9th International Radiance Workshop

Designing Visually Accessible Spaces: The role of Radiance

presented by
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Indiana University

http://www.indiana.edu/~thtr/people/bioShakespeare.shtml

www.cs.utah.edu/research/groups/percept/DEVA/

ACKNOWLEDGEMENTS/CREDITS

Designing Visually Accessible Spaces
NIH Grant 1 R01 EY017835-01

a multi-disciplinary project involving personnel from:

- University of Minnesota (visual perception, low vision)
- University of Utah (spatial cognition, computer graphics, architecture)
- Indiana University (lighting design, visualization)

www.cs.utah.edu/research/groups/percept/DEVA/

Designing Visually Accessible Spaces

- Overview
- Background and Approach
- Progress
- Personnel
- Publications
- For project members only

Personnel

I am reporting on behalf of this team

Faculty

Gordon Legge, University of Minnesota (PI)
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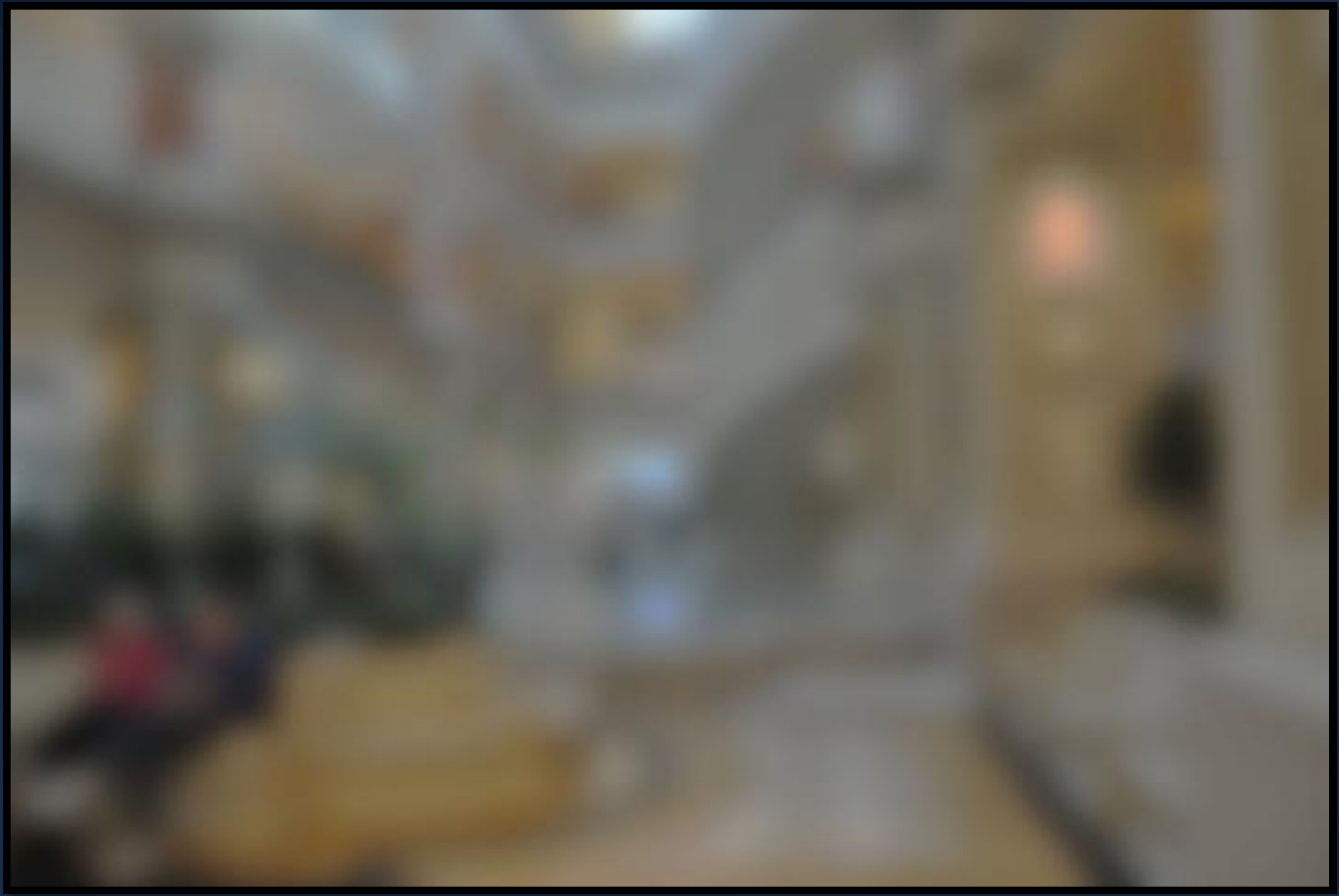
Christopher Wood, Indiana University

This is a multi-disciplinary project involving personnel from the University of Minnesota, the University of Utah, and Indiana University, and supported by the National Eye Institute of the National Institutes of Health grant 1 R01 EY017835-01.

Experience of Architecture with Vision Loss

(Photograph by Chris Wood)

Experience of Architecture with Vision Loss



(Photograph by Chris Wood)

VISUAL ACCESSIBILITY

- Environments that optimize the use of vision
  - to travel safely and efficiently through an environment
  - To perceive the spatial layout of key features in the environment
  - To keep track of one's location in the layout

VISUAL ACCESSIBILITY

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- Several million in the USA with visual impairments
- Our aim is to increase accessibility for low vision individuals, by providing tools to aid Universal Design goals (unobtrusive solutions)

PEOPLE IN USA OVER 65

Year	Percentage of Population	Number of People (millions)
1900	4.1	3.1
1997	12.7	34
2030 (projected)	?	70

Life expectancy in the USA

- Currently ~78
- 1950's ~68
- 1930's ~58

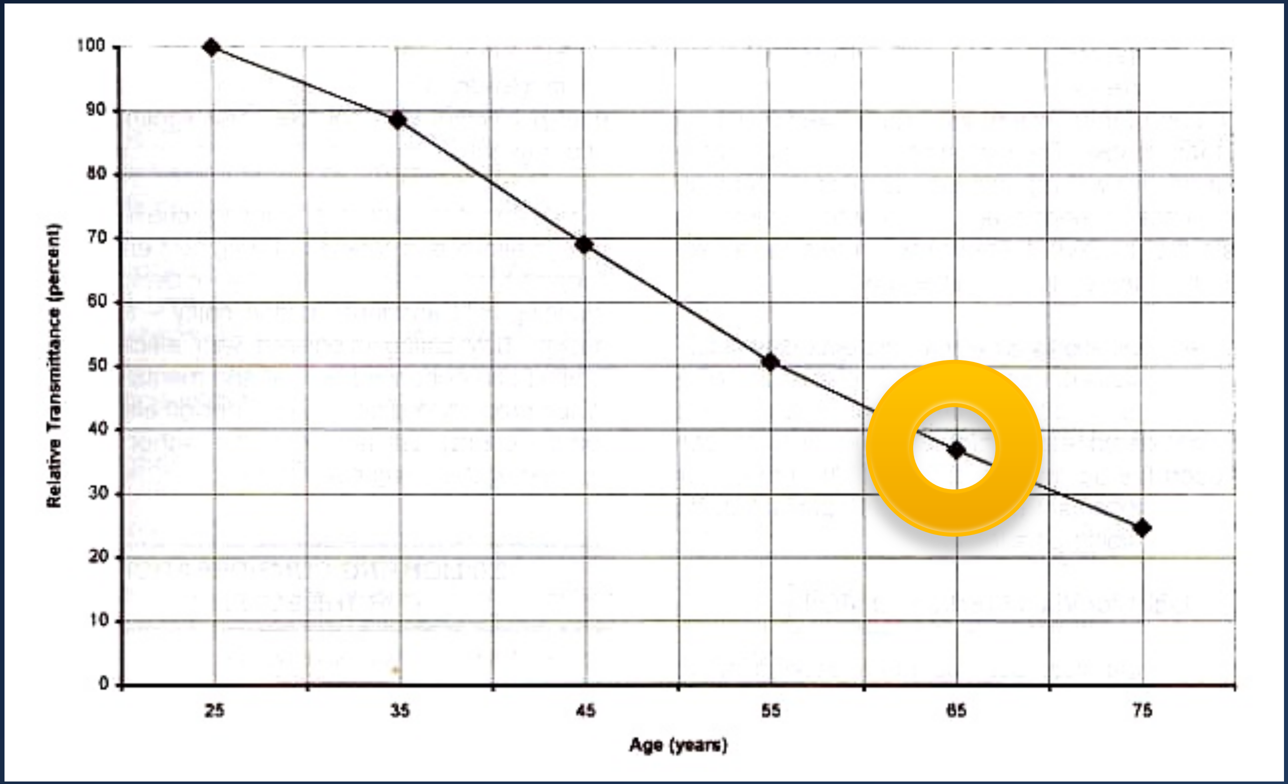
BYGONE STEREOTYPE

- Many types of low vision are also age related

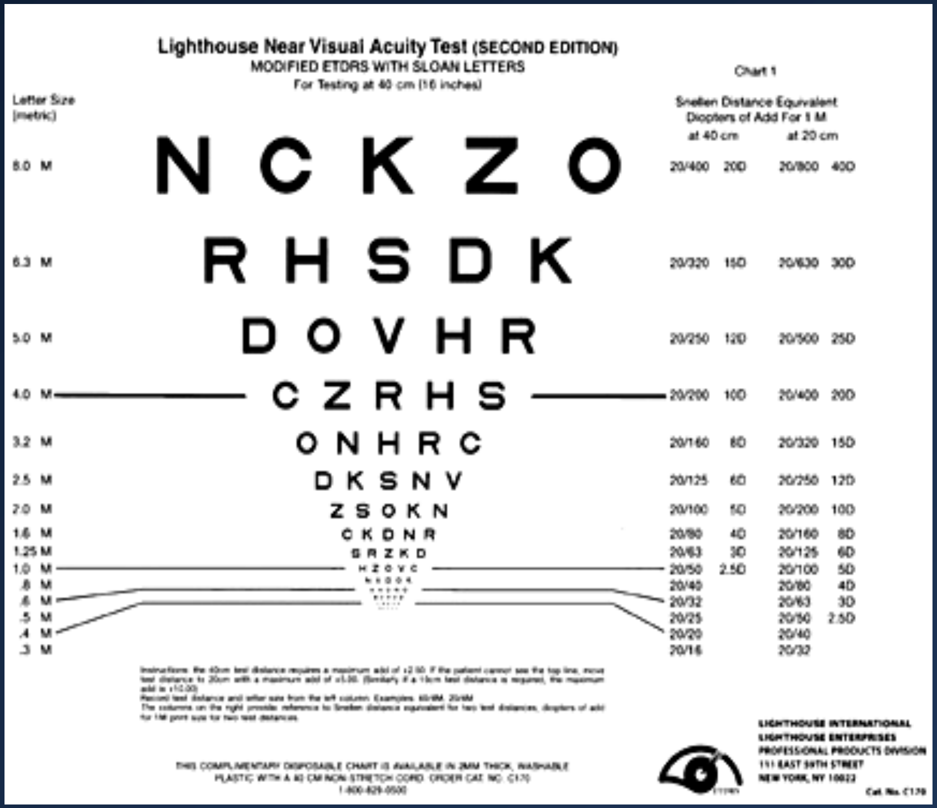
BYGONE STEREOTYPE

- Many types of low vision are age related
- Today, individuals with low vision traverse
  Subway stations, libraries, malls, restaurants, spas, parks, airports, casinos, universities, art galleries…
  - Any place you find normally sighted individuals

PEOPLE IN USA OVER 65



- Age affects even “normal” vision
  - Total light transmission decreases as people age



- Fully sighted acuity: 20/20
- Low vision (US definition) 20/40
- Legal Blindness Threshold (US): 20/200
- Utah site foil (sample[1]) : 20/678
- Limit of functional acuity: 20/2000

Low vision = useful vision

- The low vision population is growing as the US population is aging
- blindness and low vision: 1 in 28 adults over age 40
- There are many more people with low vision than with blindness
- Majority of those with low vision able to see well enough to perform many tasks under the right conditions
- Legal blindness is not the same as absence of vision
- Only 20% of those classified as legally blind have no useful vision

APPROXIMATION OF 20/678 ACUITY

Selected as the mean between "world" low vision definitions

- Observe room and screen through blur foil
  - What can you identify?
  - Could an environment be visually optimized to provide you with safe passage without aids?

  - This presentation introduces tools being developed to assist designers in accomplishing this task

ANSI/IESNA RP-28-07

- New Maintained Average Illuminance for seniors
- Design Guidelines for Senior Living
- Detailed Retirement Community recommendations
- Recurring general solutions:
  - higher illuminance levels
  - low glare
  - uniform luminance
  - contrast at architectural boundaries
  - reduced specular surfaces
- For **environments which primarily serve seniors**

ANSI/IESNA RP-28-07

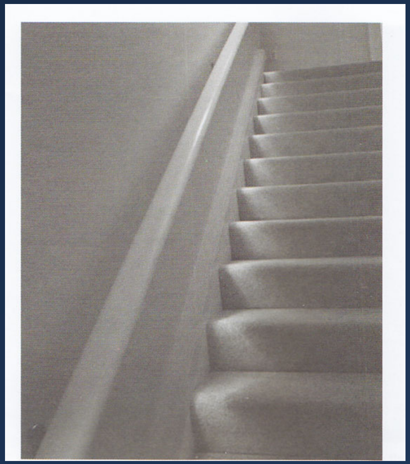
- RP example:
  - Linear source illuminates all steps with similar distribution
  - Illumination levels comply with new Minimum Maintained Average Illuminance for Older Adults
  - Luminaire in close proximity to step features
  - Low glare illumination: molding conceals light source
  - No specular surfaces: no veiling/confusing reflections

Figure 51. A rope-light installed 30.5 cm (12 in.) above the stair tread and controlled by a motion sensor illuminates the steps at night. A decorative molding above the rope-light directs the light downward and out of the eyes of the user. (photographer: Eunice Noell-Waggoner)

ANSI/IESNA RP-28-07

BUT:

- What key visual features indicate a step-up?
- Are steps identifiable through a range of acuities and approaches? … what are related risks if not detected?
- Can distance to the first step be reasonably estimated?
  - Would an additional landmark aid distance judgment?



Complex nature of low vision means that generalized design rules alone are insufficient

VISUALLY ACCESSIBLE SPACES

- How does a designer go about improving or designing for visual accessibility?

- Tools are needed to provide feedback and to rate the consequences of designer choices.

- The following pictures are of relatively new public spaces.
  - Which situations might prove challenging to navigate
  - … for a person with low vision?
  - … for a person with normal vision?

Specular wall

False-possitive steps

Luminance patterns can mask potential hazards or signal false possitive

Potential hazards not limited to stairs and ramps…

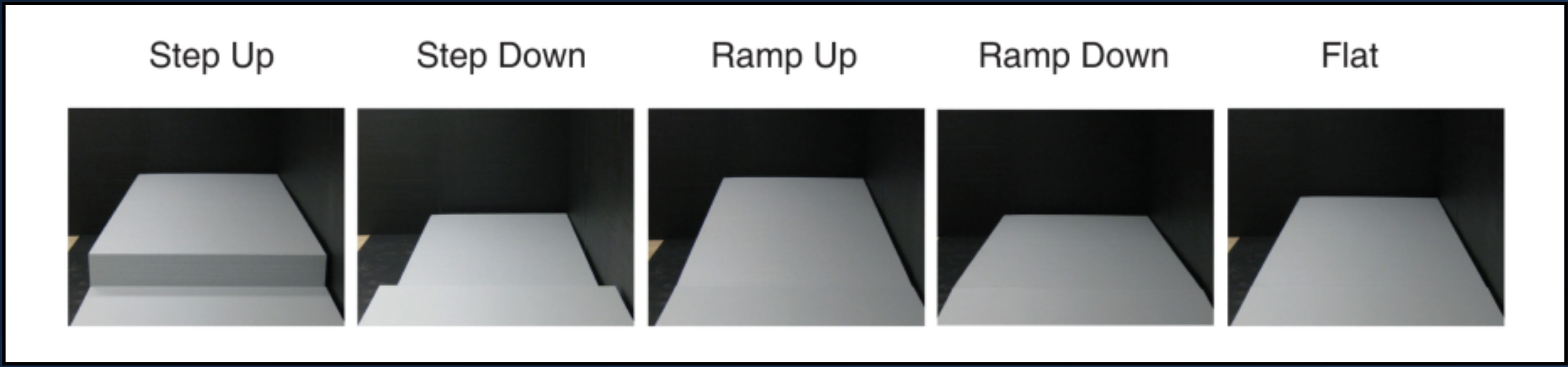
DESIGNING VISUALLY ACCESSIBLE SPACES

- A major goal:
  - To develop computer graphics and analysis tools to enable designers to evaluate hazard visibility in existing and proposed environments.
    - For use by lighting designers, interior designers, architects… *risk management?*

Radiance is a key player in this research

HAZARD DETECTION – Initiative 1

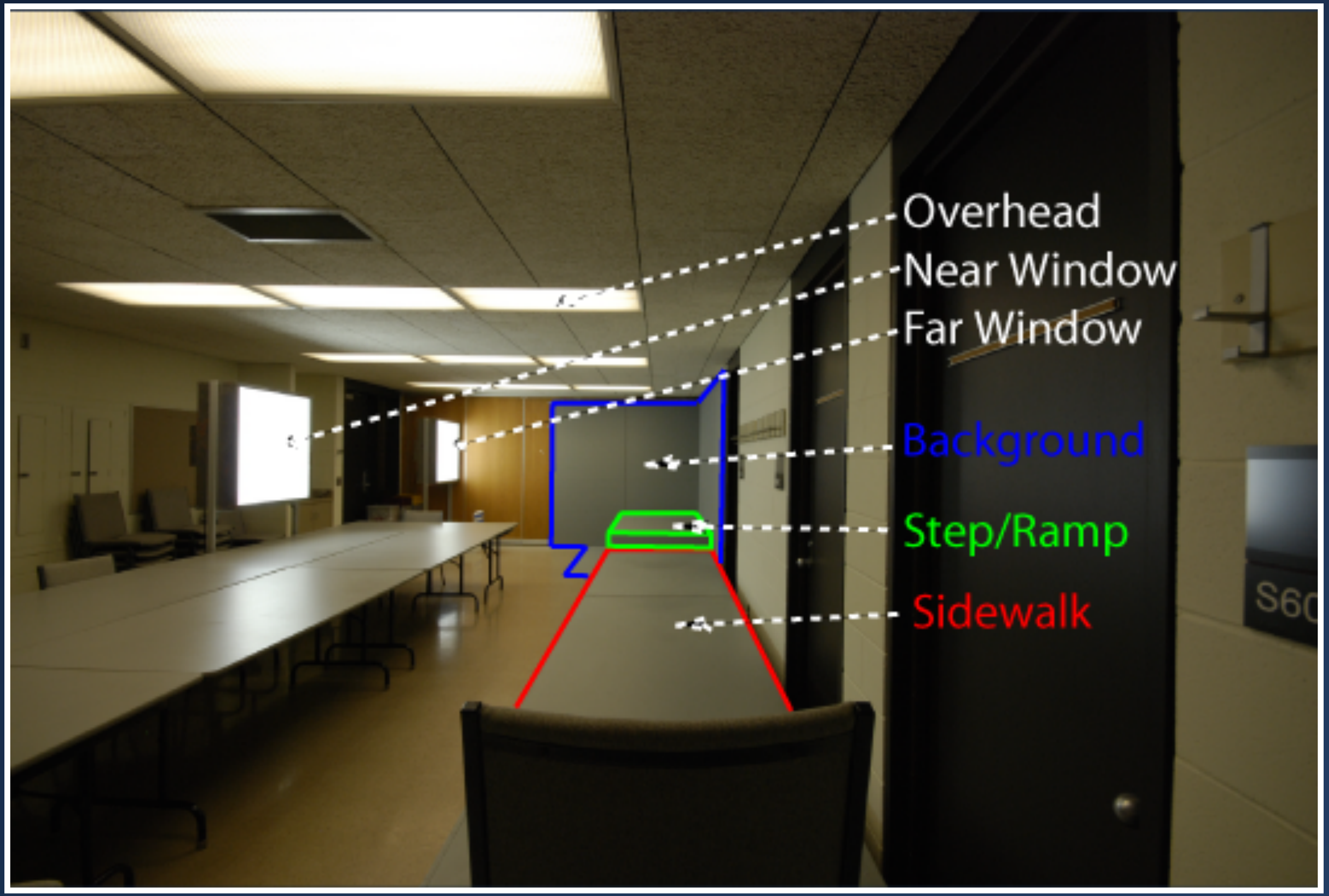
- What visual patterns trigger detection?
  In step up or down, ramp up or down hazards?



Legge G.E., Yu D., Kallie C.S., Bochsler T. & Gage R.
The visual accessibility of ramps and steps. 2011. *Journal of Vision*

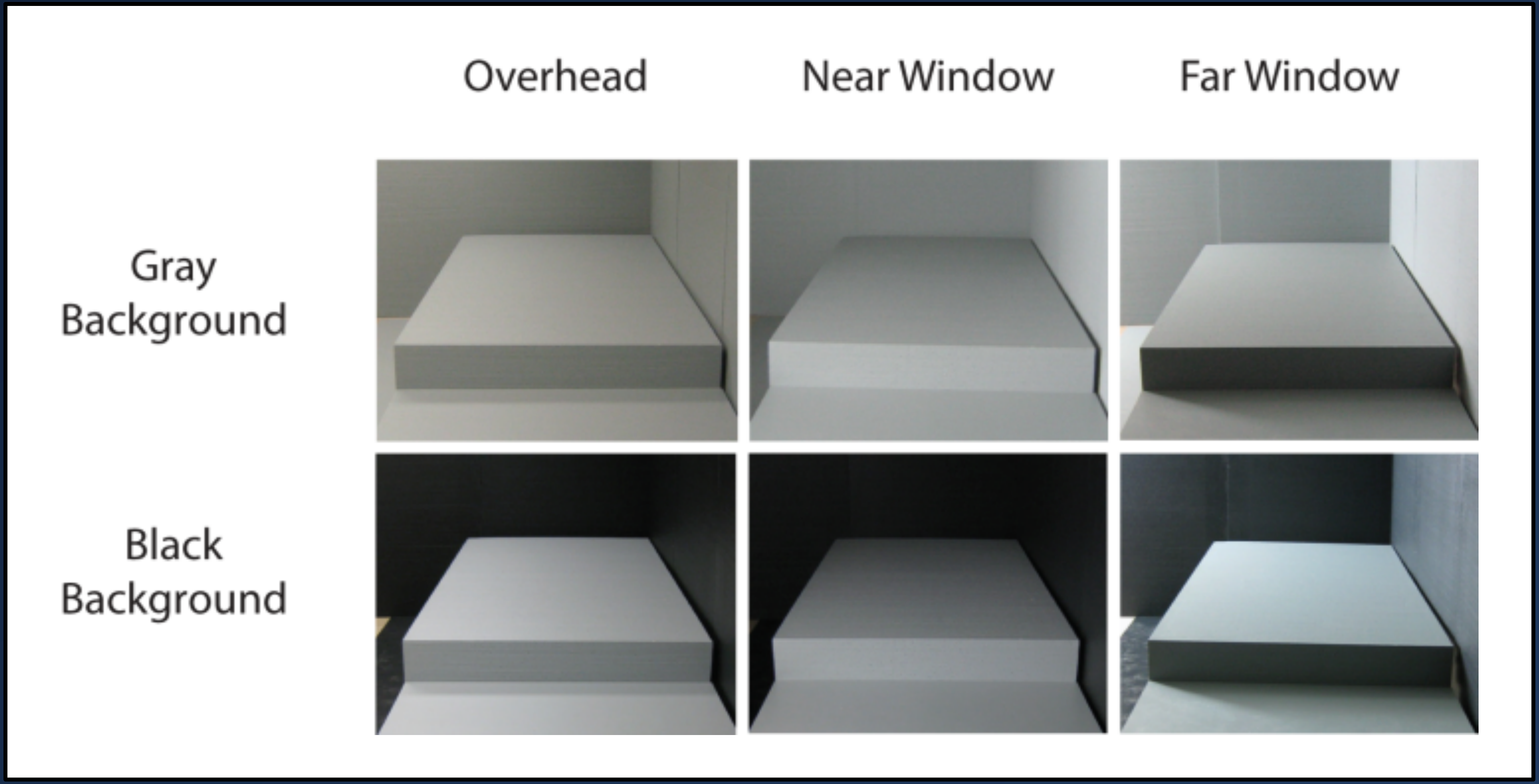
HAZARD DETECTION – Initiative 1

- Human study experiments performed using configurable sidewalk-like structure..

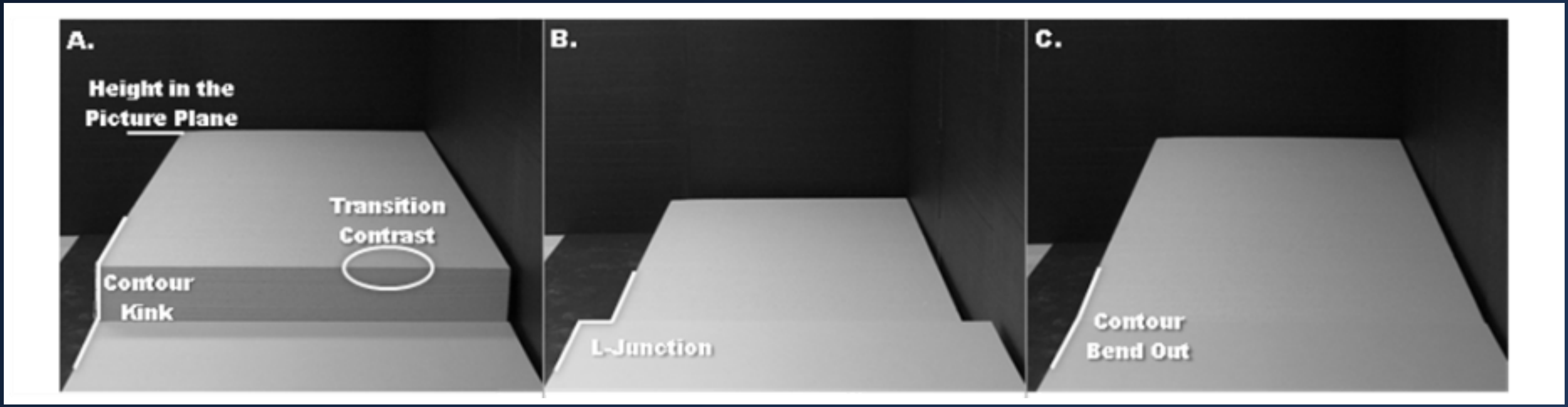


HAZARD DETECTION – Initiative 1

- Variations in lighting, viewing distance, and background



HAZARD DETECTION – Initiative 1 - Results

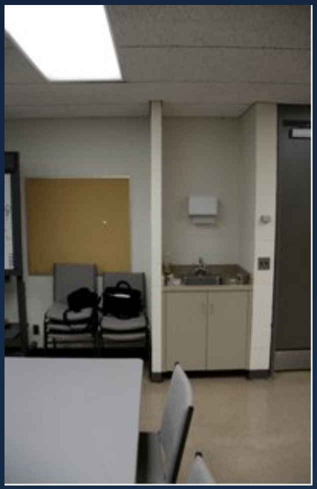


- Importance of discontinuities in edge contours at step transitions are important cues for detection: contour kinks, bends and L junctions
- Step up is usually more visible than a step down (^ risk)

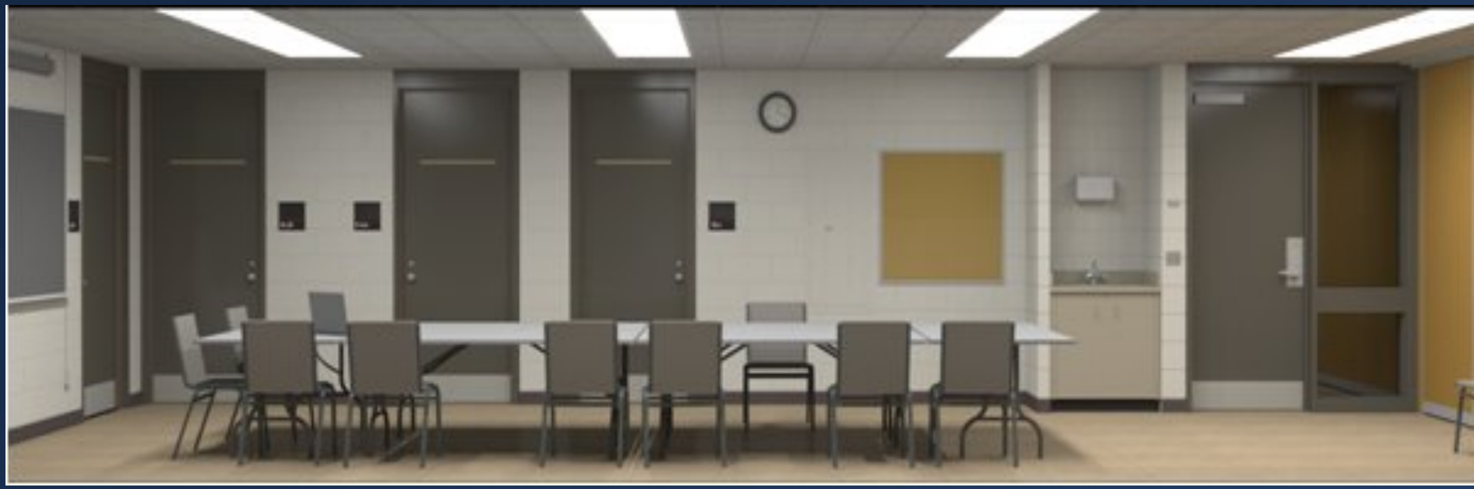
HAZARD DETECTION – software development 1

Challenge: validate automated detection of visual cues

Process: Construct photometrically accurate model of the lab environment. *Details in RW '08 presentation*.

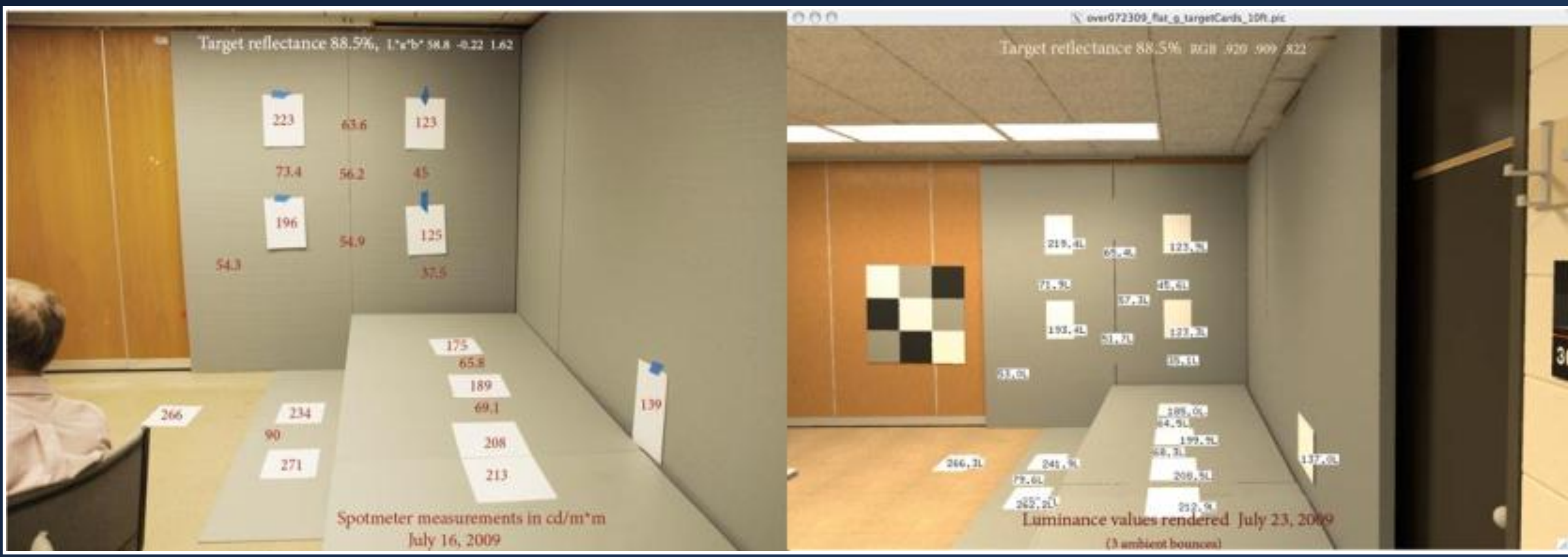


Photo



Rendering

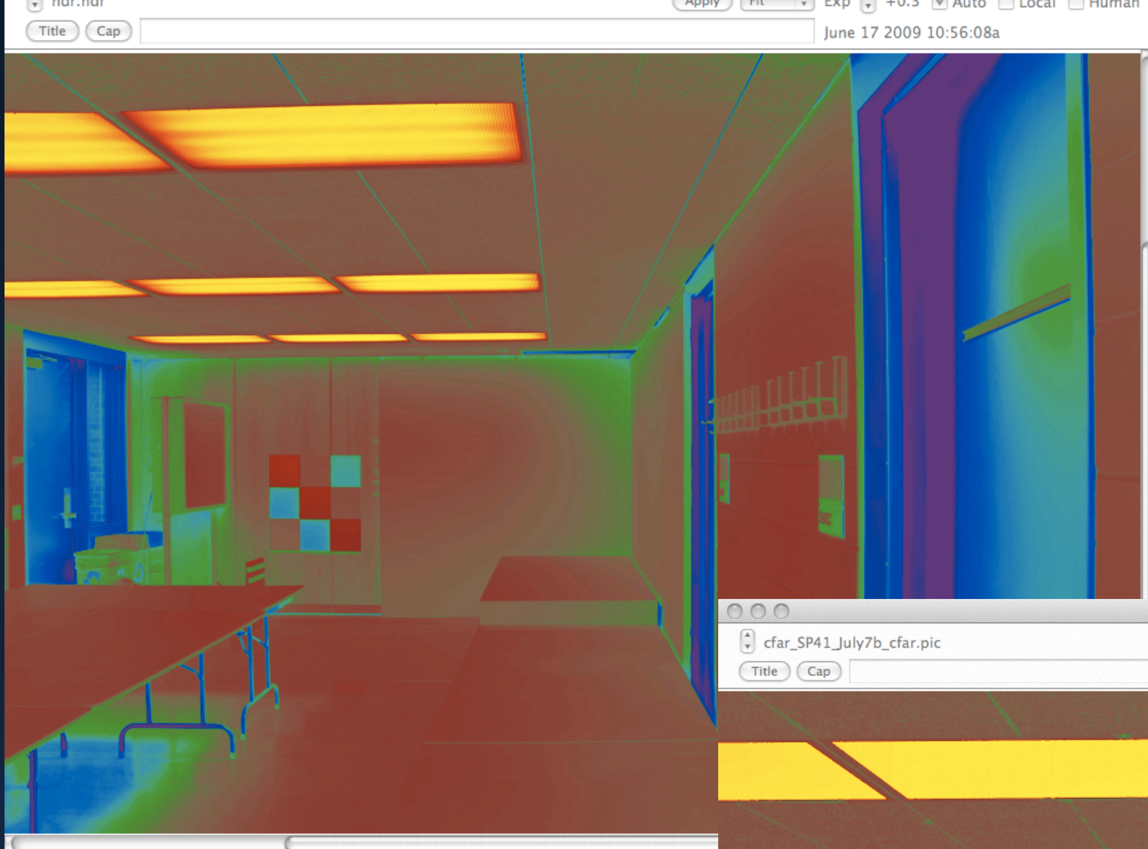
- Data collected from human subject studies in the lab is being used to compare and tune visibility predictions derived from the automated tool's analysis of the related simulations. Image must ~match the physical luminance



Photograph with luminance values Simulation with luminance values

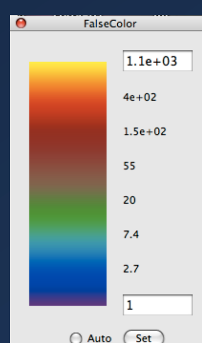
95%+ correlation

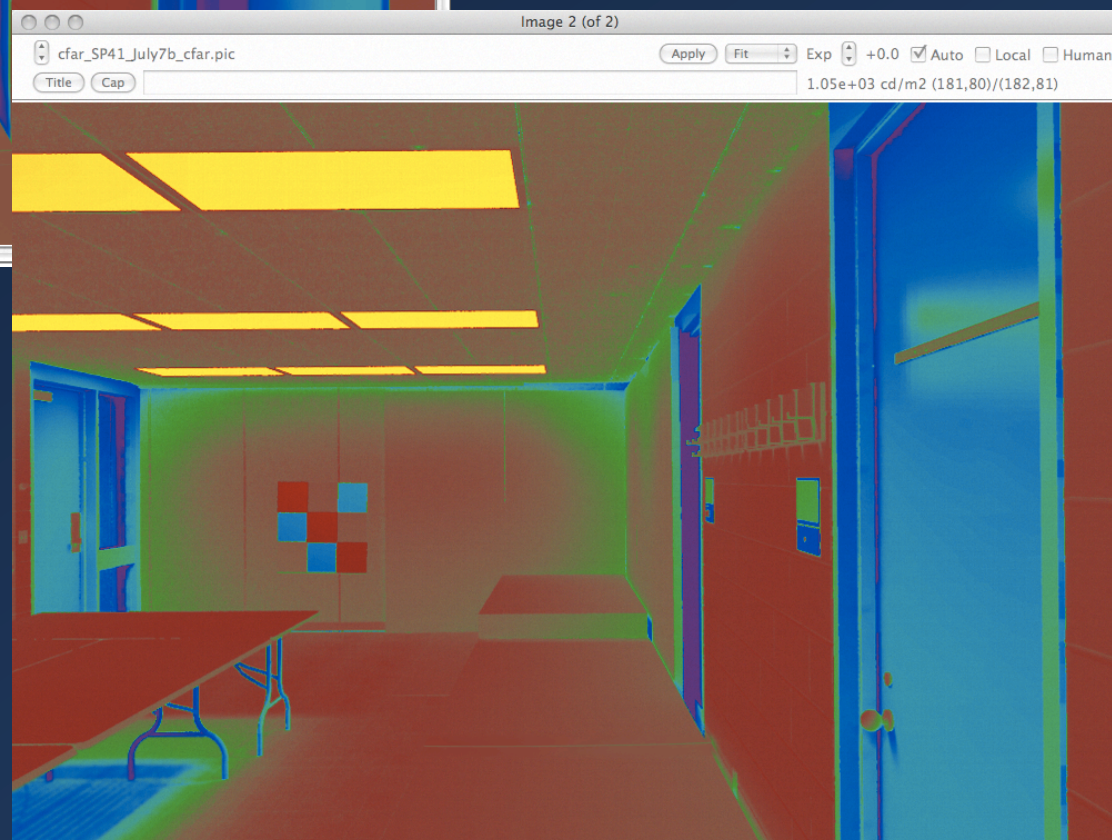
Validated Model



HDR photograph
July 15, 2009
falsecolor

HDR rendering
July 7, 2009
falsecolor
(same scale)





SIMULATION

ramp/platform arrangements

ramp flat

ramp up

ramp down

step up

step down

SIMULATION:

Lighting

"over" "near" "far"

12 x Prismatic 2'x 4'
4 fluorescent lamps

Photometry:
modified Lithonia
2SP G 4 32 A12 1/4 GEB

Lamp:
SP41 CRI 83
CIE X=.3805 Y=.3769
(Hunter lab an05-05.pdf)

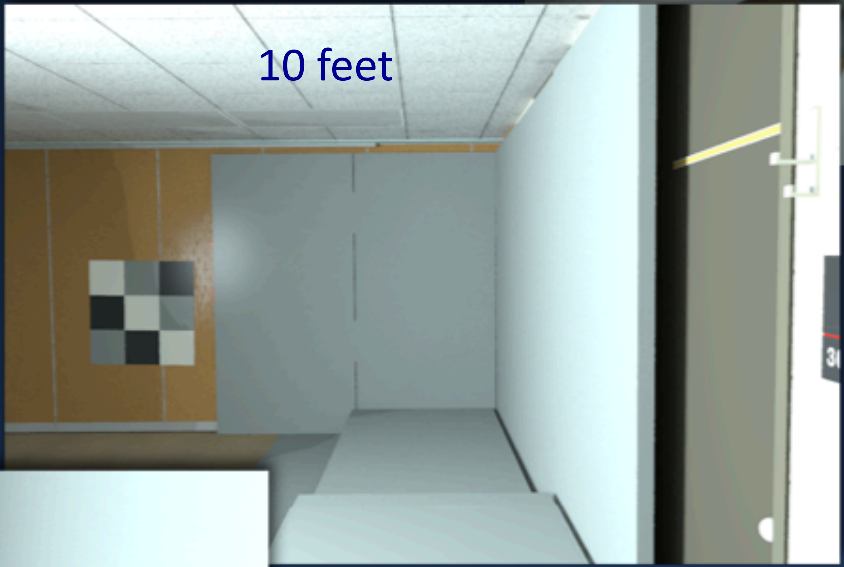
1 x LightBox 3' x 3'
12 fluorescent lamps

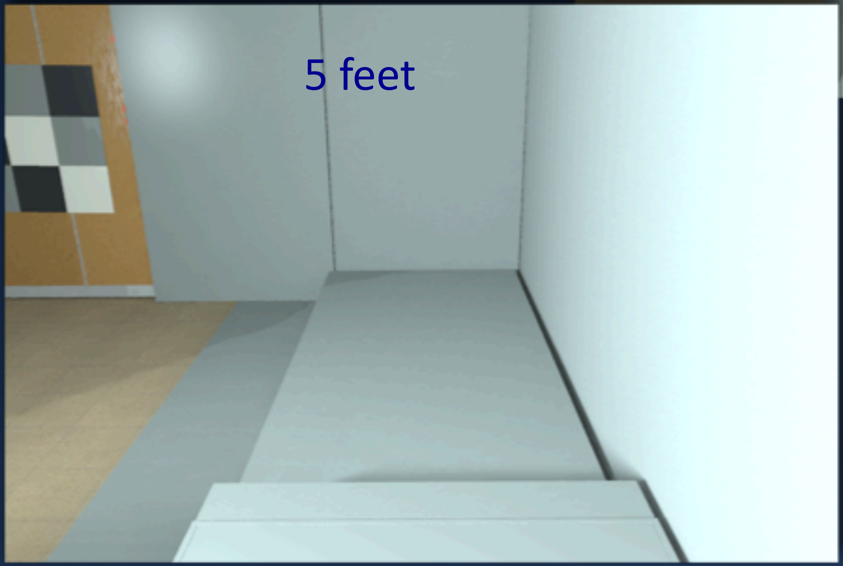
Photometry:
data by Chris Kalle
5 degree samples at 16'

Lamp:
SP65 CRI 90
CIE X=.3129 Y=.3292
(Hunter lab an05-05.pdf)

SIMULATION:

Views





SIMULATION:

backgrounds

Grey
refl ~25%

Black
refl ~ 2.5%

White
refl ~ 87%

50
refl ~50%

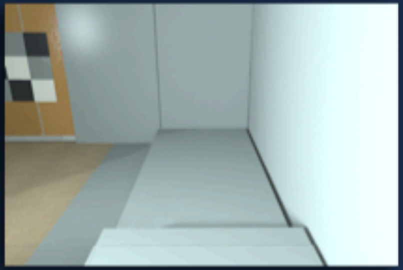
70
refl ~70%

typical walls refl 50%-70%
ceilings > 70%
floors < 50%

PROCESS:

extract data

from 225 combinations



Extract pixel referenced xyz, object and material name (& surface slope)

vwrays -fd 001.pic | rtrace -fda `vwrays -d 001.pic` -os 001.oct > 001_obj.txt

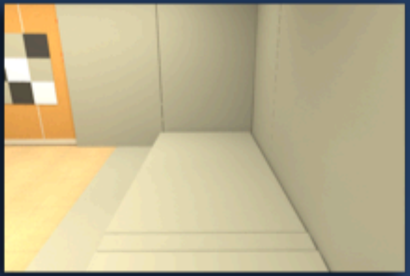
vwrays -fd 001.pic | rtrace -fda `vwrays -d 001.pic` -op 001.oct > 001_xyz.txt

vwrays -fd 001.pic | rtrace -fda `vwrays -d 001.pic` -oM 001.oct > 001_mat.txt

:	:	:
black_backing	1.735780e+01 2.195081e+02 3.004387e+01	canvasf
black_backing	1.948984e+01 2.195088e+02 3.037238e+01	canvasf
step-edger.5137	2.157784e+01 2.195095e+02 3.069411e+01	canvasf
step-edger.5137	2.362316e+01 2.195102e+02 3.100926e+01	canvasf
step-edger.5137	2.562710e+01 2.195108e+02 3.131804e+01	canvasf
step-edger.5137	2.759090e+01 2.195115e+02 3.162063e+01	styro_black
step-edger.5137	2.951574e+01 2.195122e+02 3.191722e+01	styro_black
step-edger.5137	3.140279e+01 2.195128e+02 3.220798e+01	styro_black
step-edger.5137	3.325314e+01 2.195134e+02 3.249309e+01	styro_black
step-edger.513	3.325314e+01 2.195134e+02 3.249309e+01	styro_black
:	.	:

Possibly extract luminance values of each pixel

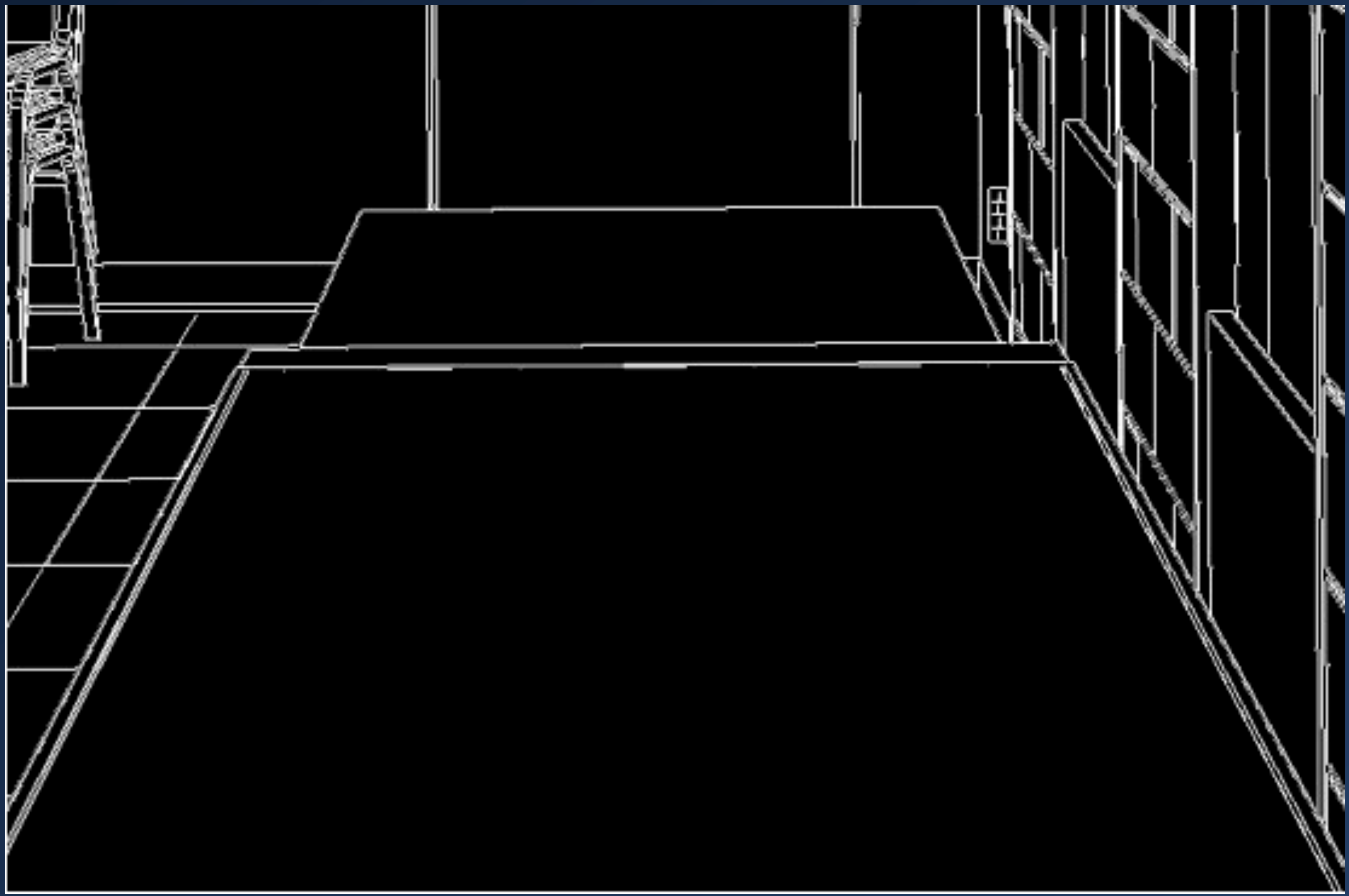
vwrays -fd 001.pic | rtrace -fda `vwrays -d 001.pic` -ov 001.oct > 001_rad.txt



Object and Material definition files (text)

Generate "ground truth" for

- feature recognition (ie stepdown contour kink. Just started research)
- **luminance pattern analysis** (partially accomplished)



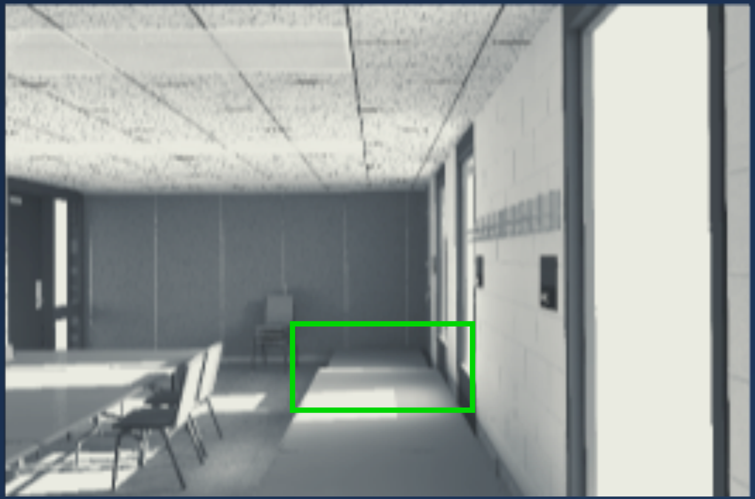
To explore a range of **luminance patterns**, a higher contrast dataset was generated. The doors of the basement lab were removed, replaced by windows, and room was elevated to ground level (also leveled Minneapolis)

An hourly daylight study was rendered from 5:00 am until 10:00 pm on July 4th using a clear sky condition at the coordinates of the lab in Minneapolis.

Approach: NORMAL ACUITY

Contrast in a selected region can predict visibility

Low contrast
in target region



High contrast
in target region

Higher contrast makes it easier to see step

LOW ACUITY

...but under loss of resolution, contrast in region can be a poor predictor of visibility

Low contrast
in target region

High contrast
in target region

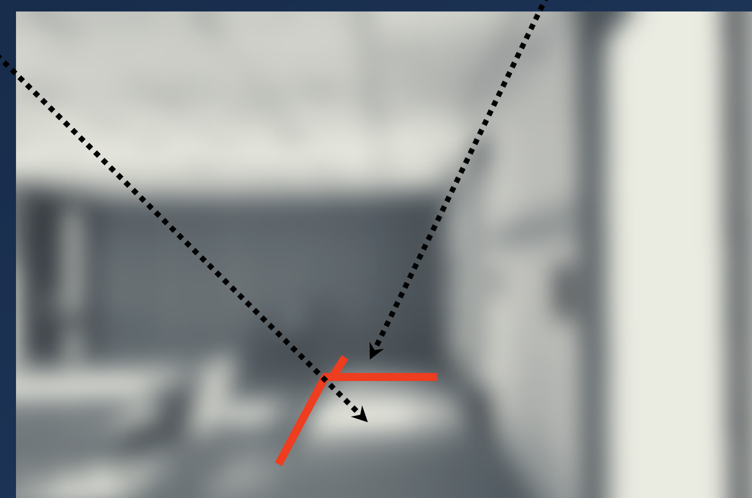
High contrast doesn't mean better obstacle detection!

LOW ACUITY

High contrast from window illumination is misleading indicator of depth change

Contrast too low at important step edge

Low contrast in target region



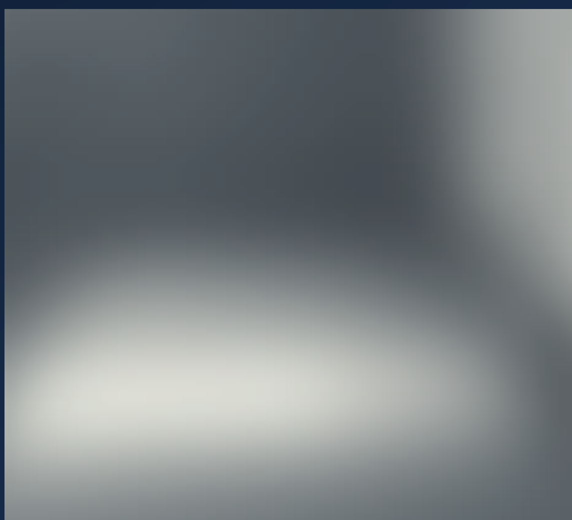
High contrast in target region

GEOMETRY-BASED VISIBILITY METRIC

- A change in intensity can be due to several causes:
  - depth or orientation change in geometry
  - illumination/shadow change
  - material change
- Depth change is critical
  - misperceiving depth changes are more costly than mistakes in detecting other causes

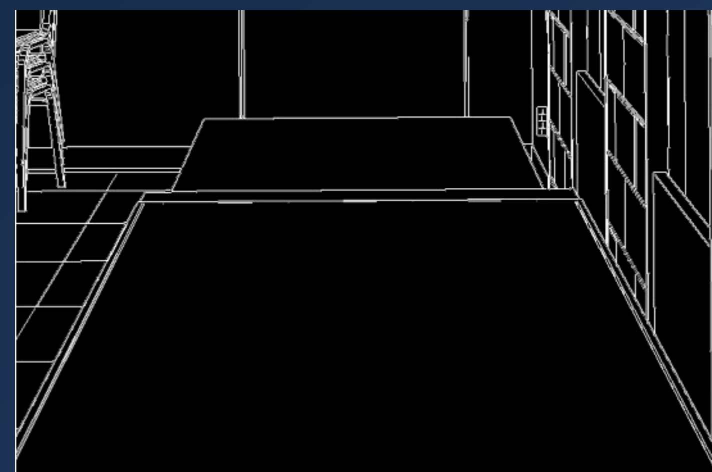
GEOMETRY-BASED VISIBILITY METRIC

How well do intensity changes in the image predict depth discontinuities in the "ground truth"?



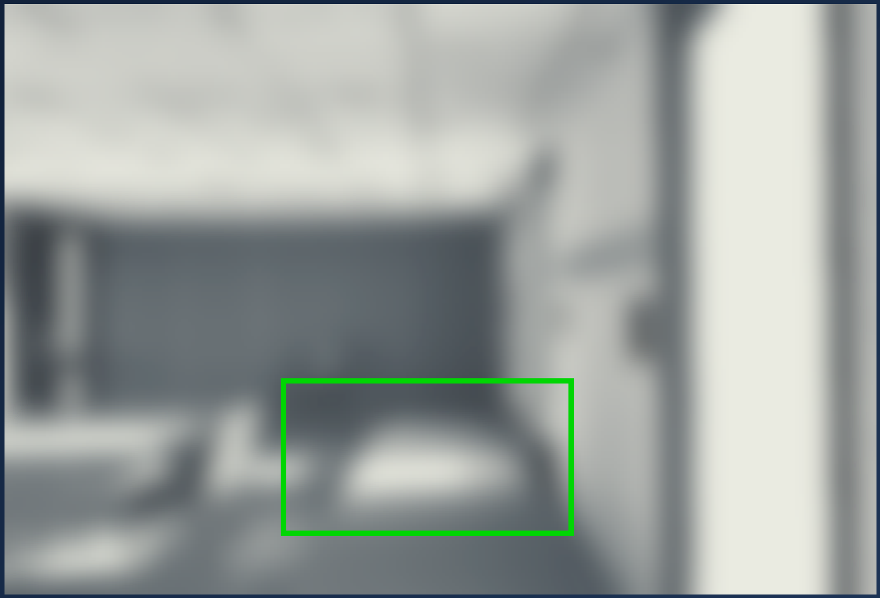
Image

?



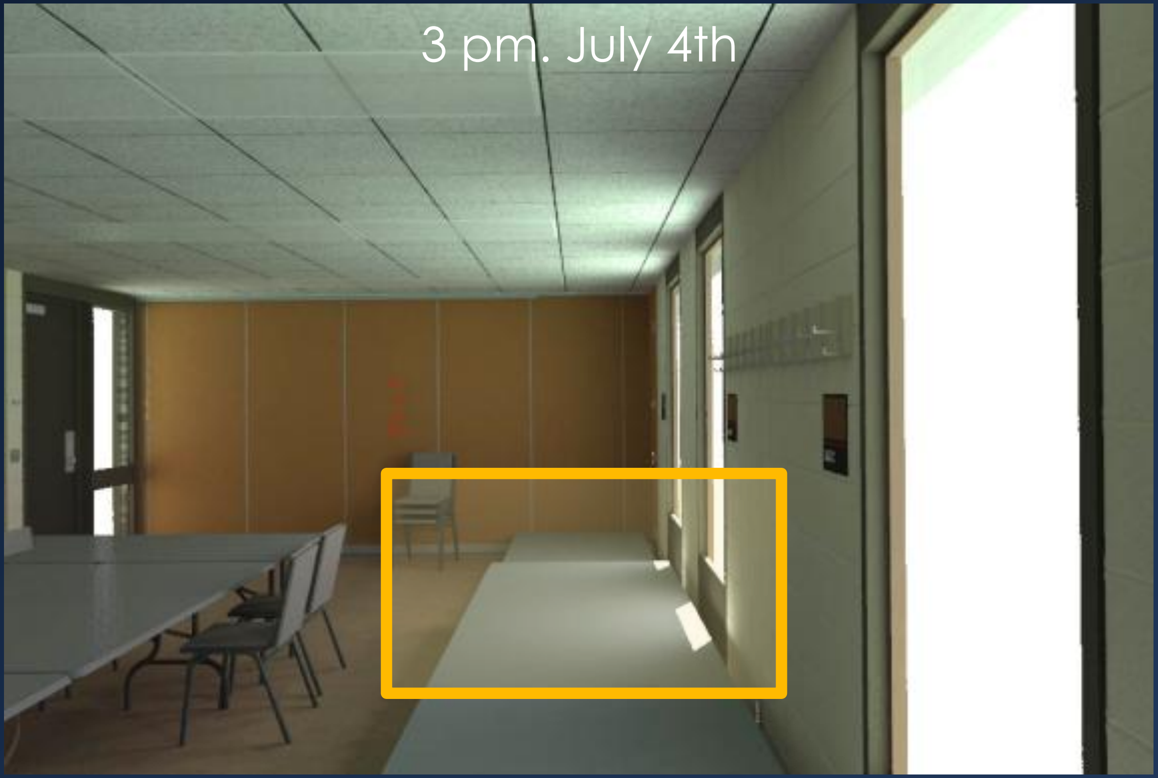
Depth discontinuities determine "ground truth"

GEOMETRY-BASED VISIBILITY METRIC



- A low value of geometry-based metric predicts low visibility
  - This is when locations of large intensity changes don't match the locations of the depth changes

AUTOMATED ANALYSIS– VISIBILITY & RISK FACTORS



- Region is selected, ready for automated analysis
- Various visibility indicators generated per picture

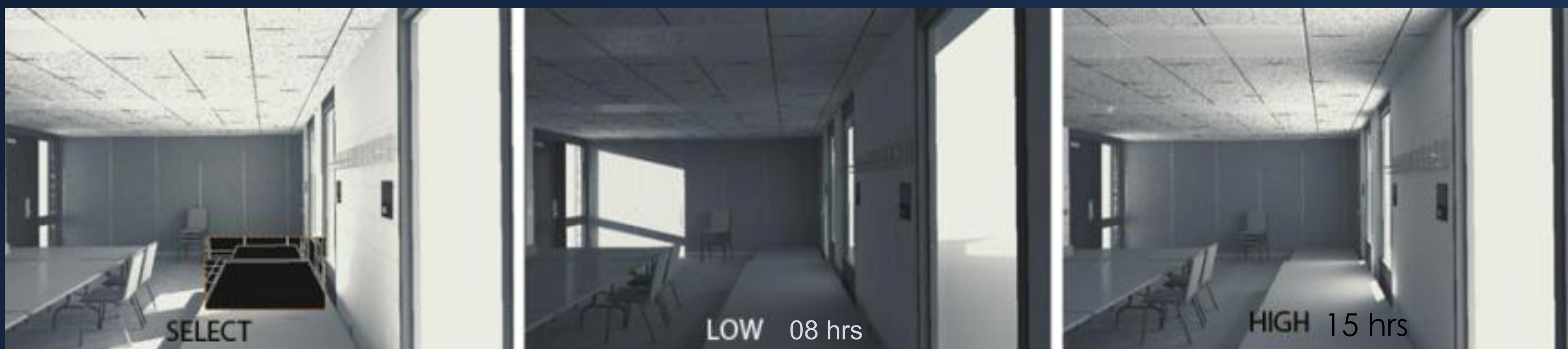
Day Sequence Analysis

- [illegible]
- [illegible]
- [illegible]

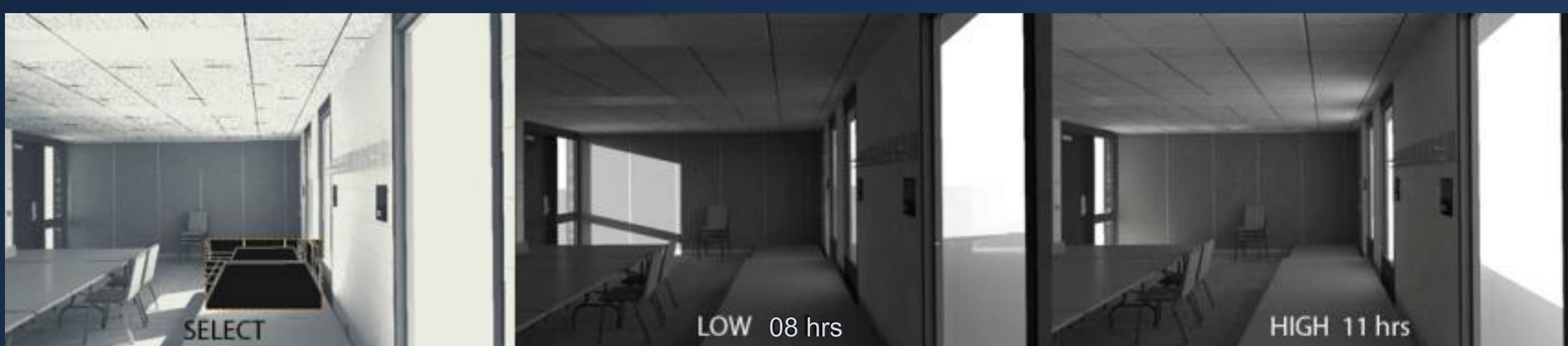
- [illegible]

AUTOMATED ANALYSIS– VISIBILITY & RISK FACTORS

- Predicted hours of highest and lowest step visibility:
  - Normal acuity and contrast



  - Reduced acuity and contrast



AUTOMATED ANALYSIS– VISIBILITY & RISK FACTORS

- Explore the visibility consequences of different lighting systems plus daylight

AUTOMATED ANALYSIS– VISIBILITY & RISK FACTORS

- Compare nighttime aisle light systems and visibility

LOWER

HIGHER

AUTOMATED ANALYSIS TOOL

Tool in early phases of development. Future iterations will include additional visibility factors in its predictions.

- Potential scenarios:
  - A year daylight/electric light study of a large city center atrium from several vantage points in pathways approaching potential hazards
  - Assessment report identifying most hazardous visual conditions with associated risk factors
  - Iteratively, the designers, in conjunction with owners and risk management, massage the design to achieve acceptable results, while striving to follow Universal Design principles

AUTOMATED ANALYSIS TOOL

Tool in early phases of development. Future iterations will include additional visibility factors in its analysis:

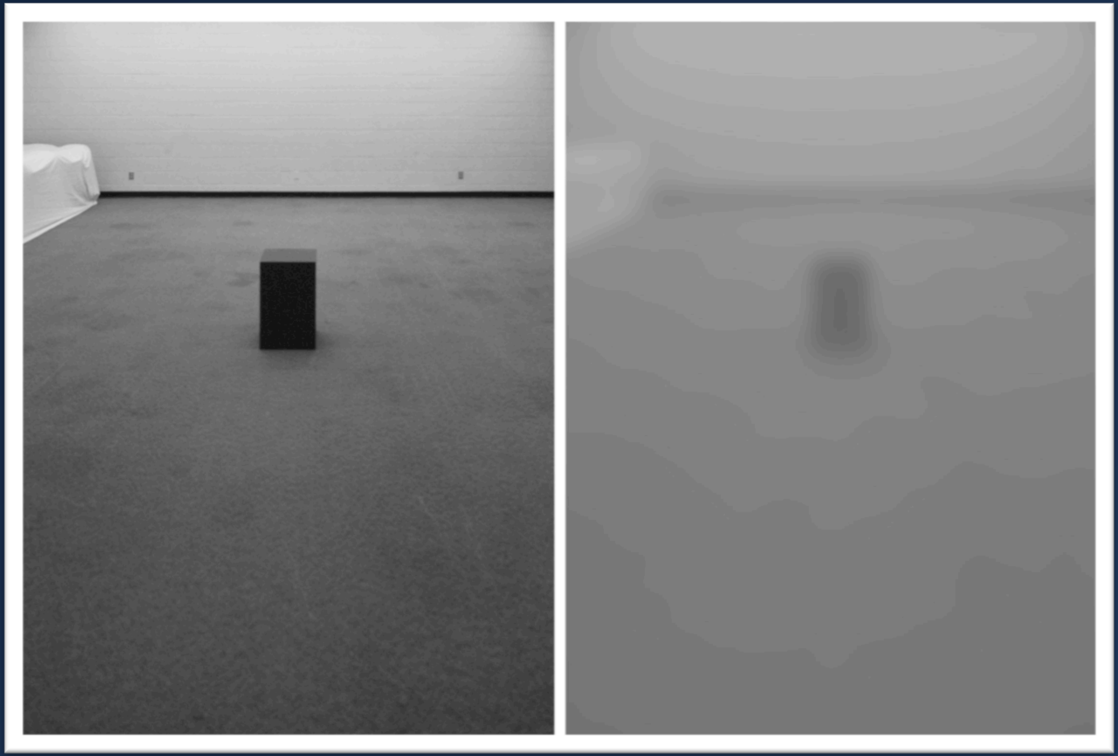
-Luminance *visibility thresholds* and *effects of glare*

University of Minnesota Study

AUTOMATED ANALYSIS TOOL

Tool in early phases of development. Future iterations will include additional visibility factors in its predictions:

-Accuracy in judging locations of objects in the environment



University of Utah Study

AUTOMATED ANALYSIS TOOL

Tool in early phases of development. Future iterations will include additional visibility factors in its predictions:

-Horizon effect on scene evaluation and orientation

University of Utah Study

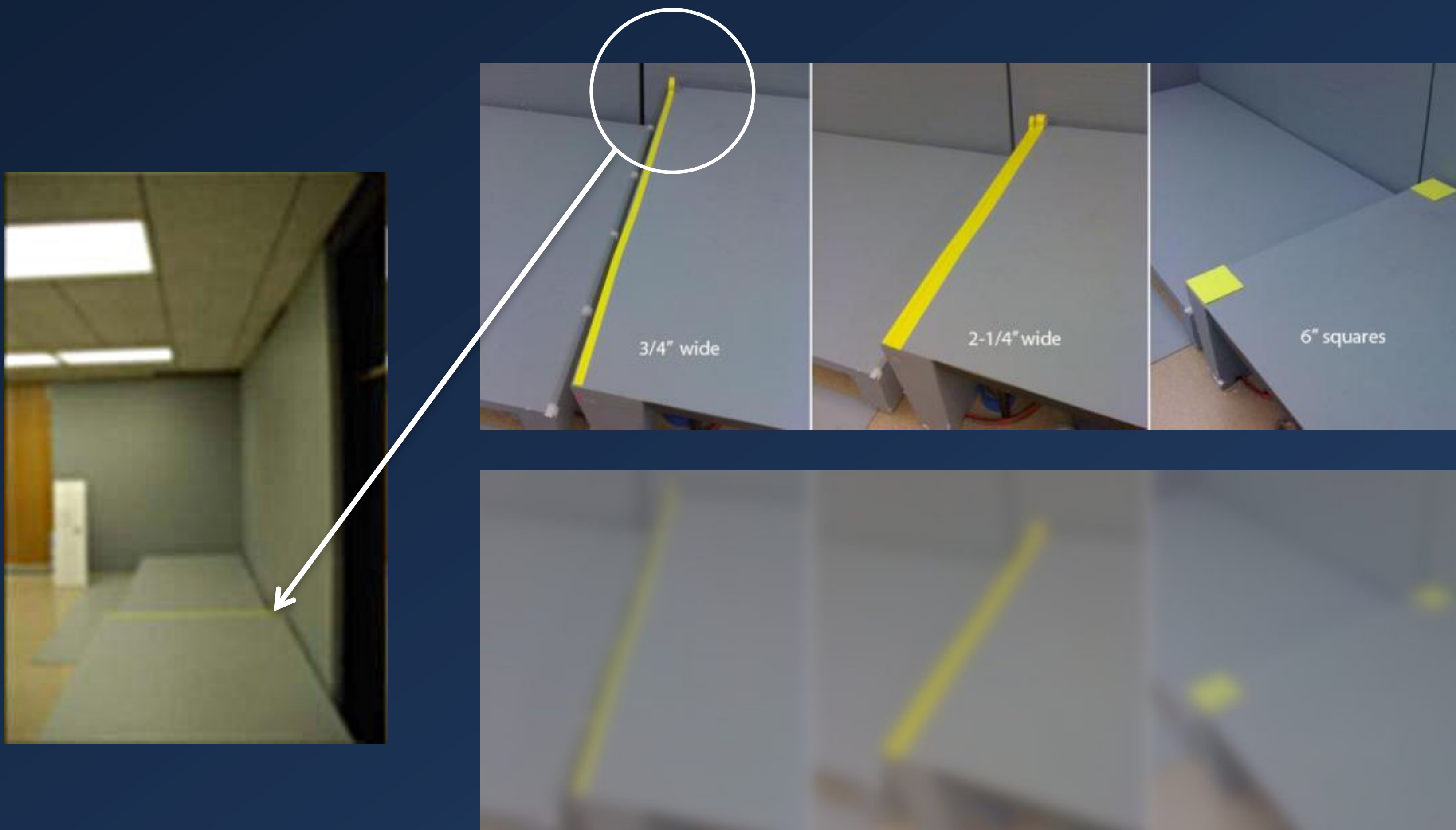
AUTOMATED ANALYSIS TOOL

Tool in early phases of development. Future iterations will include additional visibility factors in its predictions.

- Potential scenaris:
  - A year daylight/electric light study of a large city center atrium from several vantage points in pathways approaching potential hazards
  - Assessment report identifying most hazardous visual conditions with associated risk factors
  - Iteratively, the designers, in conjunction with owners and risk management, massage the design to achieve acceptable results, while striving to follow Universal Design principles

INTERACTIVE DESIGN TOOL

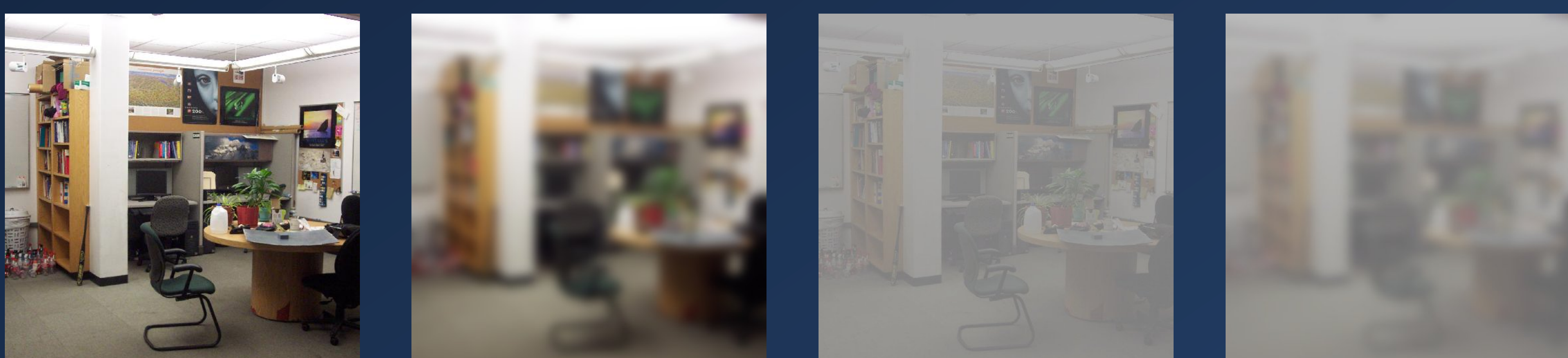
- Present to normally sighted designer the appearance of a space under (simulated) low vision



INTERACTIVE DESIGN TOOL

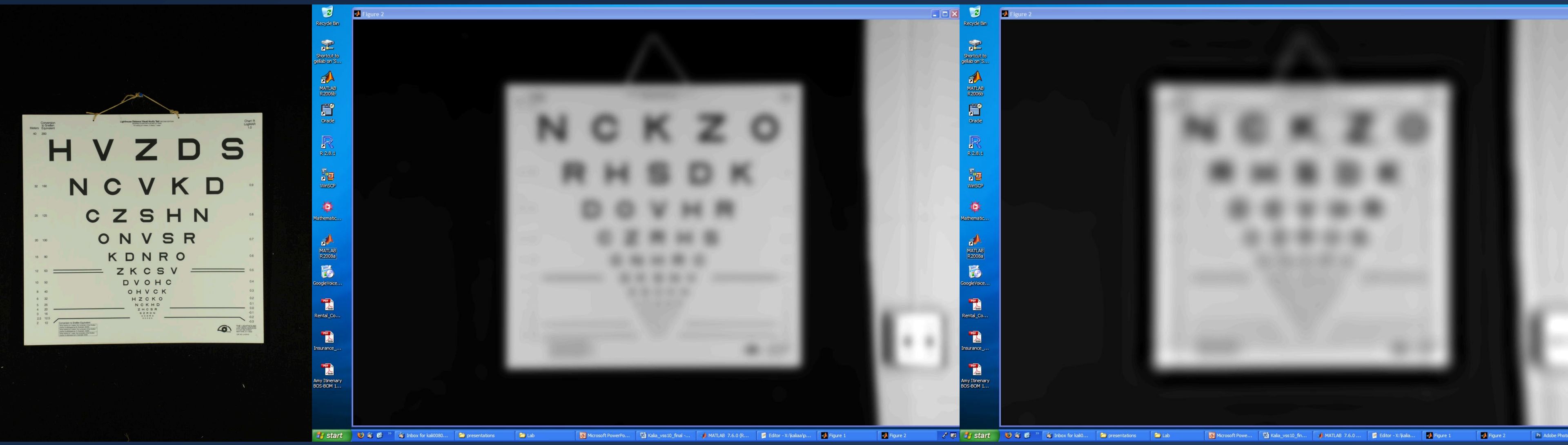
- The challenges:
  - Need photometrically correct model of low vision deficit being simulated

    - Nature and magnitude of blurring and contrast reduction functions need to match a reasonable spectrum of the low vision population



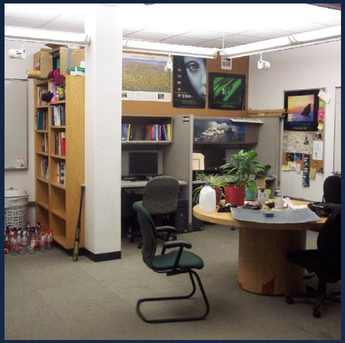
INTERACTIVE DESIGN TOOL

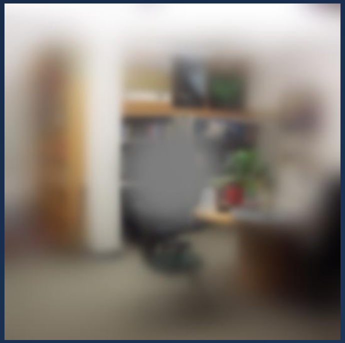
- The challenges:
  - Need controlled viewing conditions that preserve contrast and acuity
    - Calibrated display device
    - Fixed viewing position relative to display
    - Control of ambient lighting



INTERACTIVE DESIGN TOOL

- Limitations:
  - Simulations of contrast/acuity are only approximate
  - Can't realistically simulate effects of field loss





  - Spatial orientation (e.g., distance perception, updating) is different when viewing display than when viewing a physical environment

- ***… but viewing a display will give a reasonable approximation of the visibility of hazards!***

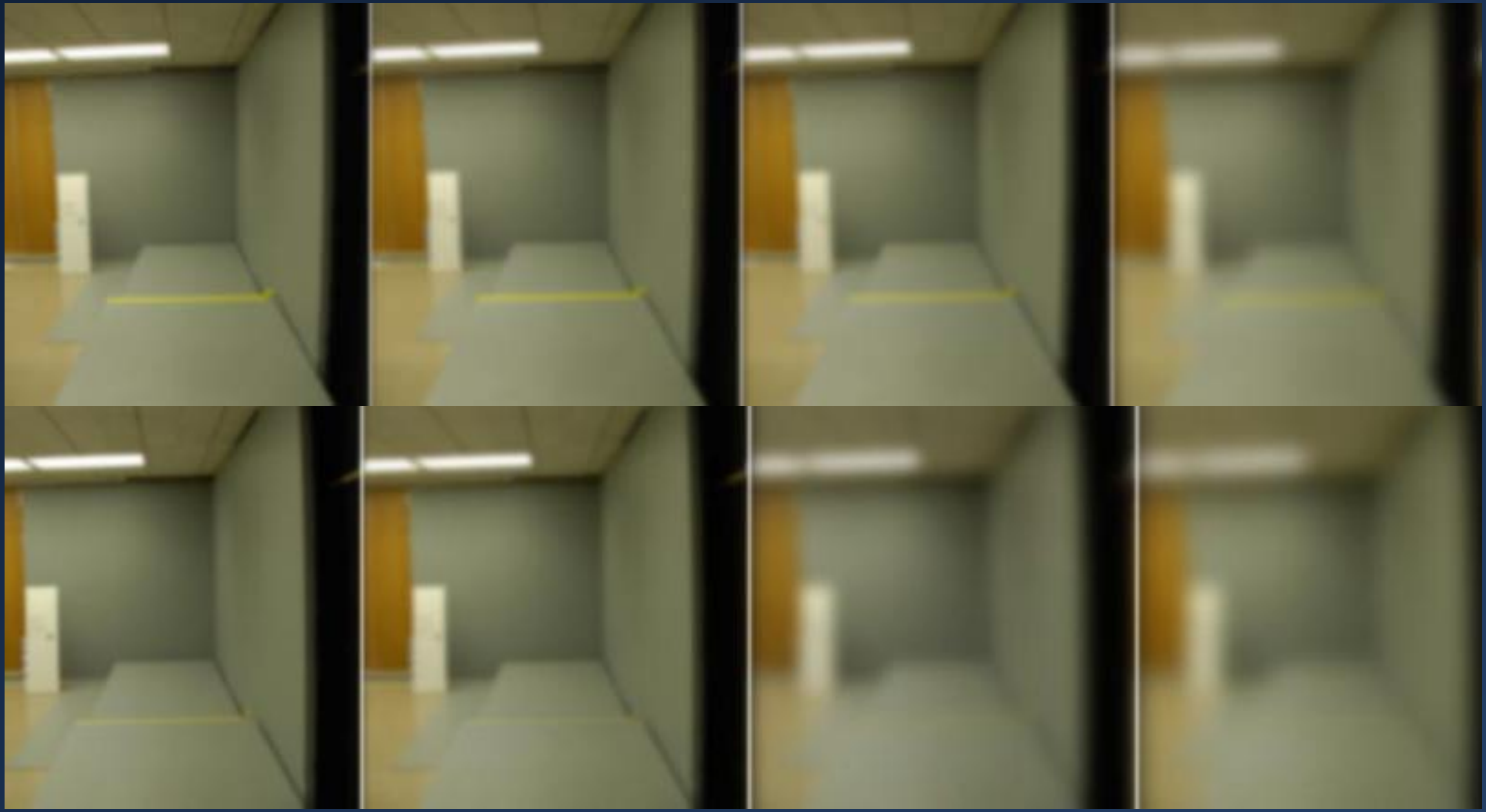
INTERACTIVE TOOL

- Mockup demonstration from lab
  - “Blurred” to approximate low acuity: 20/200 to 20/800

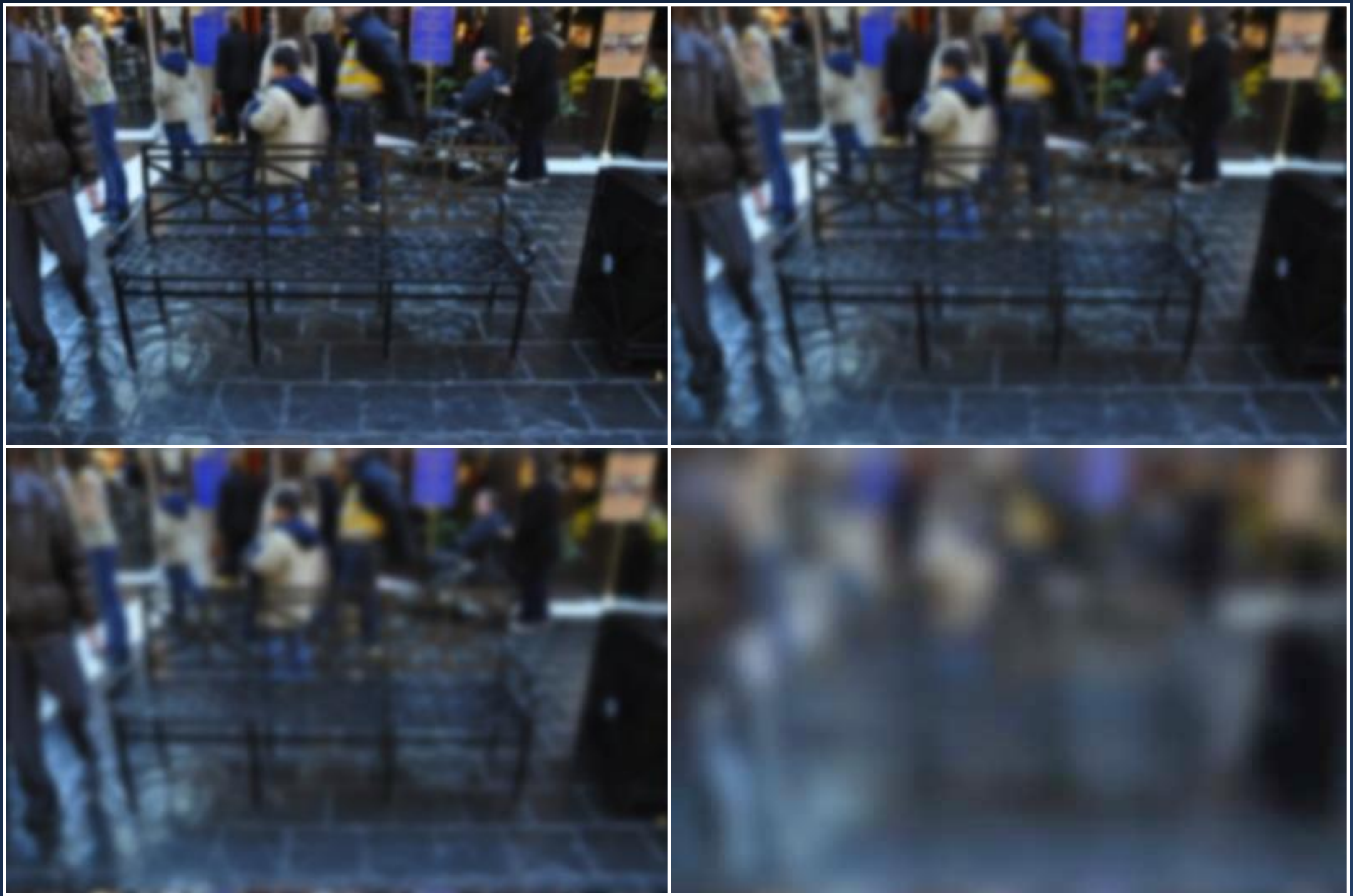
(image not calibrated : viewing distance not considered)

INTERACTIVE TOOL

- Mockup demonstration from lab
  - Compare visibility of 2 ¼” and ¾” stripes



INTERACTIVE TOOL – MOCK UP



INTERACTIVE TOOL – ground truth known

Luminance change without geometric change

FALSE-POSITIVE

Geometric change without luminance change + hazard recognition

Expanding the interactive tool’s range

More false positive cases

FALSE POSITIVE DETECTION

- This entry poses a significant challenge

Low Vision:
Appears to be a step-up

Build study model

Distance to identify false hazard (angular displacement)

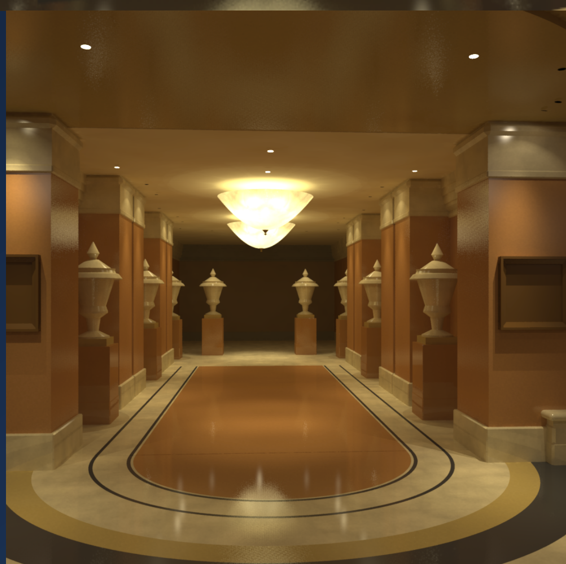
Distance to resolve NOT a false hazard?

Determine visbility ZONE for hazard


False Positive


Positive

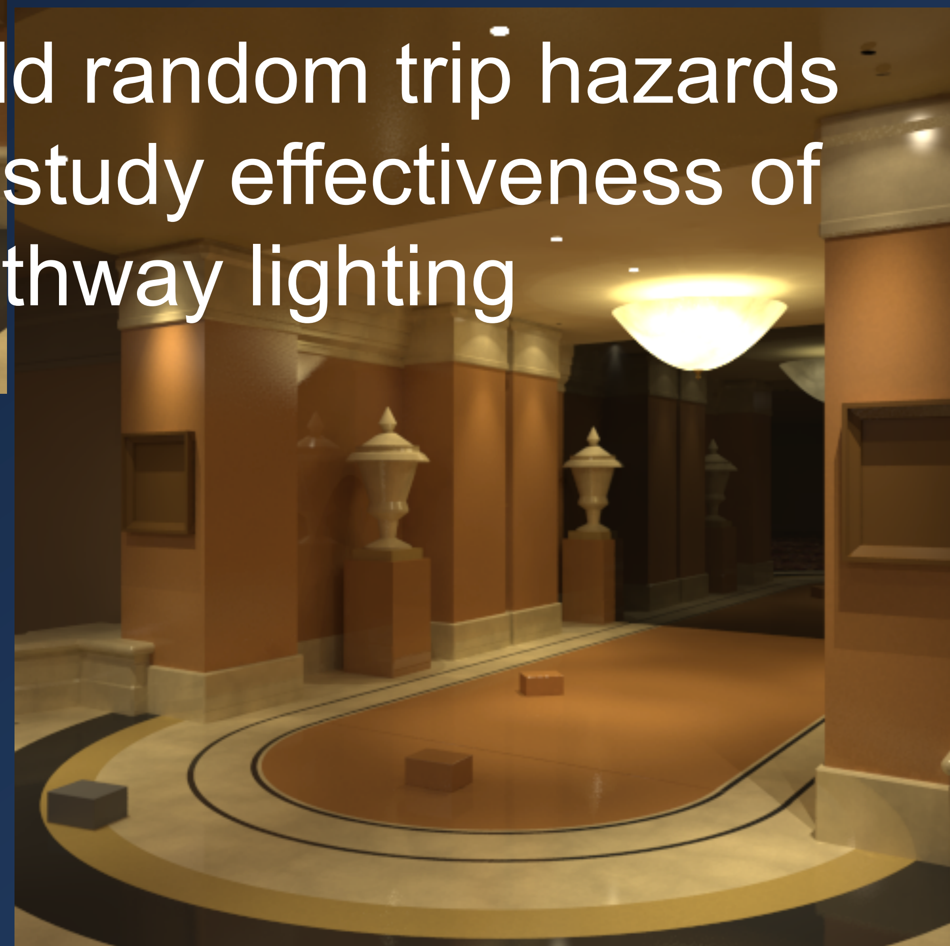
Add glass reflection to studies

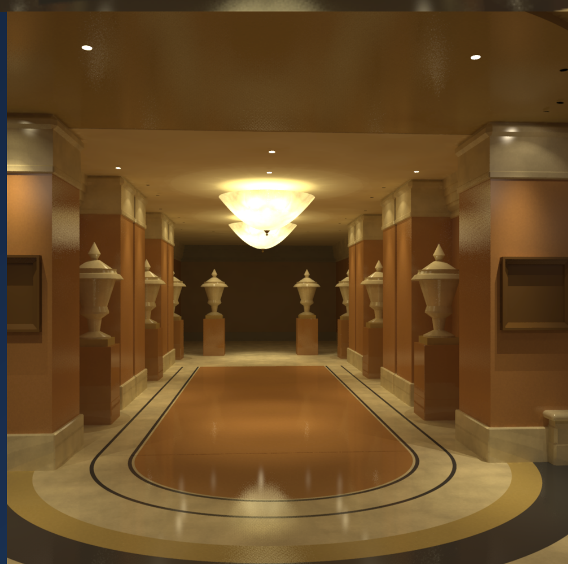


Add high contrast luminance patterns to challenge detection

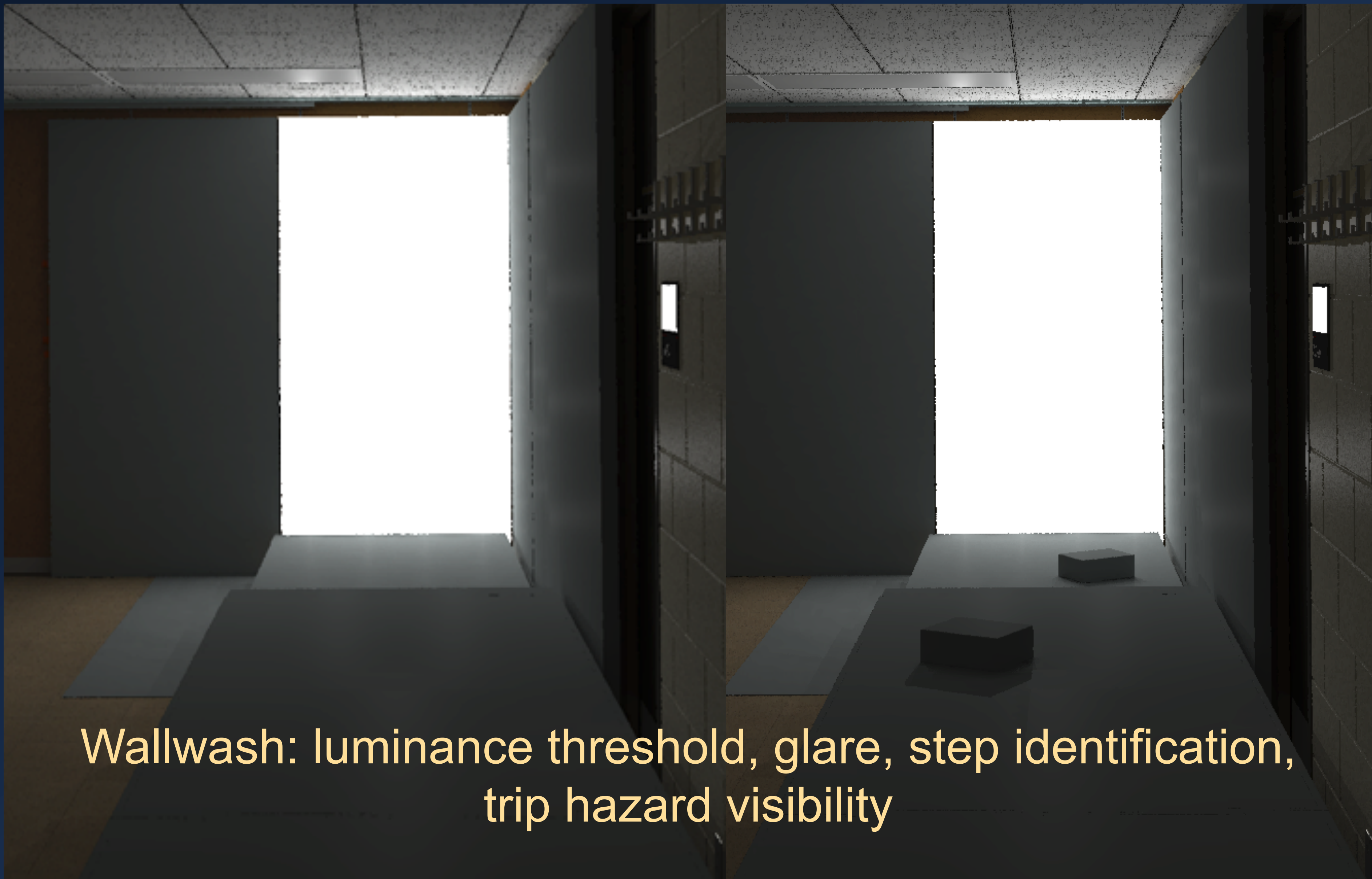
Explore ranges of distance, contrast, reflections, & lighting, to expand visual accessibility range

Add random trip hazards to study effectiveness of pathway lighting





Tool could aid in exploring visibility index for alternative/greener lighting schemes




Too dim?
Too bright?
50 nits 20ft sd
100 nits 20ft sd
200 nits 20ft sd
50 nits 20ft sd
100 nits 20ft sd
200 nits 20ft sd

SUMMARY

Current and Future work:

- A better understanding of low vision perception and action involving mobility
- Better methods for simulating the effects of low vision in design systems
- Better computational models for automating the prediction of the effects of lighting and other aspects of architectural design on visual accessibility
- Integration with the real-world design process

SUMMARY

Principal goals for this session:

- Sensitize you to the challenges of low vision

- Present research in developing computer tools to aid in creating visual accessible spaces… using ***RADIANCE***

DESIGNING VISUALLY ACCESSIBLE SPACES

THANK YOU FOR YOUR ATTENTION

Rob Shakespeare

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