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National Surface Transportation Safety Center for Excellence

Instrumentation for Assessing Lighting in Naturalistic Driving

Virginia Tech Transportation Institute

Lighting Data

- Two Magnitudes of Detail
  - Simple Glare Assessment
    - Evaluation of Light entering the Driver's Eye
    - Vertical illuminance detector
  - Scene Assessment
    - Provide an image of the entire visual scene
    - Luminance (Brightness) assessment through an optical system

First Level – Glare Assessment

- Glare is typically assessed by evaluating the vertical illuminance on the drivers eye
  - Amount of light falling on a Vertical plane at the eye
- Disability Glare

$$L_{SEQ} = \frac{k \cdot E_{gl}}{\theta^{n}}$$

- Discomfort Glare

$$W = 5.0 - 2.0 LOG_{10} \frac{E\max}{0.003 * \left(1 + \sqrt{\frac{La}{0.04}}\right) * \theta_{\max}^{0.46}}$$

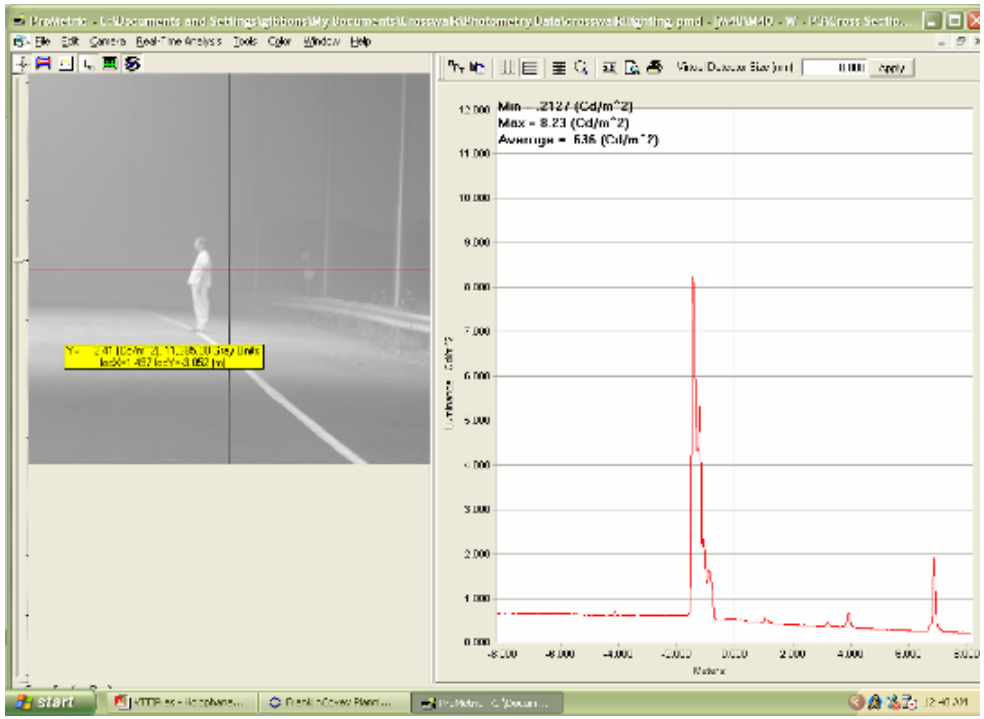
First Level Measurement

- A small light sensor and a vertical capture plane can be linked with glare
  - Limited – No source Discrimination
    - Overhead lighting
    - Sun
    - Vehicle headlamps
- A video based spatial system can be used for more accurate assessment

Luminance Camera

- The Luminance Camera project was the development of a system which allows for the capture of live luminance data from a moving vehicle.
  - For use in a naturalistic suite of instruments to capture roadway luminance from a driver in crash scenarios

CCD Photometry



- "This is not your Parent's photometry"
- We have barely started to scratch the surface of how this instrument will change the way we look at lighting

Luminance Camera

- 12 bit Point Grey Digital Firewire camera.
  - Calibrated against a Prometric Still Luminance Camera
- Varying shutter and gain values determine the range of luminance measured
  - 2 cameras can be coupled to increase dynamic response
- Individual images are stored for later analysis

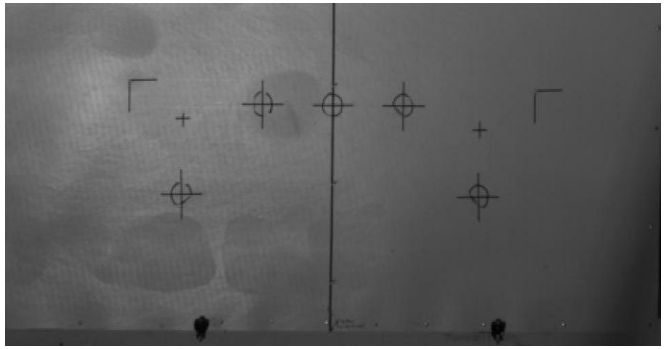
Luminance Camera

Luminance Camera Calibration Procedure

- In controlled environment, with adjustable lighting levels:
  - Take simultaneous, “identical”, pictures with:
    - Radiant Imaging ProMetric Photometer – results in luminance (cd/m^2)
    - CCD Camera – results in grayvalues
  - Vary CCD attributes
    - gain, shutter, autoexposure, sharpness, and brightness during image acquisition
  - Use MATLAB software to automatically extract pixel values from over 800 images

Calibration - Procedure

- Controlled environment
- Simultaneous image capture with ProMetric photometer and Luminance Cameras
  - Software automatically adjusts Luminance Camera variables



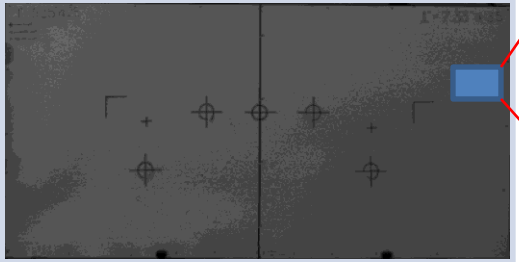
Light Level (cd/m2)	24.1, 15.6, 7.99, 1.87
Camera Gain (dB)	24, 21, 18, 15, 12, 9, 6, 3, 0, -2.25
Camera Shutter (ms)	267, 213, 159, 105, 51, 41, 36, 31, 26, 21, 16, 11, 6, 1

Calibration - Procedure

Overlay of images completed automatically through software

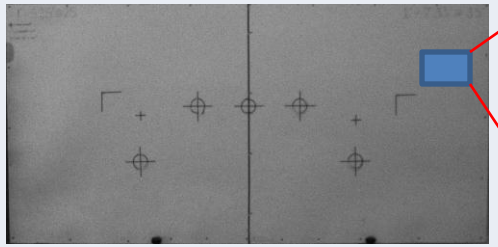
Pixel Value

Luminance (cd/m^2)



2.13	2.13	2.10
2.13	2.13	2.10
2.08	2.08	2.13

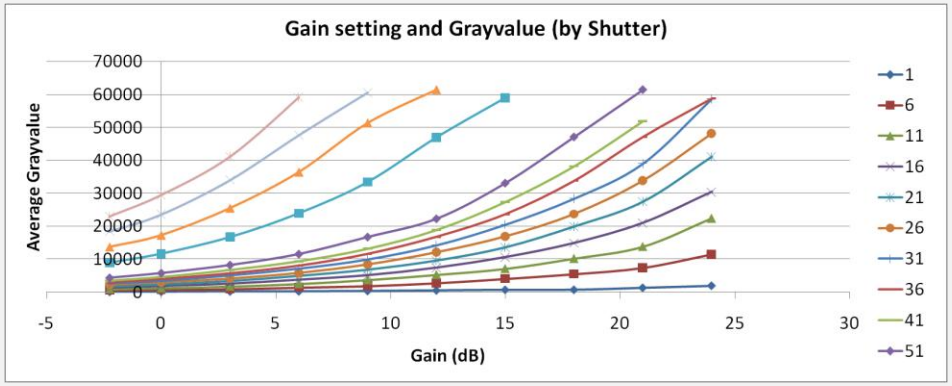
grayvalues



2608	2704	2816
2704	2928	2624
3152	2848	2656

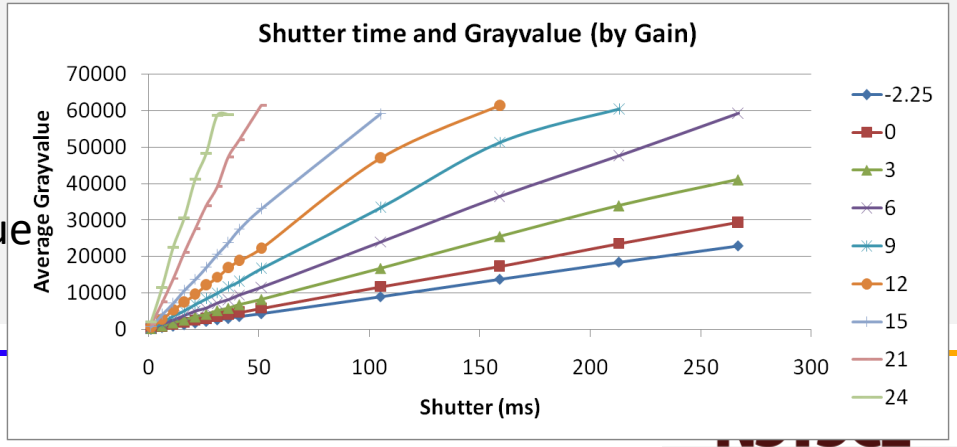
Calibration - Results

- Pixel analysis



Positive relationship of Luminance Camera gray value and gain

Positive relationship of Luminance Camera gray value and shutter



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Dynamic Evaluation – Procedure Camera Setting Selection

Estimation of maximum luminance

Darkened image → High pixel saturation

Increase in image noise ↓

	SHUTTER (ms)													
GAIN (dB)	**1**	**6**	**11**	**16**	**21**	**26**	**31**	**36**	**41**	**51**	**105**	**159**	**213**	**267**
-2.25	899.4	172.6	96.2	66.6	48.4	40.6	34.7	30.1	26.5	21.7	10.8	14.0	6.8	7.3
0	732.1	120.8	69.1	47.2	39.3	**32.2**	25.9	23.2	20.7	15.8	7.8	5.4	3.6	3.0
3	477.8	89.3	49.2	34.9	26.8	21.7	19.3	15.0	14.0	12.5	5.5	3.5	2.7	2.2
6	332.8	64.0	35.1	24.5	19.4	15.2	13.3	12.6	9.9	7.7	3.7	2.5	1.9	1.6
9	214.1	40.6	23.4	17.6	12.6	10.0	9.6	7.7	6.1	5.5	2.8	1.7		
12	165.4	33.6	18.6	12.0	9.7	7.5	6.1	5.6	5.2	3.9	2.0			
15	107.3	22.9	12.7	9.8	6.8	5.4	4.4	3.7	3.2	2.7	1.7			
18	81.2	14.8	8.2	6.2	3.9	3.2	2.5	2.4	2.0	1.8				
21	56.1	12.1	6.9	3.8	3.3	2.6	2.2	1.8	1.8					
24	41.8	7.0	5.2	2.4	2.0	1.8	1.8	1.7						

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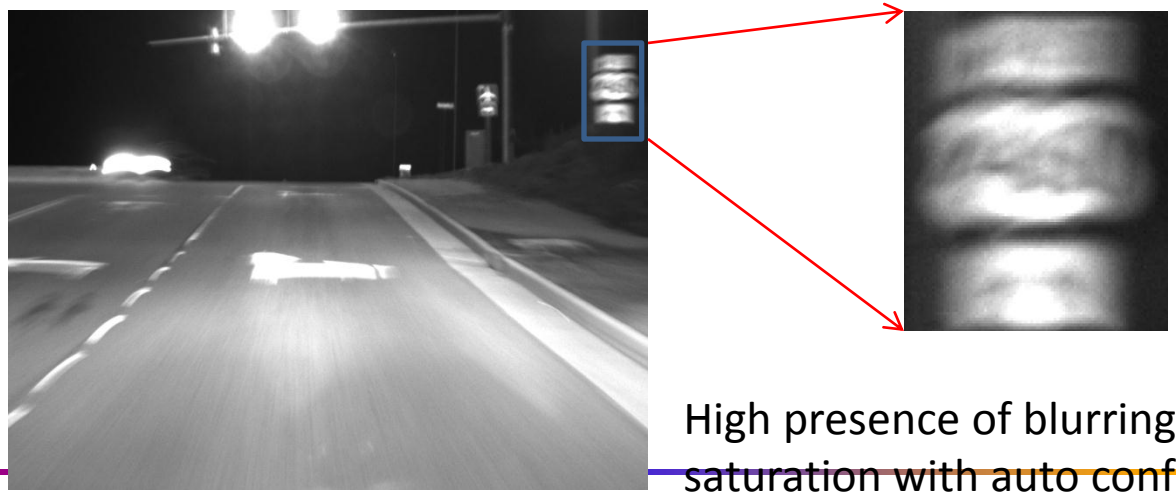
Dynamic Evaluation - Results

Manual

Automatic



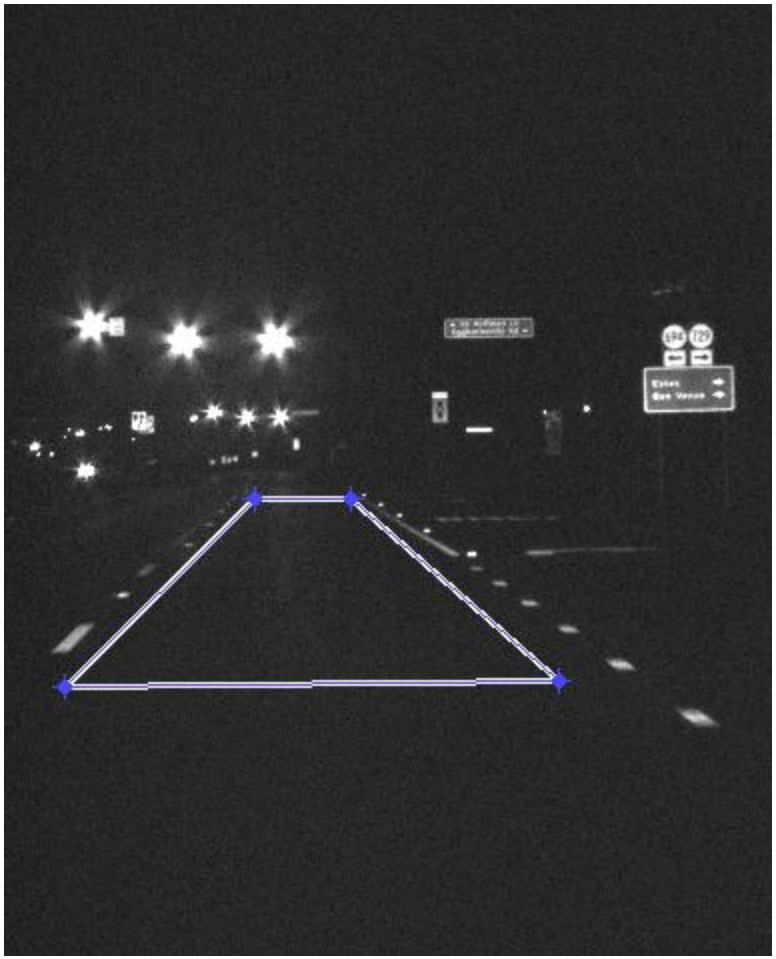
High presence of blurring and saturation with auto configuration

Luminance Camera Performance

- 16 bit image
  - 1 to 55000 ratio of luminance within image
- Camera capture
  - 7.5 frames/second
    - 1024x768 resolution
    - At 40 mph → 1 frame every 7.8ft
  - 3.75 frames/second
    - 1280x960 resolution
    - At 40 mph → 1 frame every 15.64ft
    - For a 2 hour Video
      - 44 GB of data

Rural Intersection Lighting – Luminance Data Reduction

- Semi-automated process in MATLAB
  - Roadway area selected by user
  - Luminance data extracted for image + following images in sequence



Contrast Assessment

Color Camera Measurement System

- New High performing color cameras are now available.
  - USB 3.0 rather than FireWire
- Working on the calibration of a color camera for use in the instrumentation

Color Camera Measurement System

- Calibration
  - Color impressions change with the light source
    - LED versus HPS versus Incandescent
  - Similar calibration procedures as with the luminance camera but varying light source for validation

Links with Eye Glance Data

- Through the instrumentation and the eye glance data, we are able to assess:
  - Adaptation
  - Visual Behavior

Highway – Right Curve

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Luminance Camera Results

- The data collection method developed using the two camera system shows an adequate level of certainty in for both high and low ranges of the lighted environment.
  - Color Cameras are being assessed
- The camera has been integrated into the VTTI instrumentation system using an additional laptop and an Ethernet Link
  - Tighter integration is being worked on.