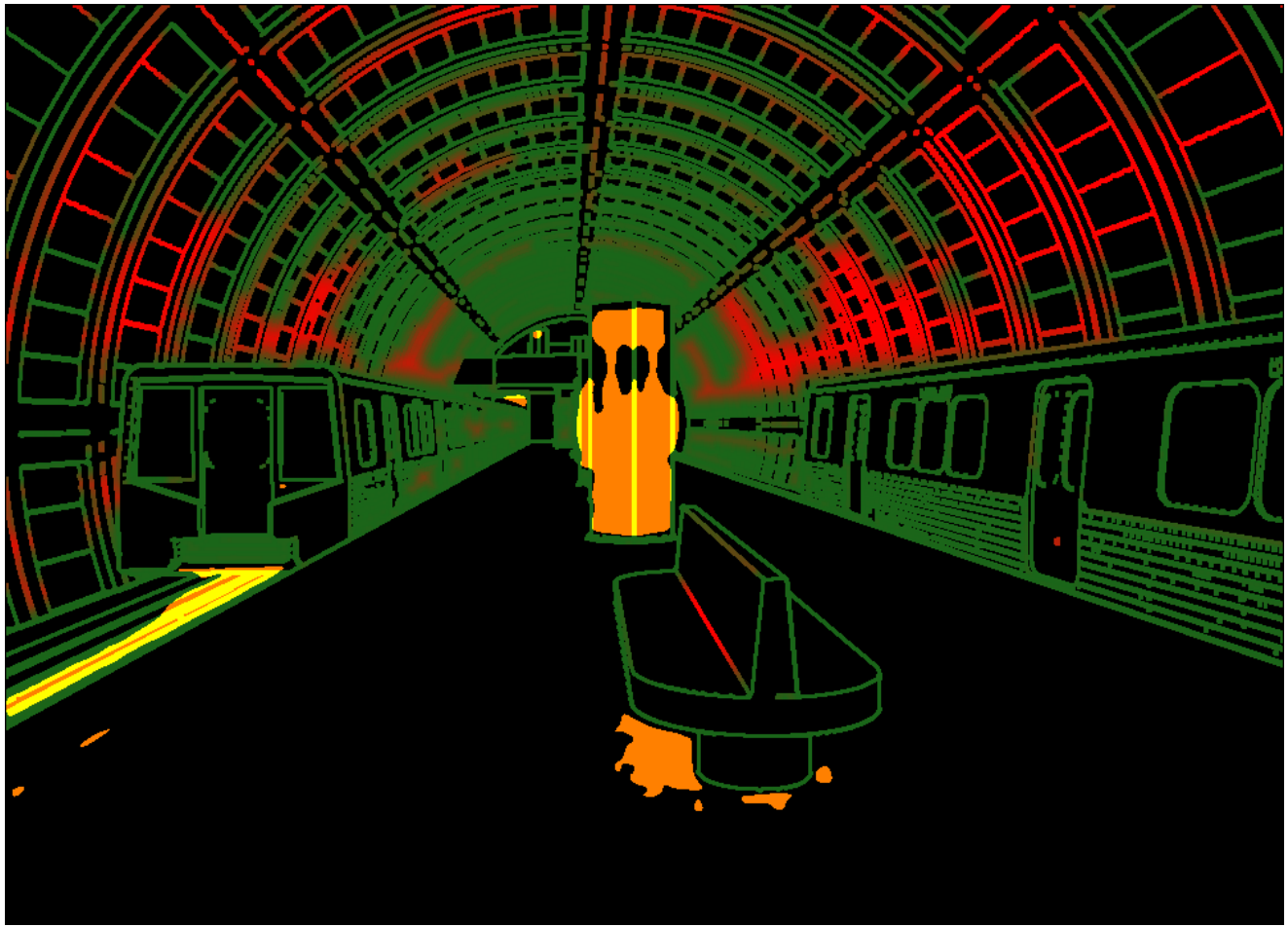


Low Vision: Severe

DeVAS Visibility

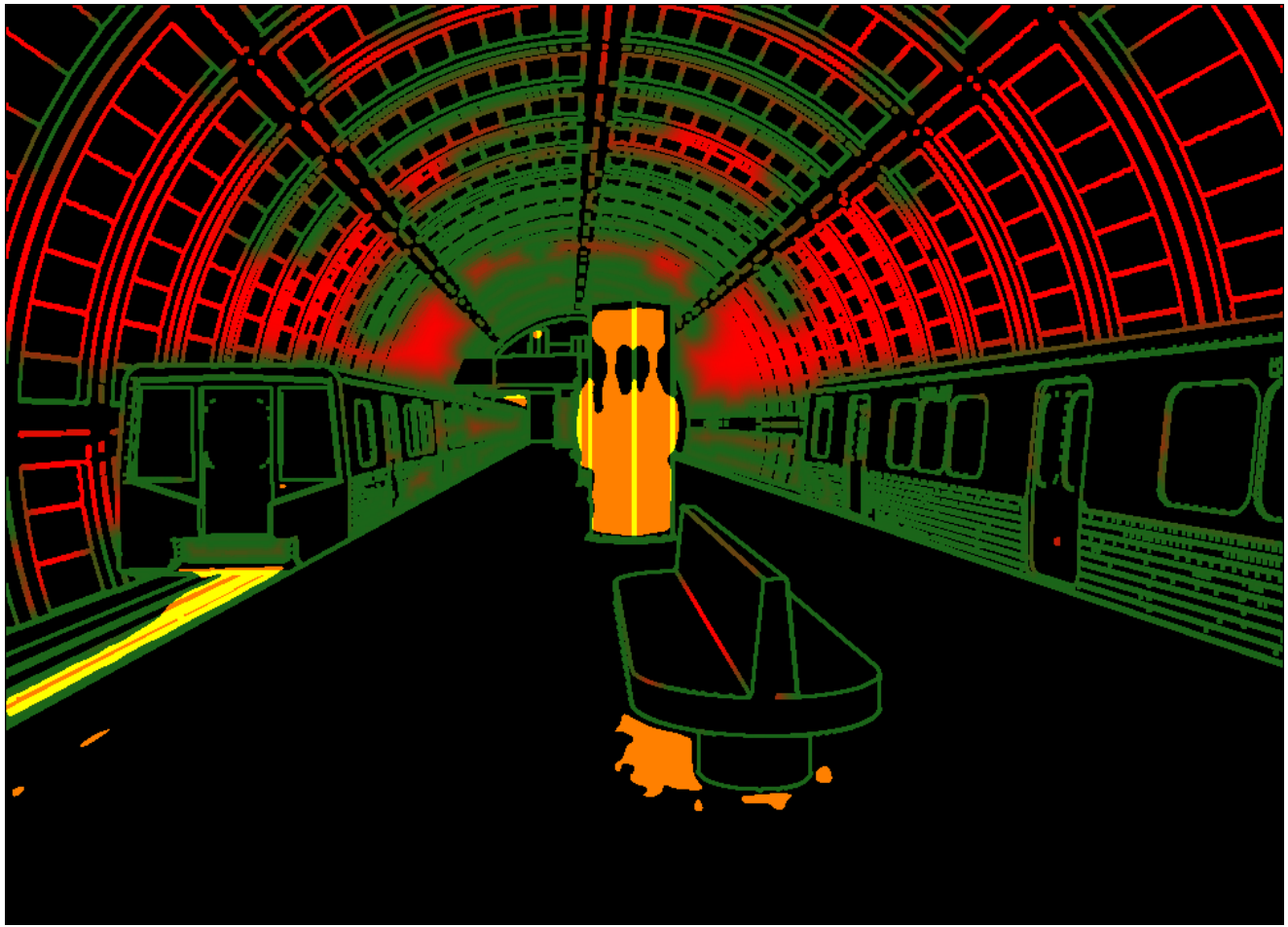
Change bench material

DeVAS Visibility



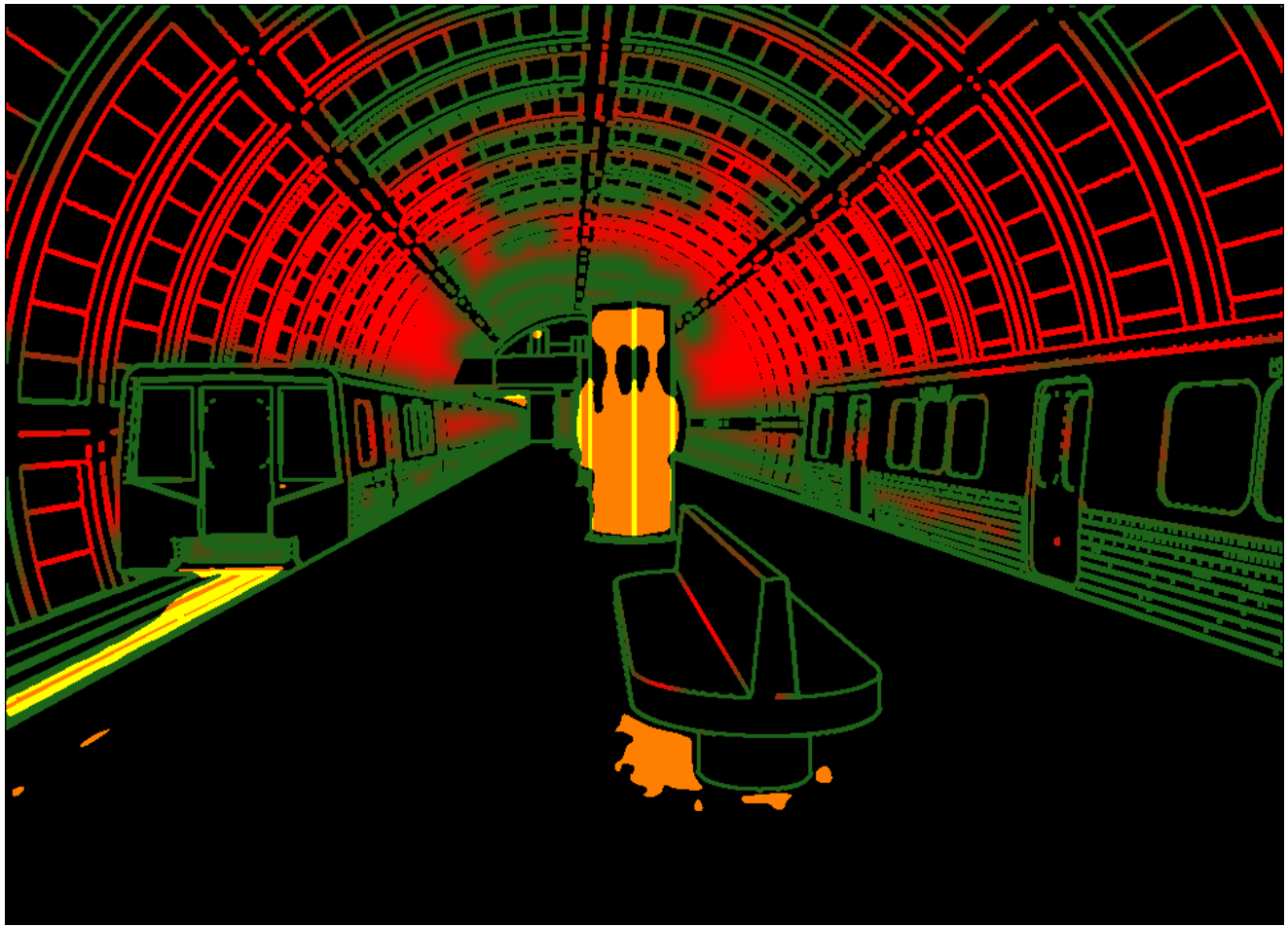
Low Vision: Mild

DeVAS Visibility



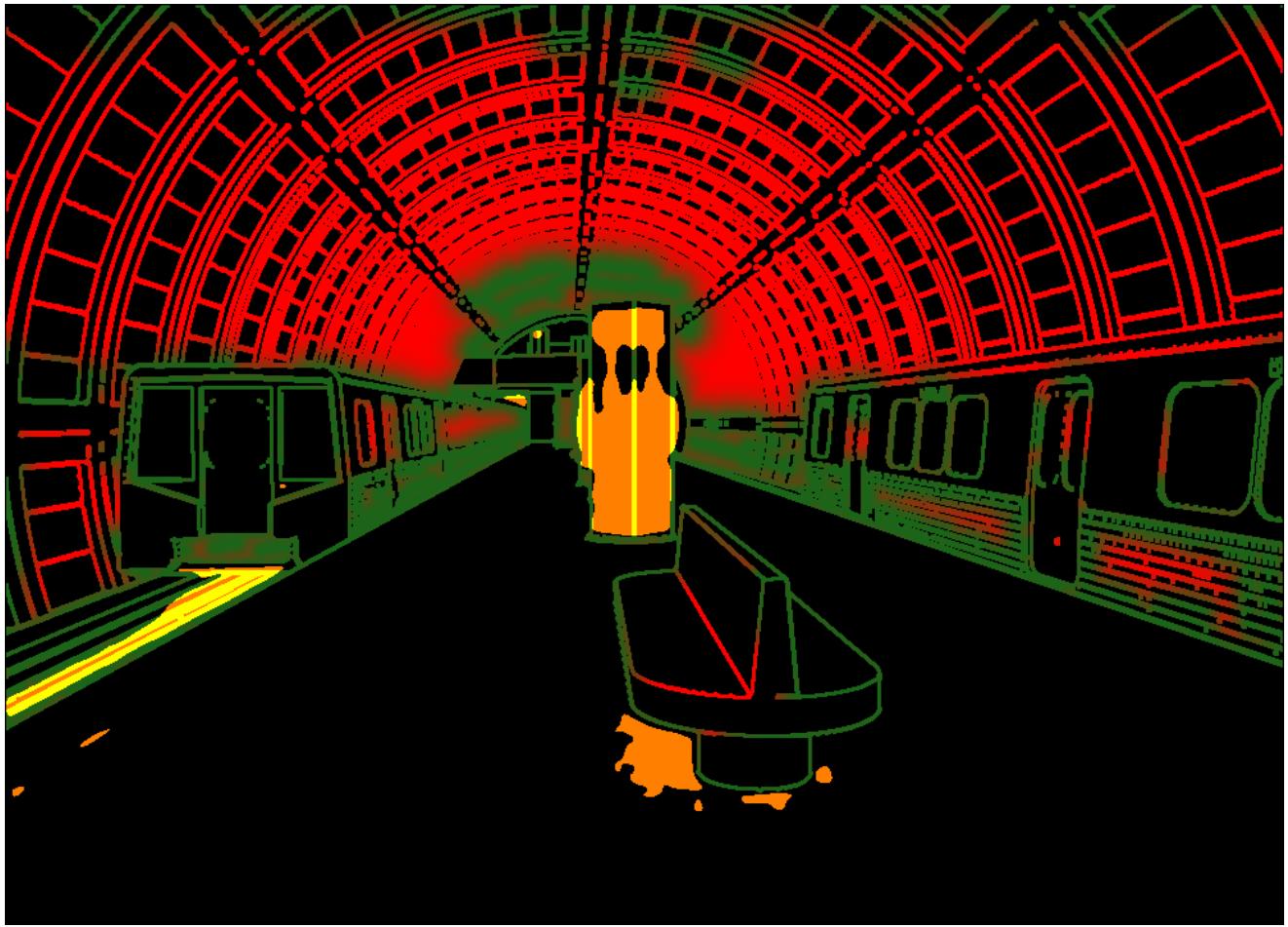
Low Vision: Moderate

DeVAS Visibility



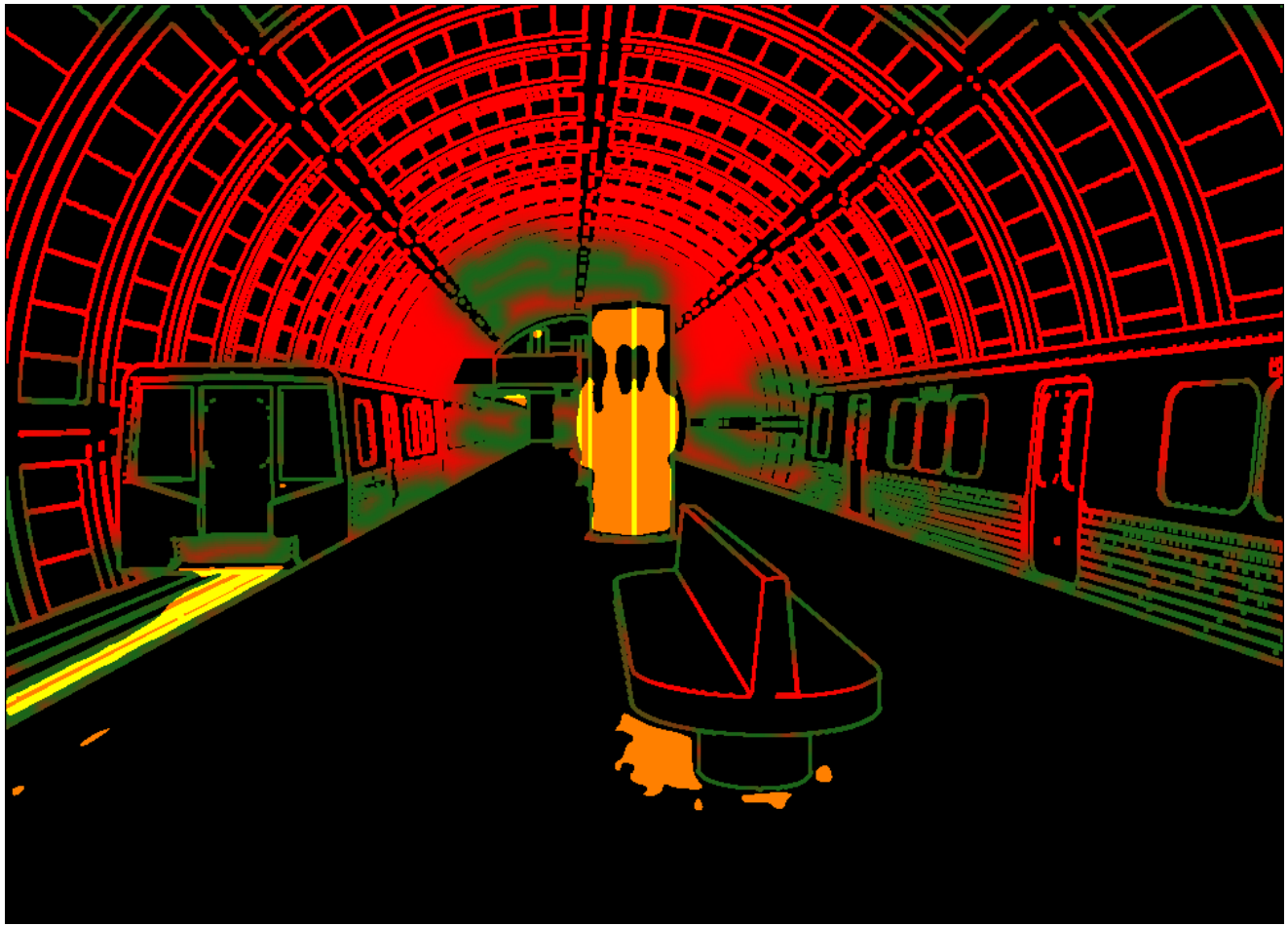
Low Vision: Legally Blind Threshold

DeVAS Visibility



Low Vision: Severe

DeVAS Visibility

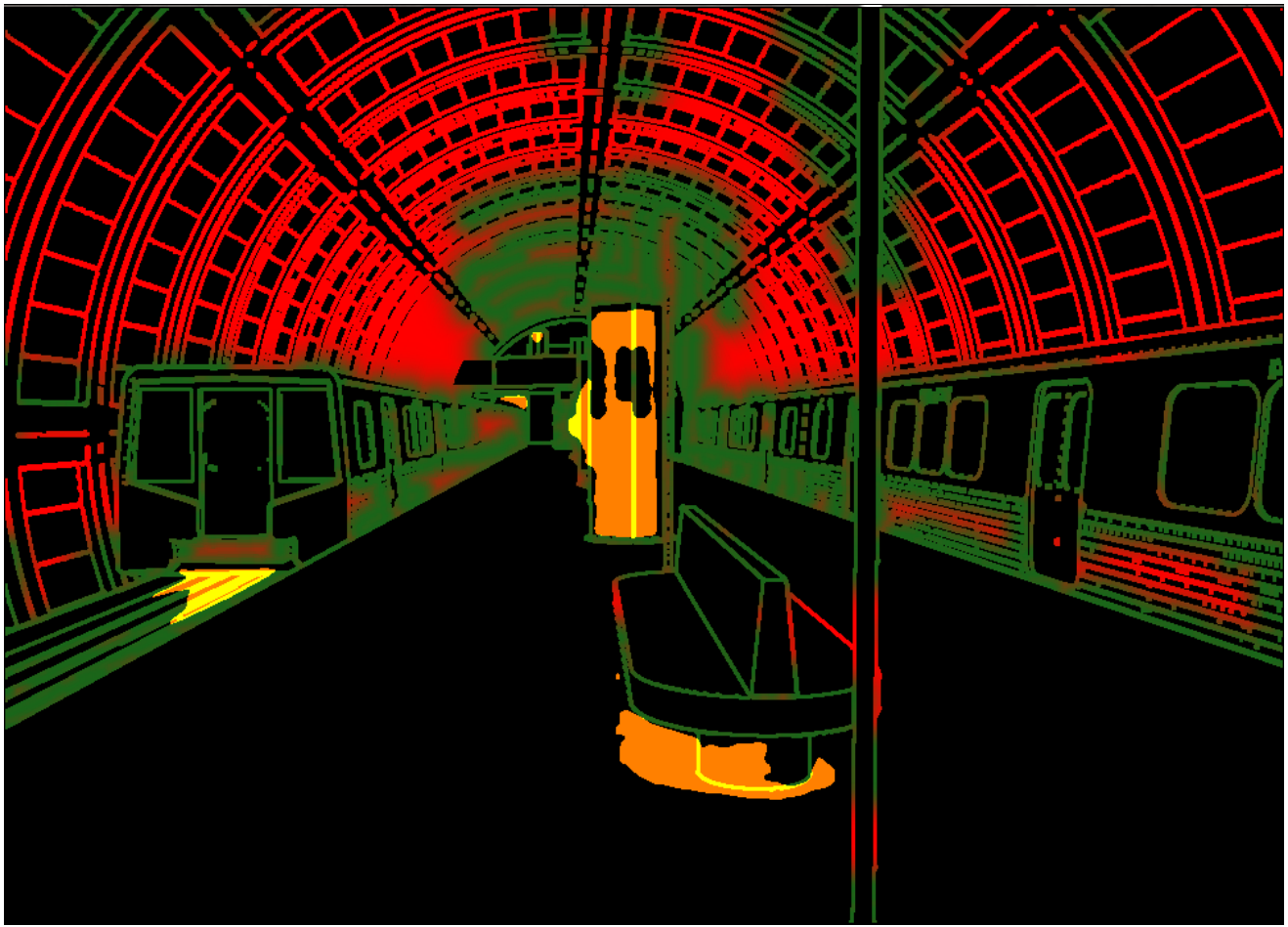


Low Vision: Profound

DeVAS Visibility

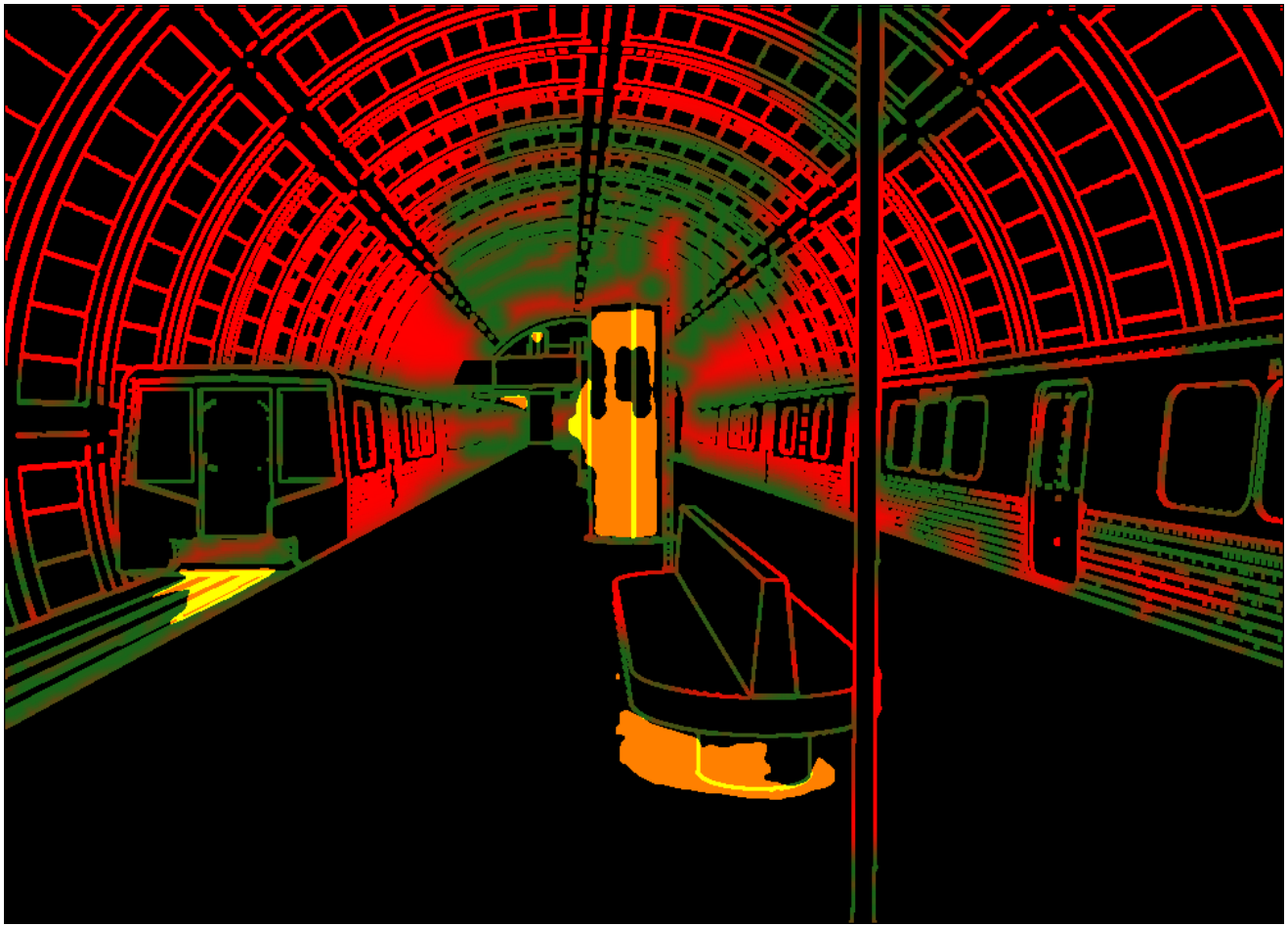
Change the illumination

DeVAS Visibility



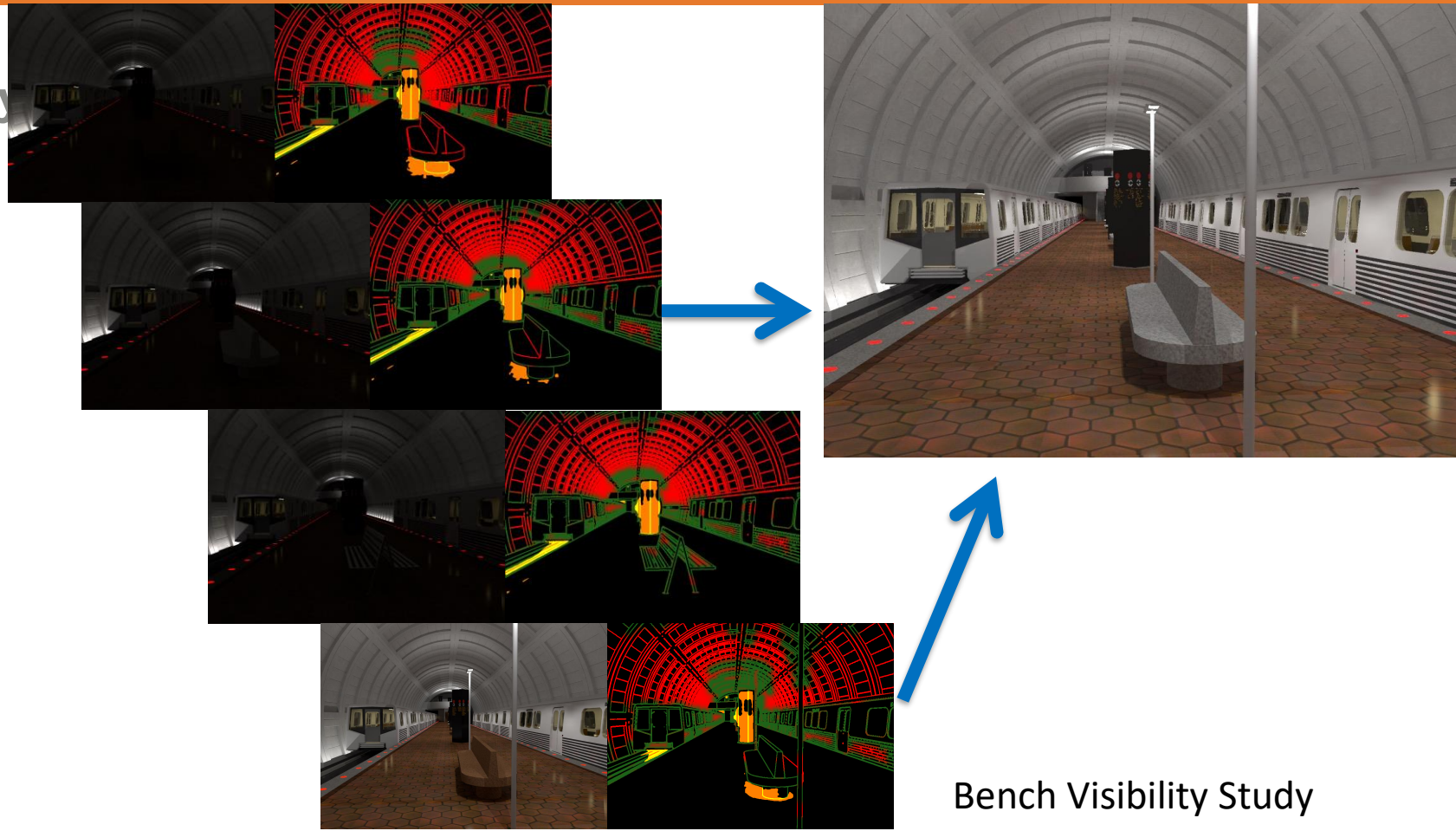
Low Vision: Severe

DeVAS Visibility



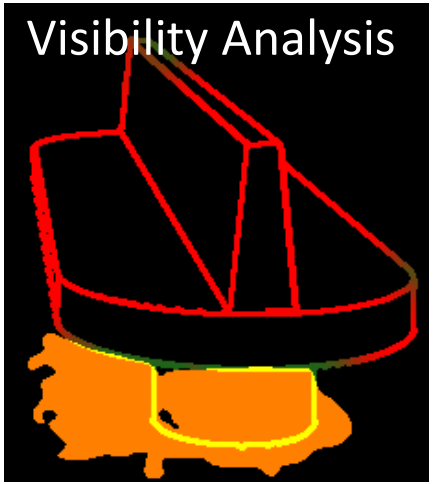
Low Vision: Profound

DeVAS Visibility



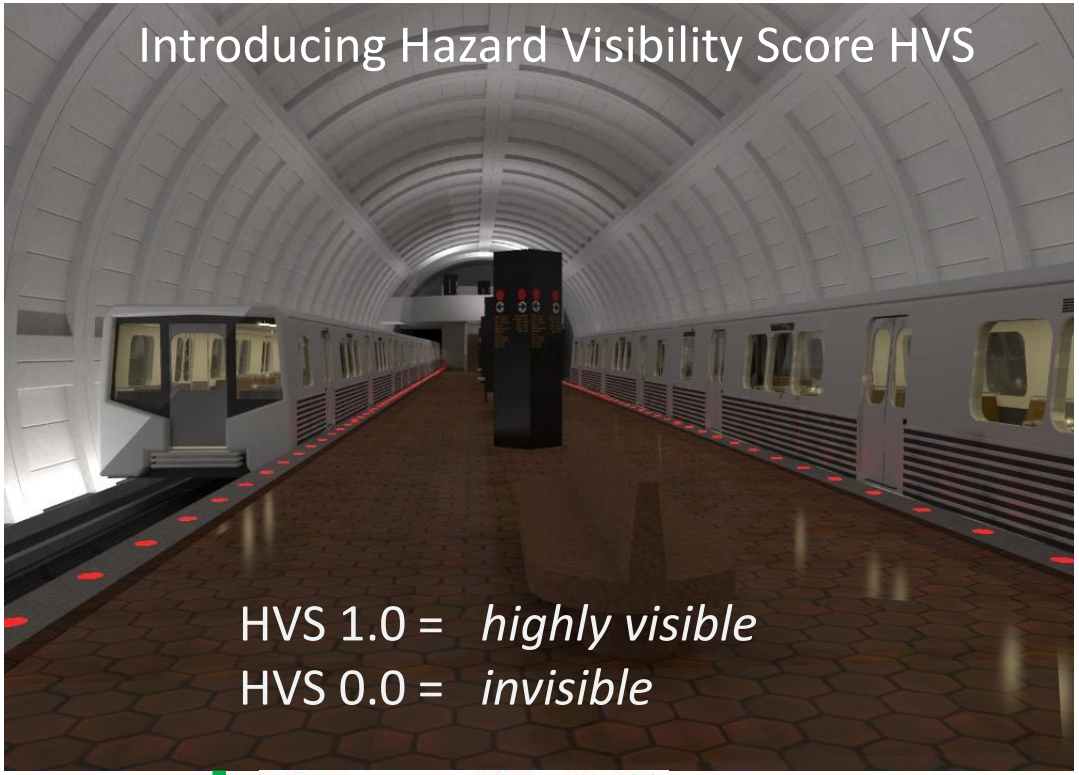
Bench Visibility Study

DeVAS
HVS

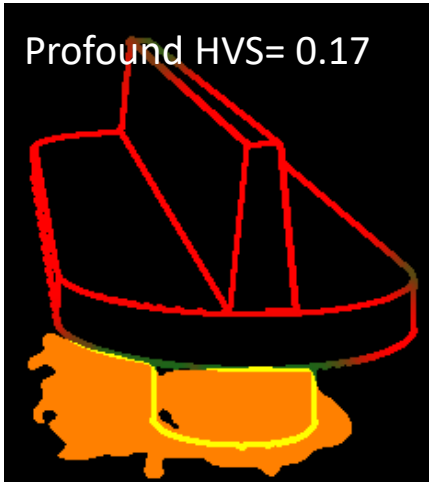


A Region of Interest ROI is created which contains the potential visual hazard.

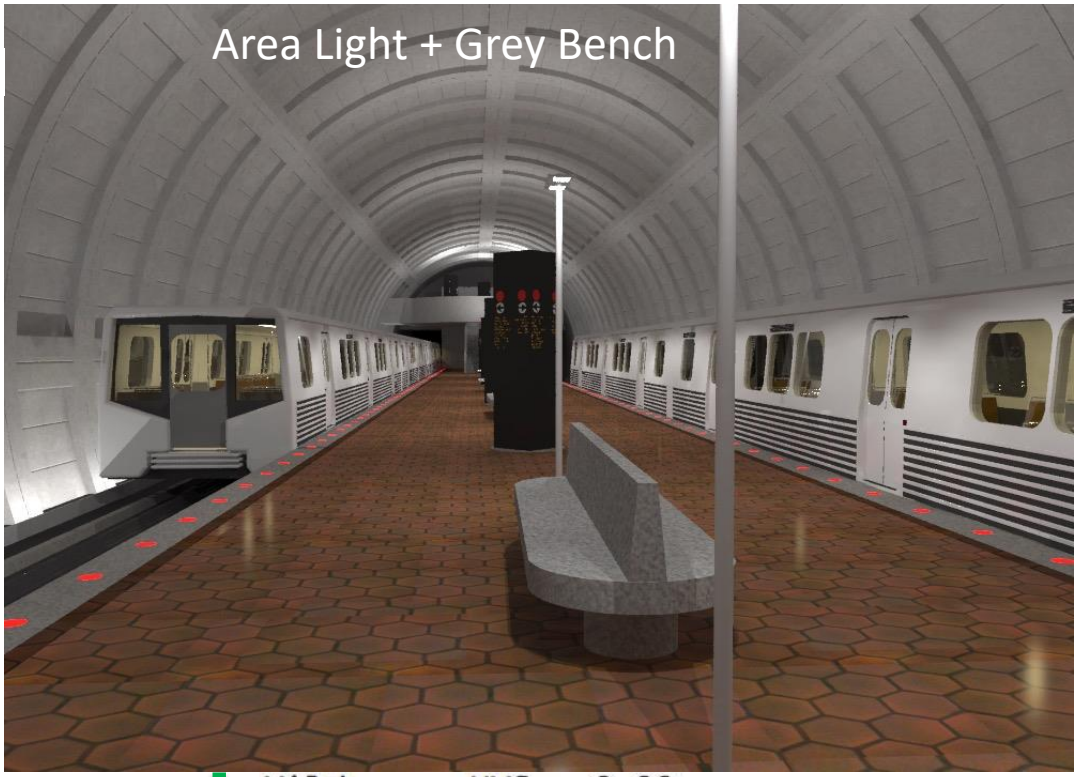
DeVAS HVS

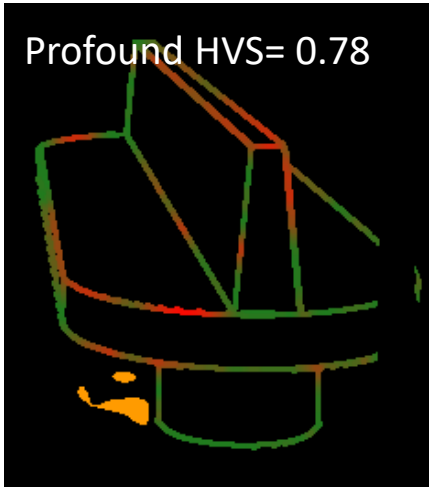


Mild	HVS= 0.84
Moderate	HVS= 0.74
LB	HVS= 0.67
Severe	HVS= 0.51
Profound	HVS= 0.17



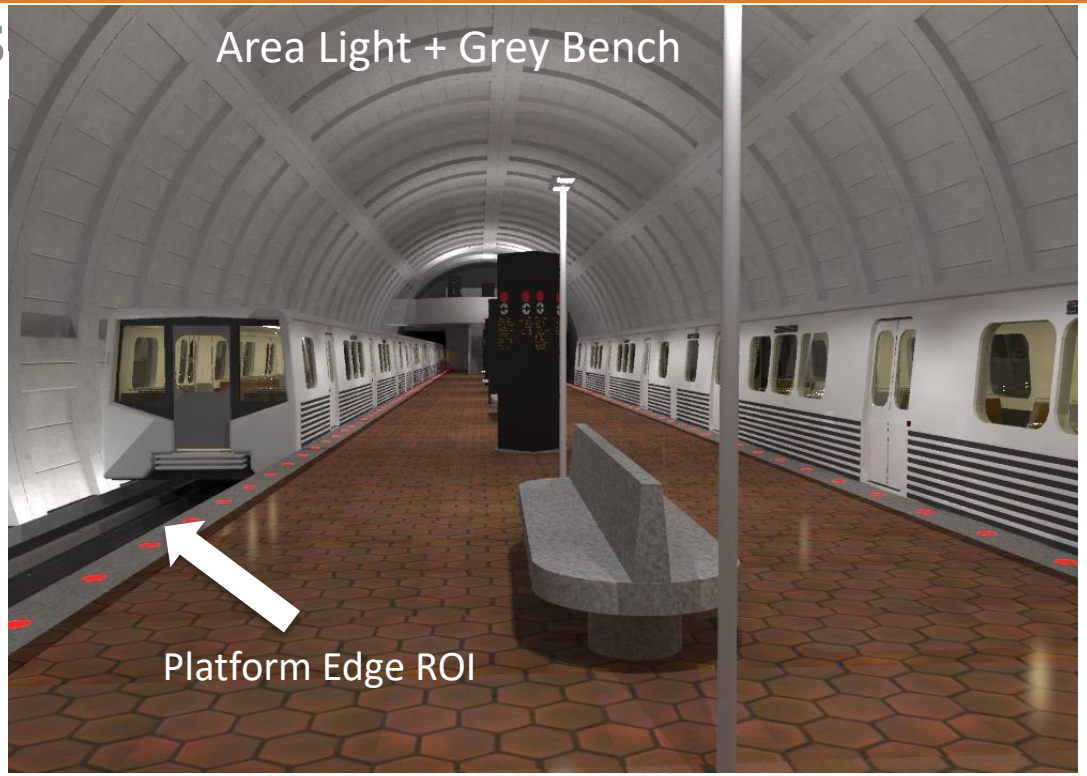
DeVAS HVS



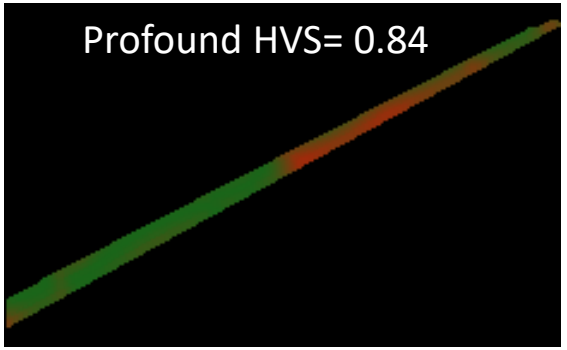


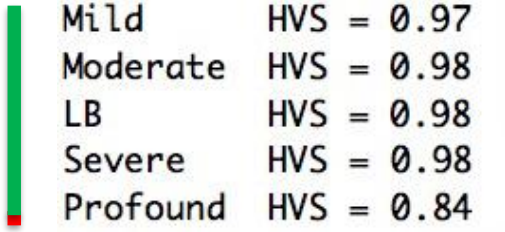
Mild	HVS	= 0.99
Moderate	HVS	= 0.98
LB	HVS	= 0.95
Severe	HVS	= 0.92
Profound	HVS	= 0.78

DeVAS HVS

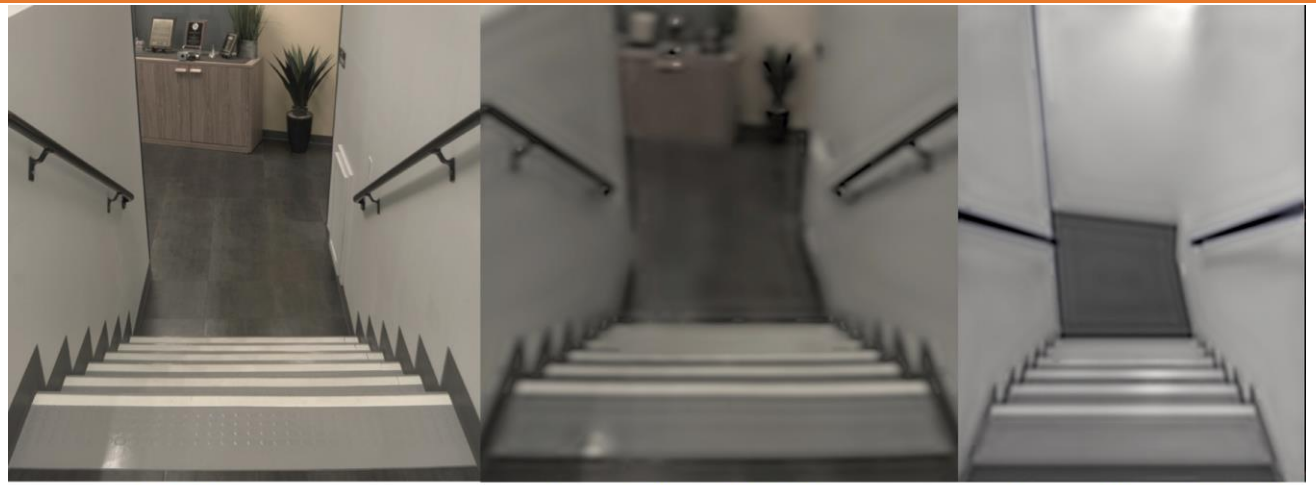

Area Light + Grey Bench
Platform Edge ROI

Severe HVS= 0.98


Profound HVS= 0.84


Mild HVS = 0.97
Moderate HVS = 0.98
LB HVS = 0.98
Severe HVS = 0.98
Profound HVS = 0.84

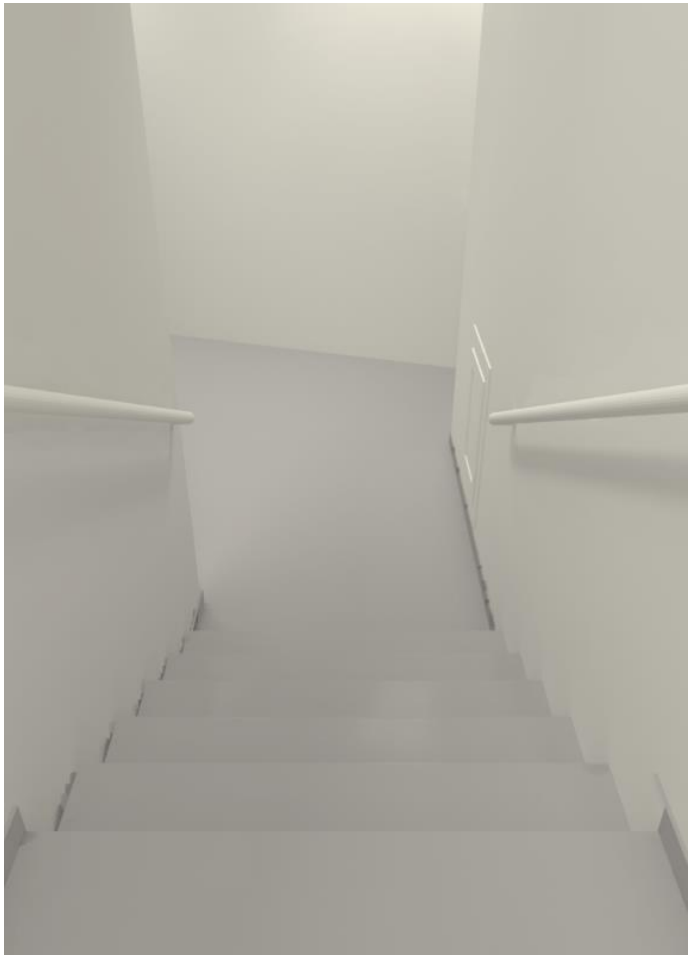
DeVAS Steps Study



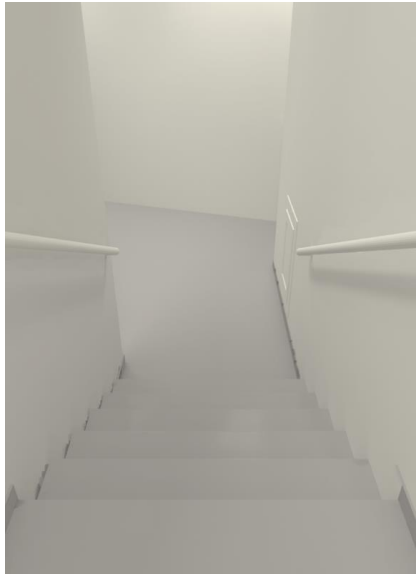
HDR Photo | Severe Filter of HDR Photo | Severe Filter of Model

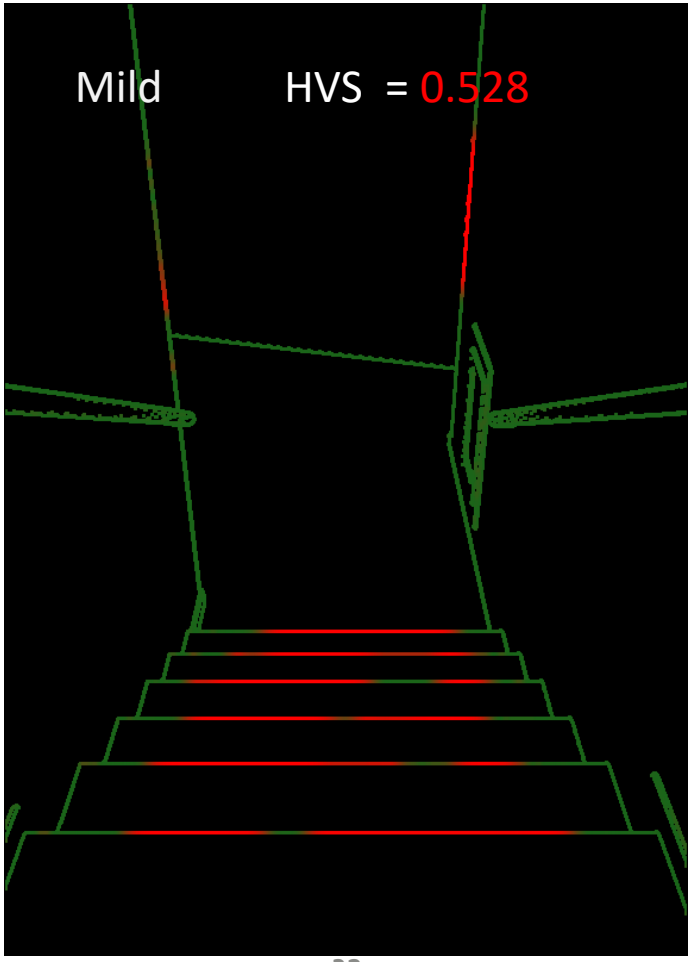
HDR Photo | Severe Filter of HDR Photo | Severe Filter of Model

DeVAS
Steps Study



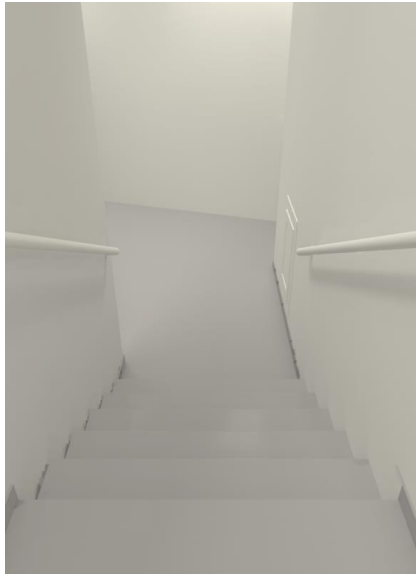
DeVAS
Steps Study

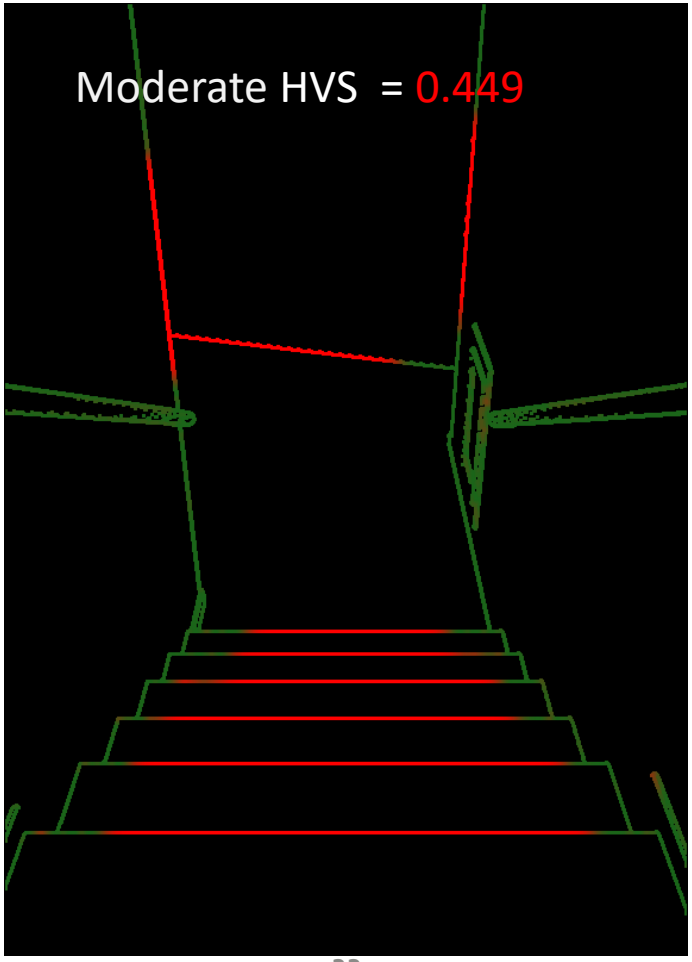




Low Vision: Mild

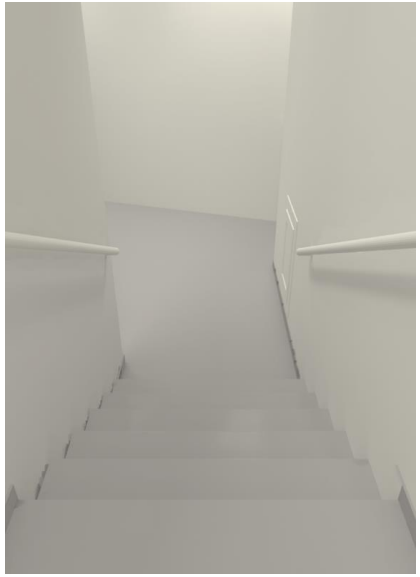
DeVAS
Steps Study

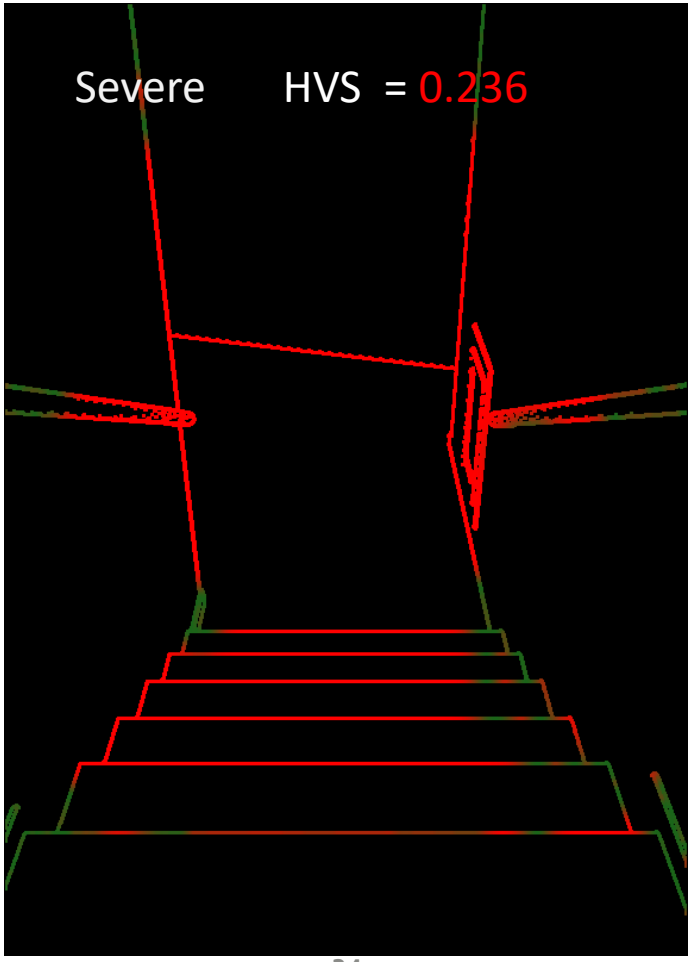




Low Vision: Moderate

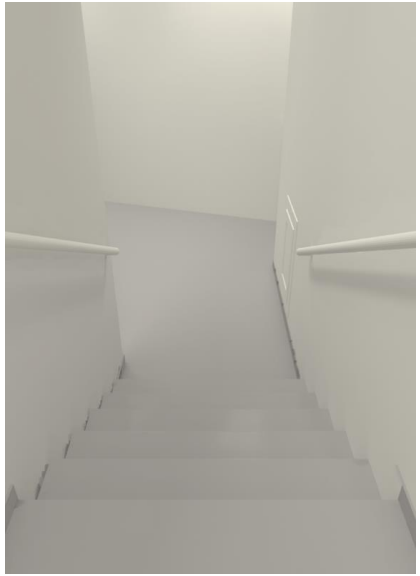
DeVAS
Steps Study

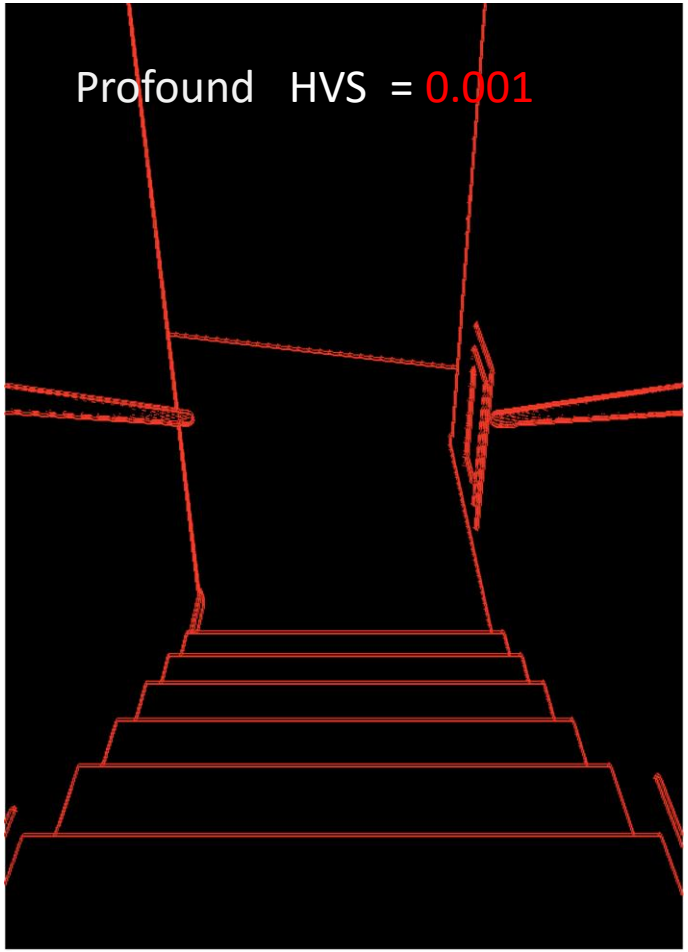




Low Vision: Severe

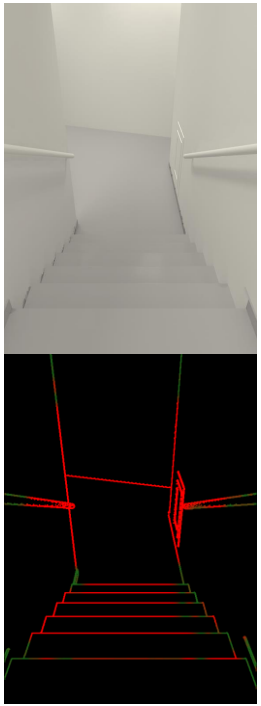
DeVAS
Steps Study

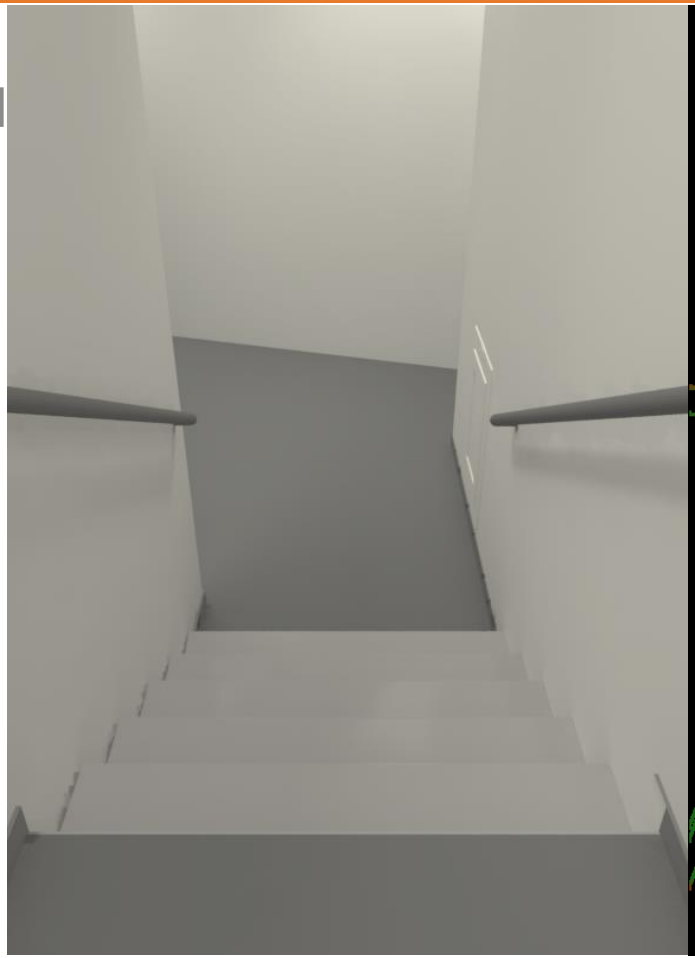


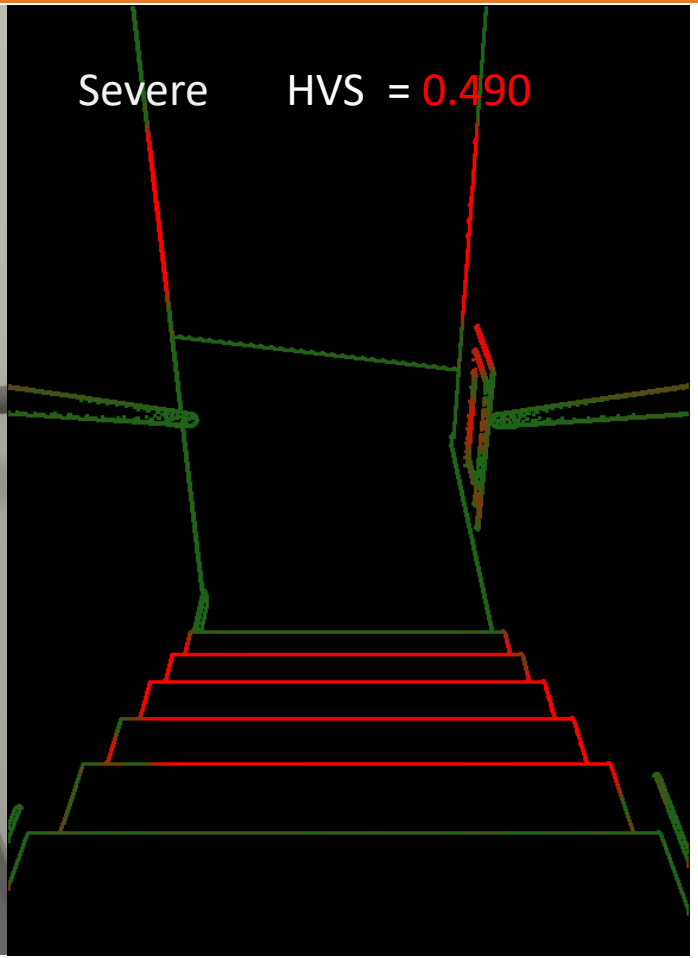


Low Vision: Profound

DeVAS Steps Stud



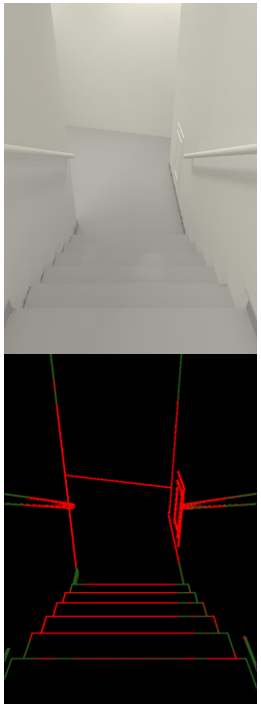


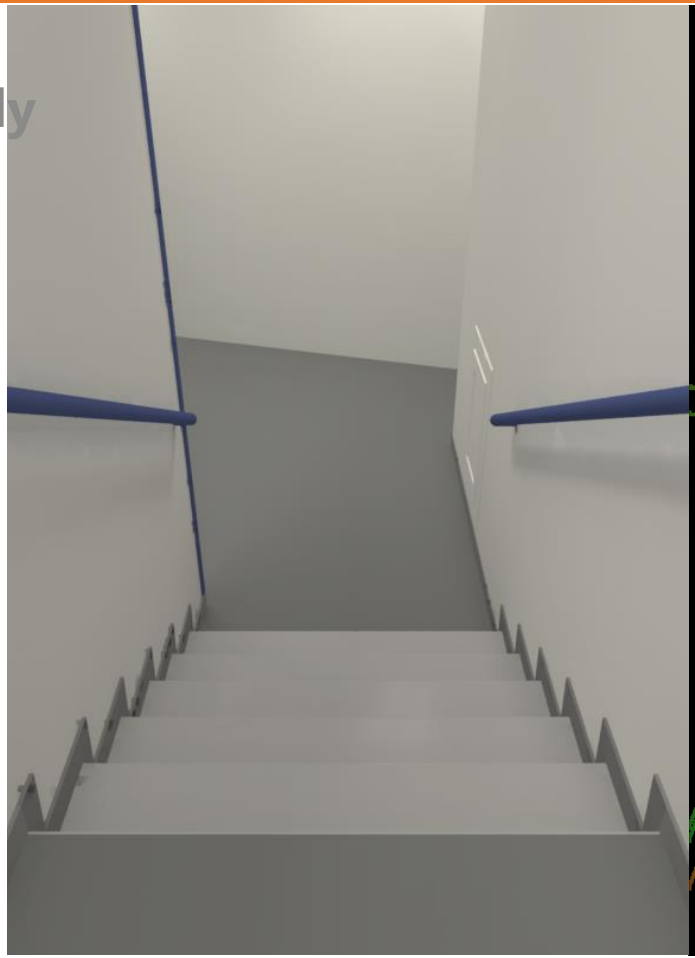


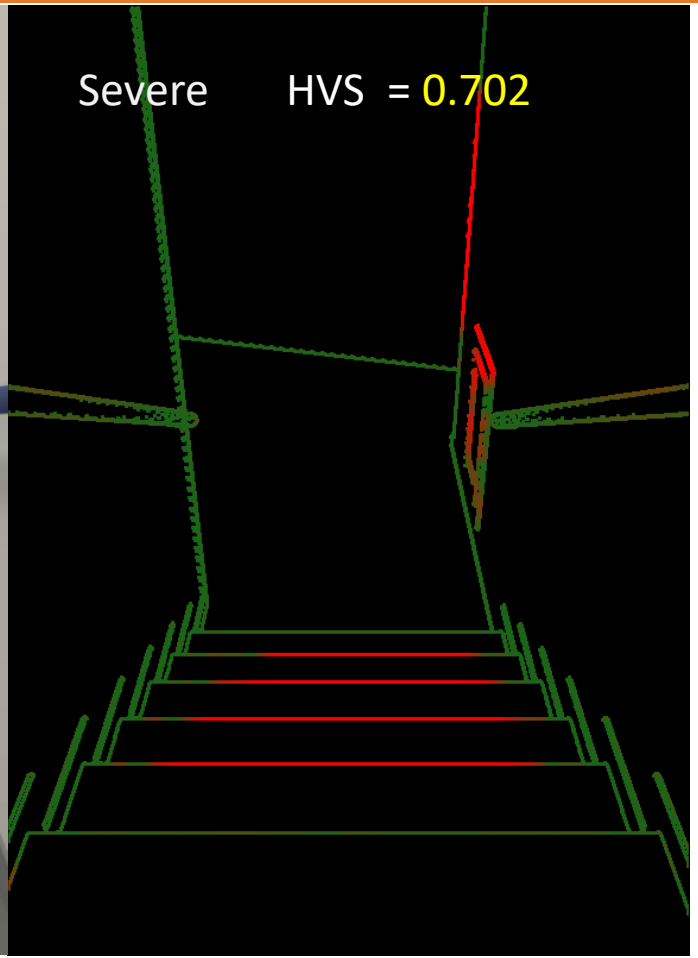
Change flooring

Low Vision: Severe

DeVAS Steps Study







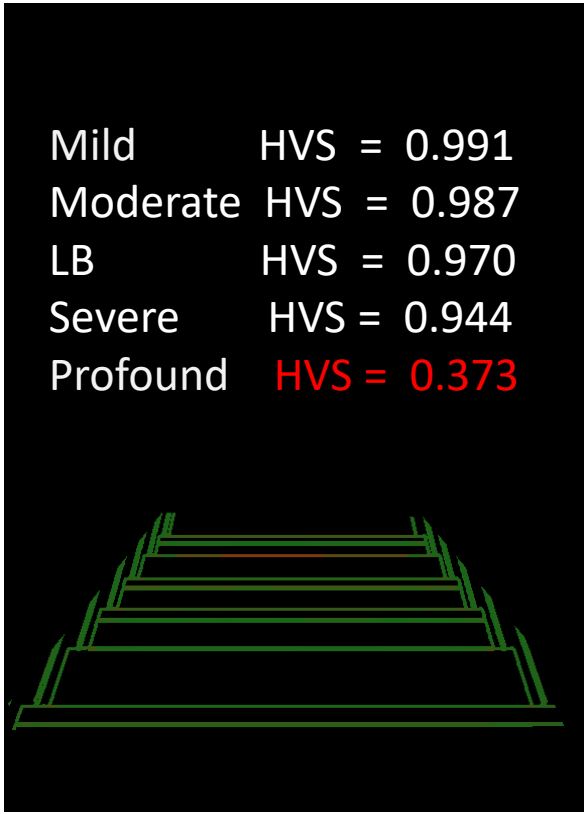
Change baseboards

Low Vision: Severe

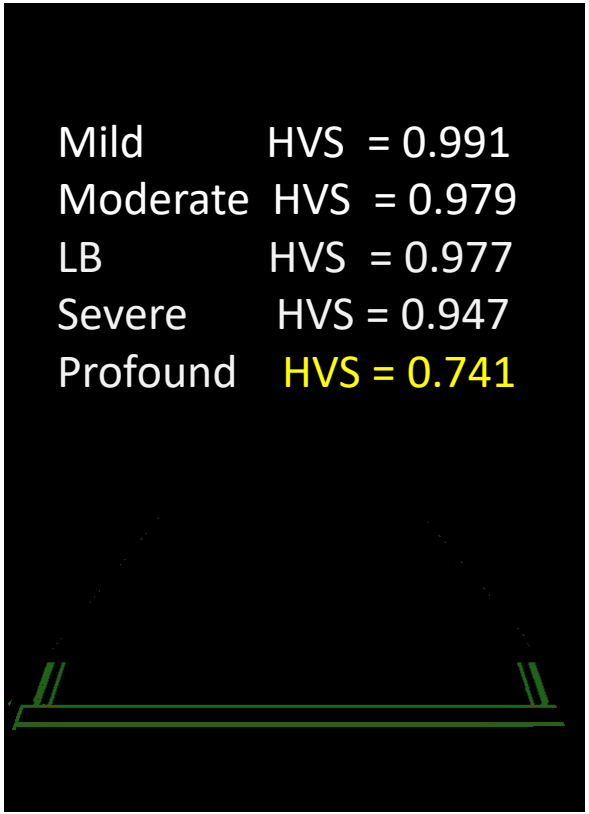
DeVAS Steps Study

Add white stripes

Hazard Visibility

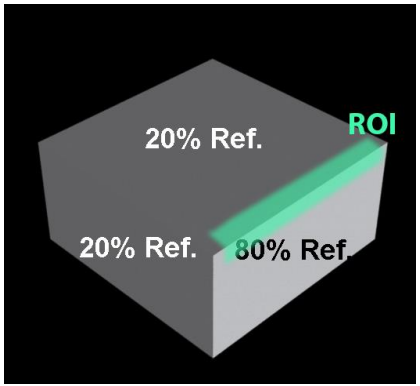


Hazard Leading Edge Visibility



Low Vision: Severe

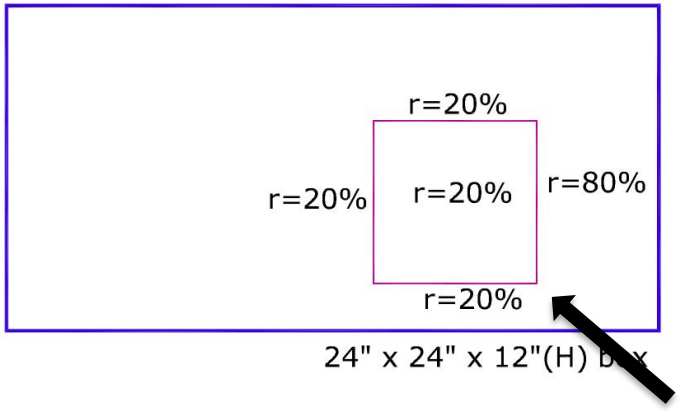
DeVAS
Daylight Study



Design by luminance

48" x 96" skylight at 8' above floor

WEST

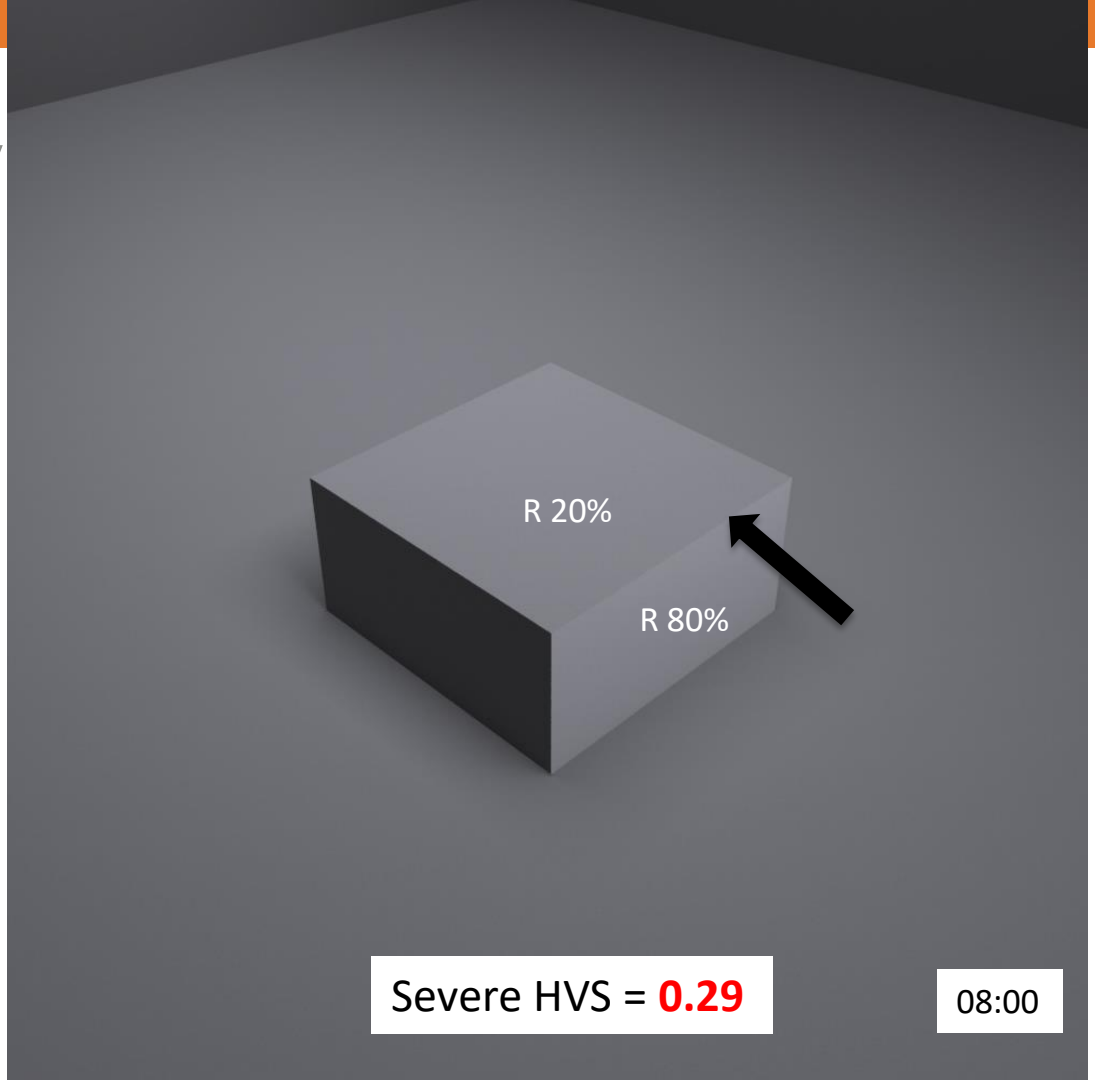


EAST

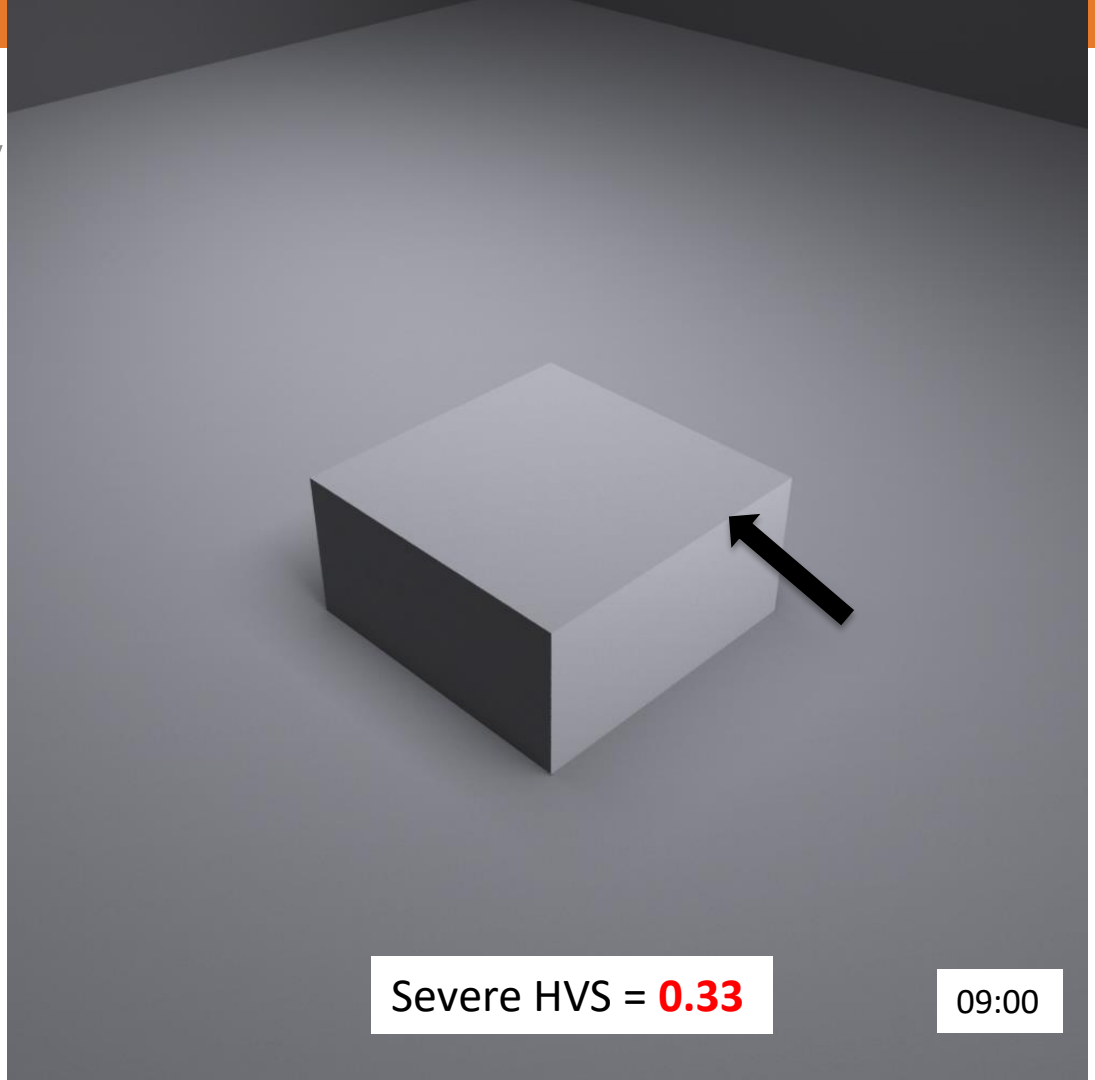
r=20%

VIEW

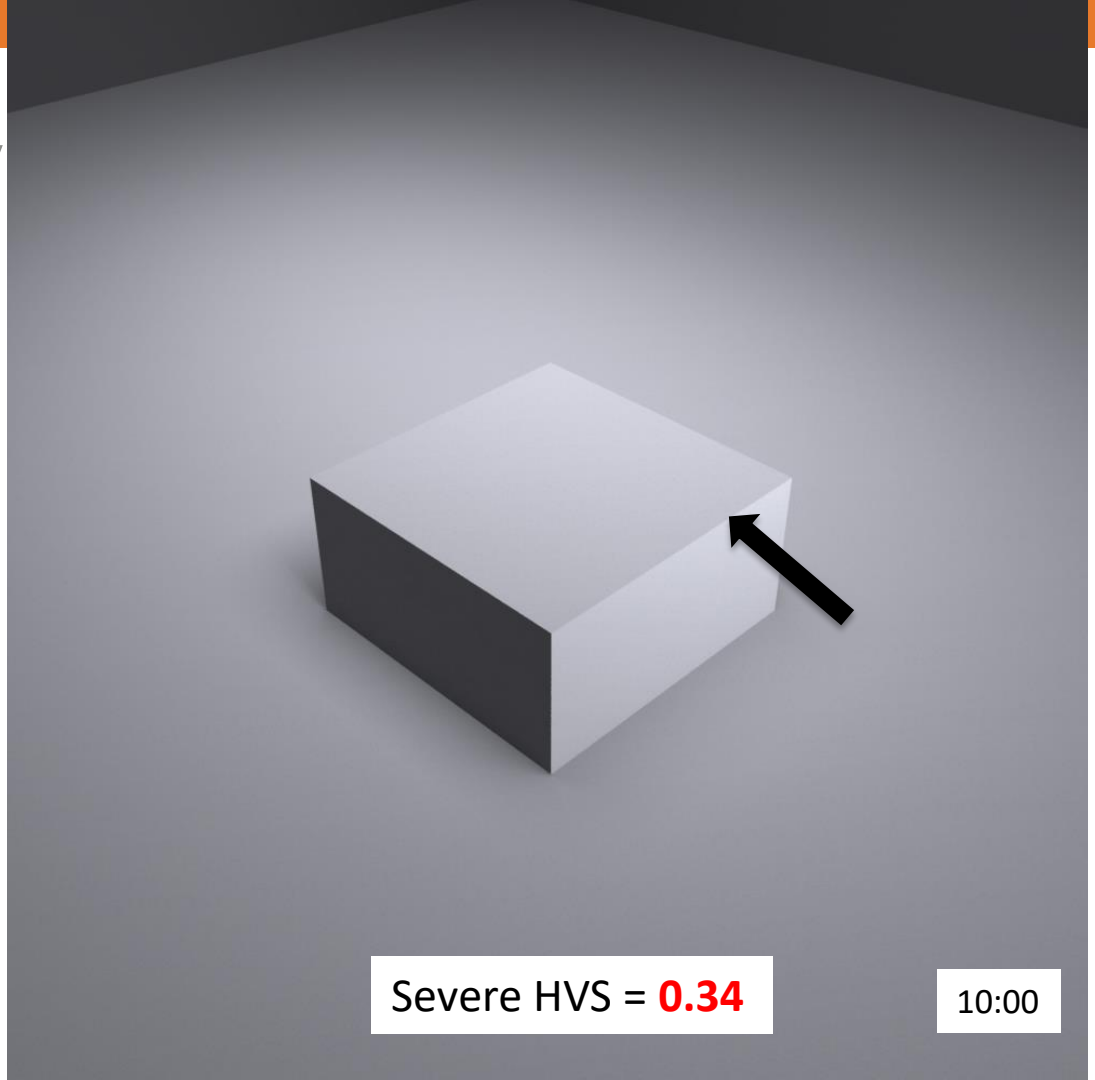
DeVAS
Daylight Study



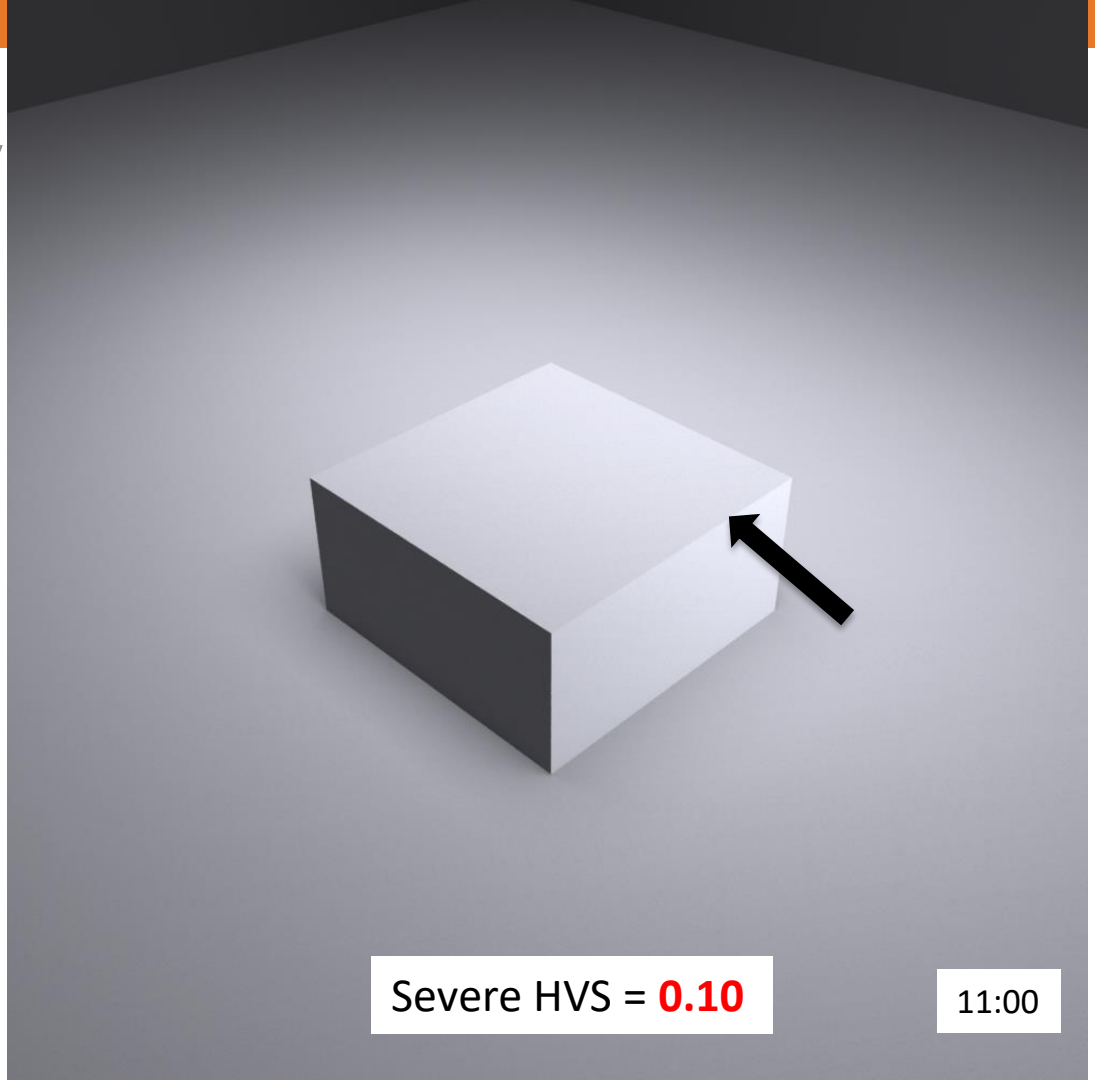
DeVAS
Daylight Study



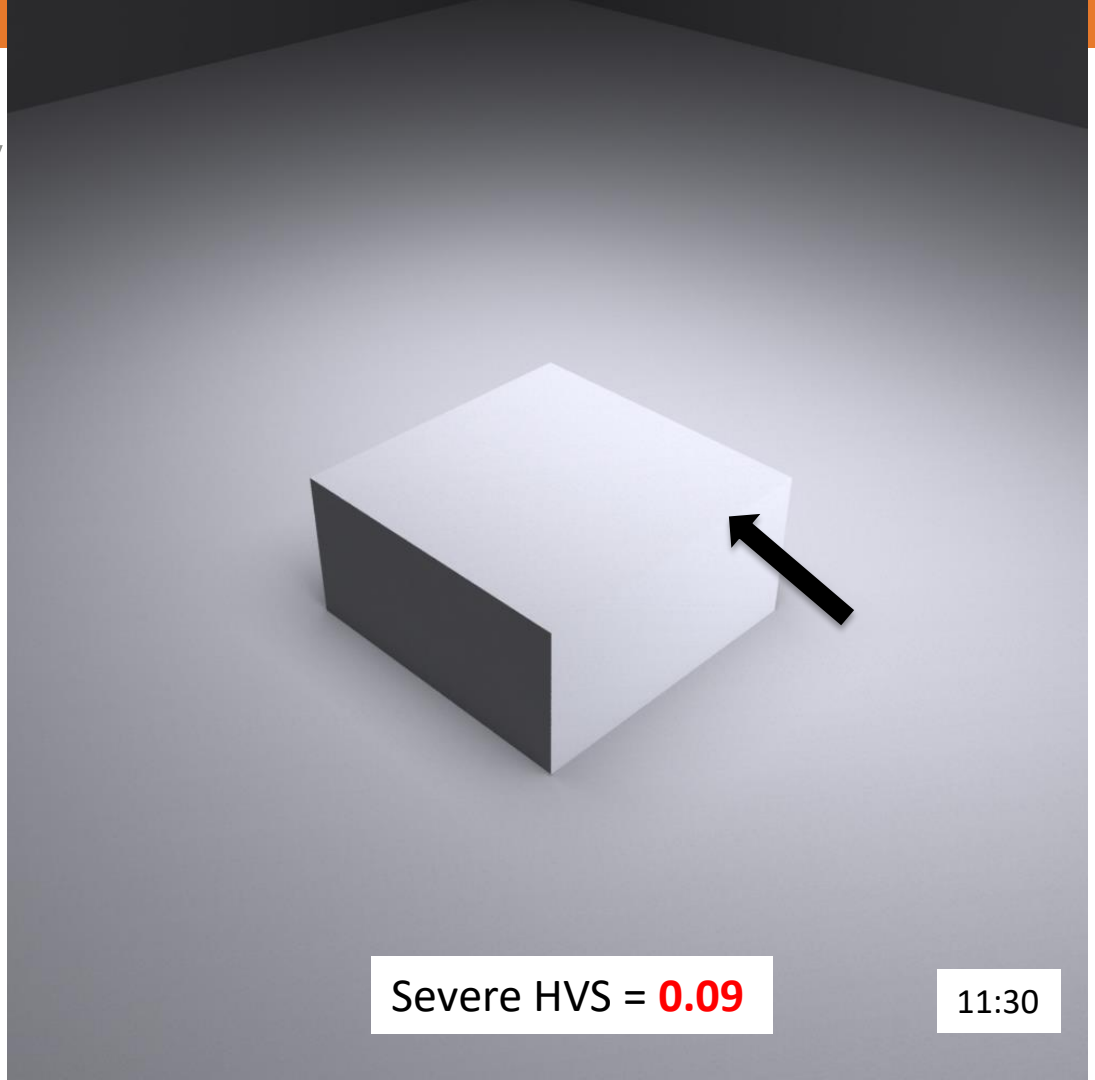
DeVAS
Daylight Study



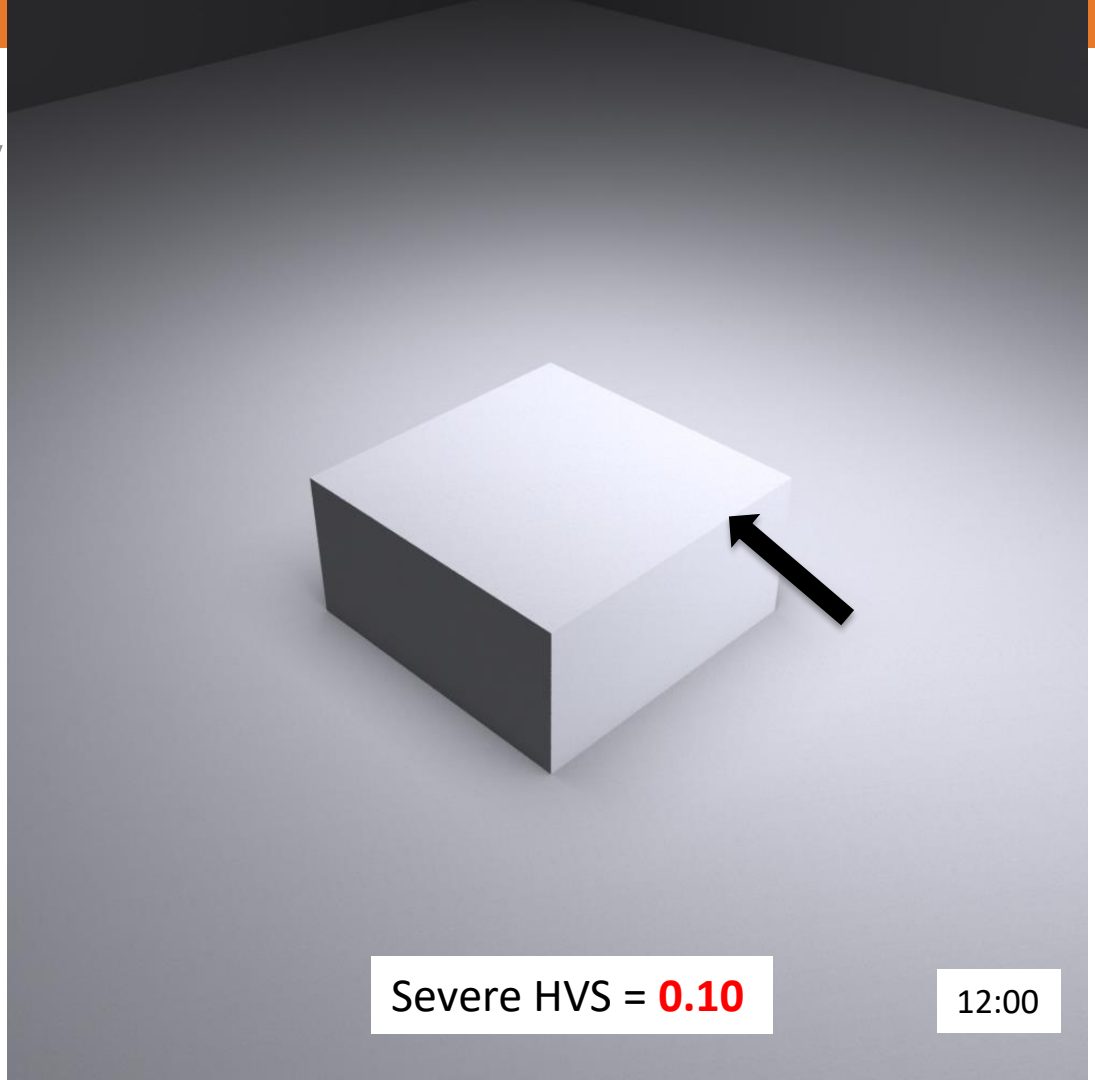
DeVAS
Daylight Study



DeVAS
Daylight Study



DeVAS
Daylight Study

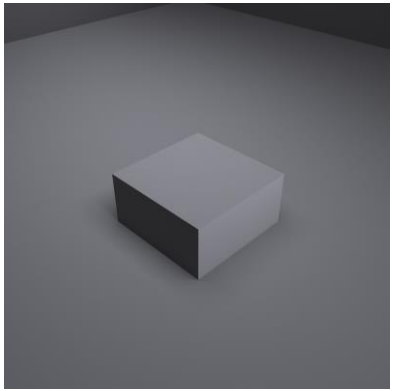


DeVAS
Daylight Study

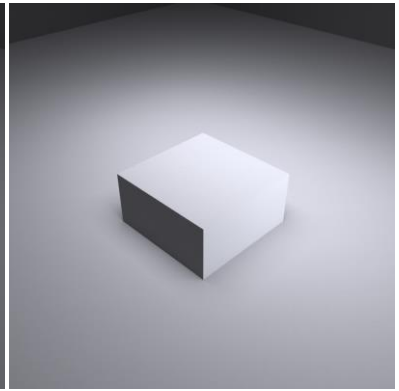
DeVAS
Daylight Study

DeVAS
Daylight Study

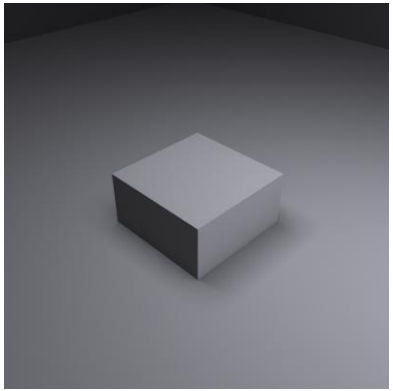
DeVAS
Daylight Study



Severe HVS = **0.29** 8:00



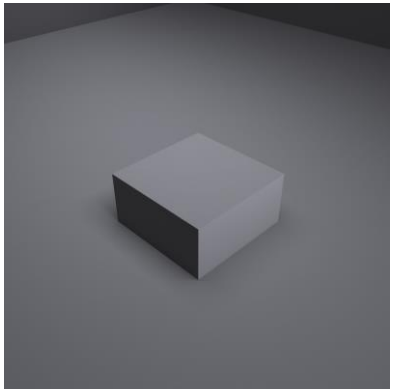
Severe HVS = **0.09** 11:30



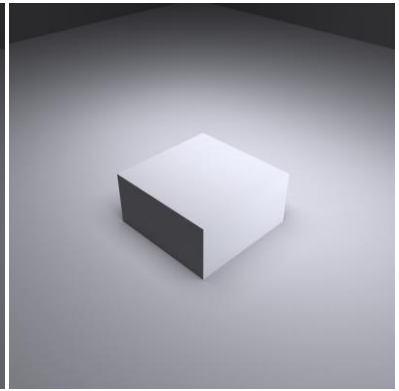
Severe HVS = **0.97** 15:00

Possible atrium/exterior annual daylight HV studies?

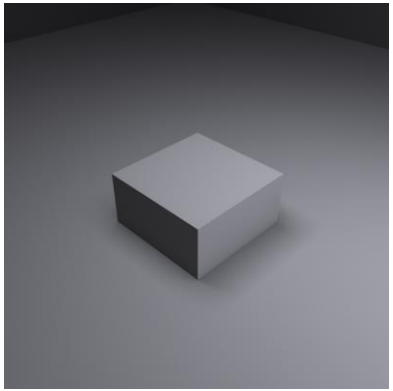
DeVAS
Daylight Study



Severe HVS = **0.29** 8:00



Severe HVS = **0.09** 11:30

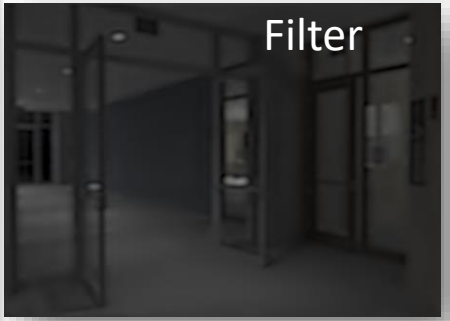


Severe HVS = **0.96** 16:00

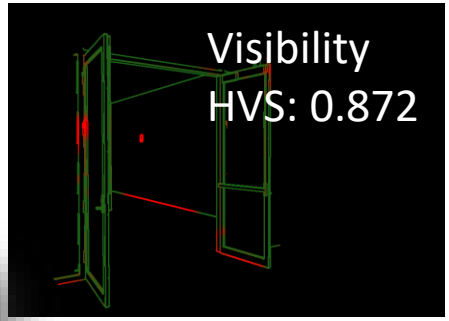
Possible annual atrium/exterior daylight HV studies?

Determine dangerous hazard times/dates and address

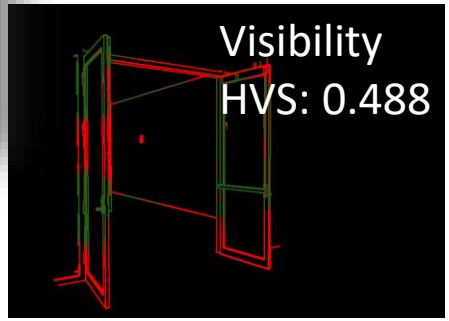
DeVAS Toolset



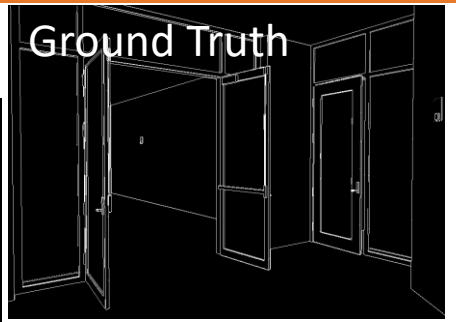
Mild 20/45
Moderate 20/115
LB 20/200
Severe 20/285
Profound 20/710

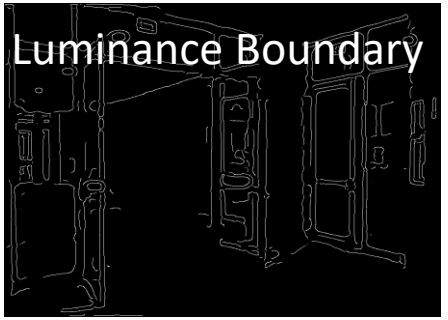


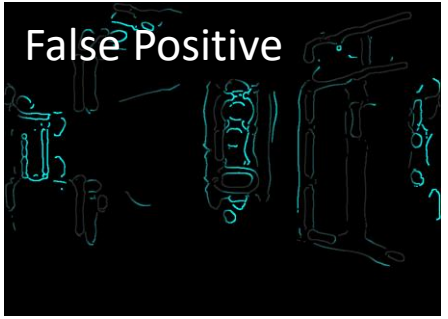
Severe 20/285 + CSF



Profound 20/710 + CSF



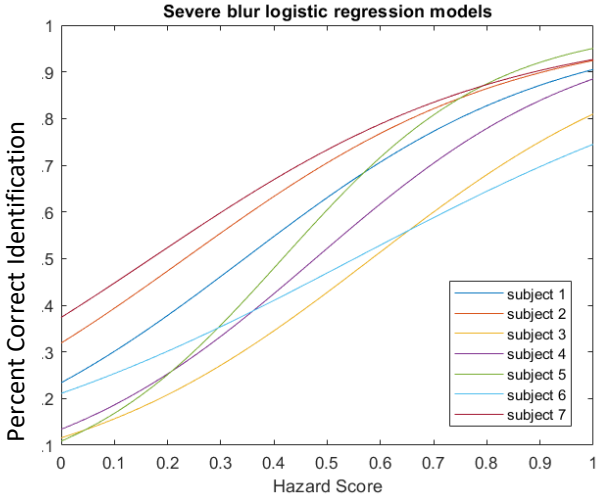


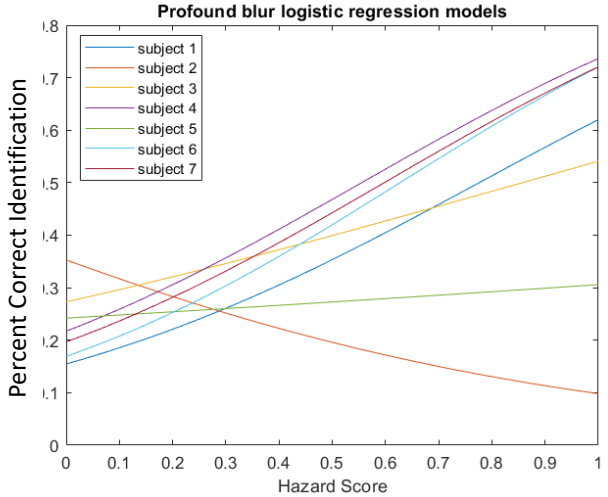


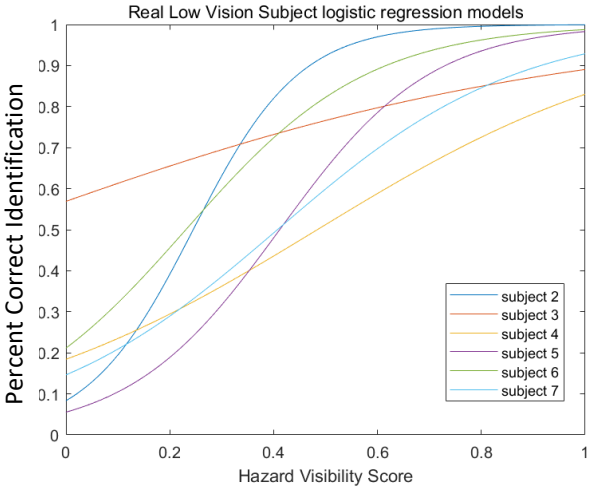
DeVAS Validation Study Results:

Hazard Visibility Score (HVS) predicts Human Performance!

- As HVS increases, probability of identifying the step correctly increases







5 Views x 5 Platform Variations x 5 Lighting Conditions x 2
250 images x 14 subjects = 3500 samples

DeVAS Limitations

View Dependent

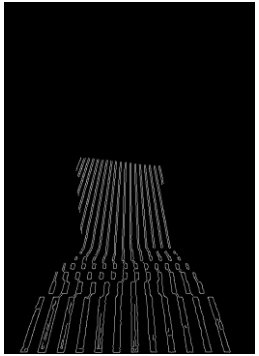
Requires lighting and material specifications

High luminance areas can mask nearby lower luminance details

Strident high contrast material patterns can result in incorrect visibility analysis

NEED Visibility Recommended Practices to evaluate: Compliant/not Compliant

Simulation



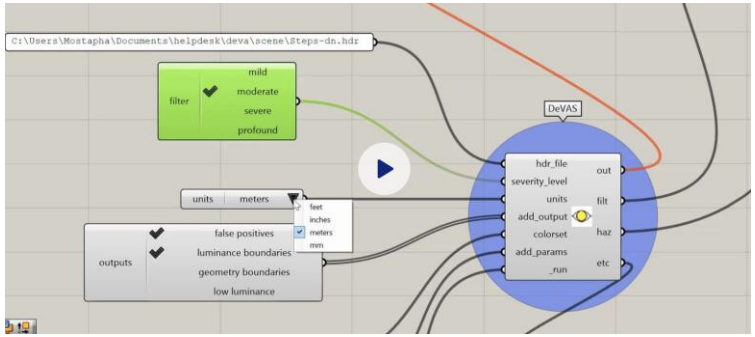
Luminance Boundaries

Photographs

DeVAS Future

DeVAS Tools are open source, fully functional prototypes compiled for Windows and OSx. DeVAS Visibility is being incorporated into LADYBUG, a RHINO/GRASSHOPER plugin. **We welcome other developers**.

rtpict: a gift from Greg that generates and associates all files necessary for DeVAS-visibility



RTPICT(1) RTPICT(1)

NAME

rtpict - generate a RADIANCE picture or layerd image using rtrace

SYNOPSIS

rtpict -n nproc [-o[vrxlLRXnNsmM] out_dir][-d ref_depth/unit] [rpict options] [@file] octree

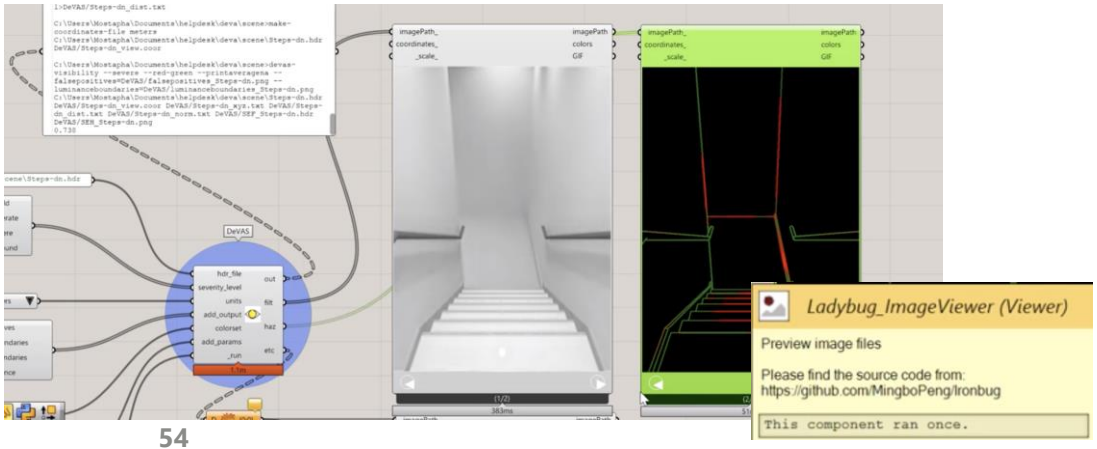
DESCRIPTION

Rtpict is a script that generates a picture from the RADIANCE scene given in *octree* and sends it to the standard output, or to a file specified with the *–o* option. Most options and defaults are the same as *rpict(1)*, although a few switches are silently ignored. Options incompatible with multi-processing can generate an error.

The *rtrace(1)* tool is called with *vwrays(1)* to perform the actual work. This enables the *–n* option for multiprocessing on platforms that support it. If the *–n* option is not specified or is set to 1, then *rpict* is called directly. There is no benefit in setting the number of processes to anything greater than the number of virtual cores available on your machine. Also, it is very important to set the *–af* option if an irradiance cache is being generated; otherwise, your speed-up will be far from linear.

If the *–o* option has additional characters corresponding to output types from *rtrace*, it must be followed by the name of a directory that either exists or will be created to contain image layers, one per output type. The supported types are listed below, and do not include types that are useless or have no convenient representation. The table below shows the correspondence between output type and file name in the specified directory:

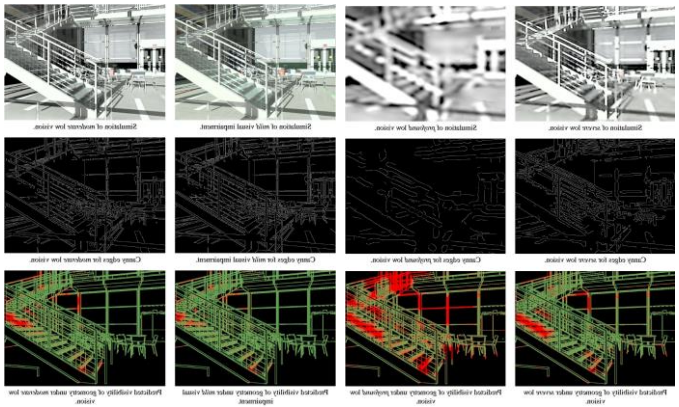
v	radiance.hdr
r	mirrored.hdr
x	unmirrored.hdr
l	effective.dpt
L	firstsurface.dpt
R	mirrored.dpt
X	unmirrored.dpt
n	perturbed.nrm
N	unperturbed.nrm
s	surface.idx
m	modifier.idx
M	material.idx

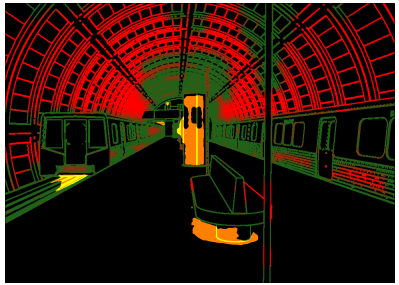


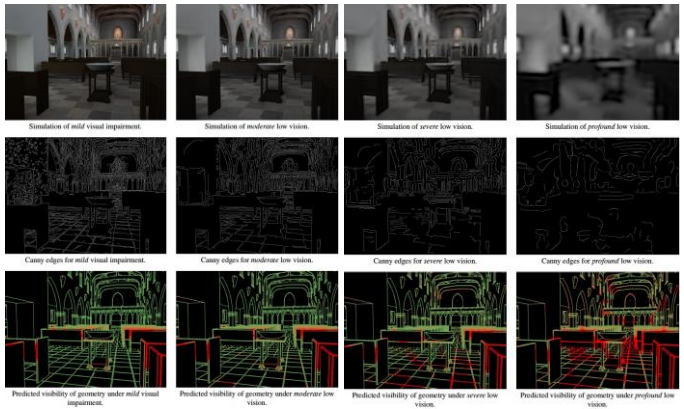
DeVAS Future

DeVAS tools enable the designer to analyze and improve visibility of hazards, potentially within the design palette of the project, to aid in the creation of architectural spaces that are accessible to those with vision impairment who make use of vision for mobility.

Standards could potentially be structured for luminance studies,
such as DeVAS, where compliance is sought to a visibility metric standard







Thank you!

Principal Research Team:
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Dr. Bill Thompson, Computer Science, University of Utah,
Dr. Sarah Creem-Regehr, Psychology, Cognition and Neural Science, University of Utah
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