Glare Measurement with HDR Photography

Axel Jacobs
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Structure

- Intro
- Spatial Calibration
- Captured Range
- Lamp Flicker
- Vignetting
- RAW vs JPG
- White Balance
Introduction
Background

- Uni of Westminster: Identical IT labs, fitted with fluorescent, LED luminaires
- Q: Does one or the other type of fitting cause more glare?
Methodology

- HDR photographs with Nikon D200 and Sigma 4.5mm fisheye lens
- Same view points, camera positions in both IT labs
- Also measured: vertical illuminance at lens, luminance of test patch
Steps

- HDR sequence (tripod, AEB, tether)
- Pre-crop with ImageMagick
- `hdrgen` (exposure merge JPGs into HDR)
- `hdrexpo.pl` (apply calibration factor)
- `pcomb` (mask off circular image)
- `findglare`, `glarendx` (glare metrics)
- `falsecolor`, `xglaresrc` (images for report)
## Calibration Factor

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T5        | average | 1.298   |
|           | std dev  | 0.031   |

LED       | average | 1.492   |
|           | std dev  | 0.043   |
But wait...

How good are those UGR values? How accurate are HDRs?

The following pages show some of the results obtained from experiments involving 4000 JPG photographs, 2500 RAW photographs over the course of many months. This is work in progress. The images currently amount to 70 GB of data.
Spatial Calibration
Spatial Calibration

\[ UGR = 8 \log \left[ 0.25 \sum \frac{L^2 \omega}{p^2} \right] \]

- **Solid angle**
- **Guth position index**
Nodal Point

- Nodal point must be centre of camera rotation in later experiments
- Align two vertical objects or edges
- Nearby, faraway objects must not move relative to one another
- Move camera back, forward until good result
- Needed: tripod and sliding camera mount (mine was not very good)
Nodal Point

NP is somewhere between front of lens and front of barrel
Image Centre

Centre of fisheye is some 10..20 pixels off image centre. This is very likely camera-specific.
Projection

- Sigma claim their 4.5mm lens has an equi-solidangle projection
- But does it?
- Test:
  - Mount camera on motorised head with stepper motors (just over 16,000 steps per 360deg)
  - Rotate camera around nodal point
  - Take photograph of target every 5 degrees
  - Compare against known projections
Projection
Projection
Projection

- Lens projection is equi-solidangle
- Field of view is larger than 180deg
Projection

- planisphere
- Conformal
  - Stereographic
  - Orthographic

- Equiangular
- Equal Area
  - Lambert Azimuthal Equal Area
  - Azimuthal Equidistant

- Equidistant

- hemispherical
- Pictorial

http://www.geo.hunter.cuny.edu/~jochen
Captured Range
When deriving glare metrics from HDRs, the results are extremely sensitive to the accuracy of the highlights in the image. Make sure light sources are captured with sufficient EB range. WebHDR's heatmap shows regions in the image that are not accurately represented in the HDR. If there are any red pixels, re-shoot sequence with shorter exposure times.
WebHDR Tools

- Collection of Perl scripts for working with HDRs and EB JPG sequences
- Tidy up spaghetti code of WebHDR
- Soon to be released on JALOXA (only some web pages are missing)
- hdrcalib, jpgheatmap, jpgsep, rspplot, jpgfixexif, jpginfo, rspavrg
Lamp Flicker
Conventional Lamps

Lamp technology 1: From Tungsten to CFL
LED Lamps

Lamp technology 2: Modern LED lamps

LED replacement lamp

LED with separate driver (big brand)

LED with separate driver

Colour-tunable LED
Compact Digital Camera

100 photographs at 1/500 sec, taken with a Canon G12
Our Test Lamp
Sliding Window

- Move sliding window over measured waveform (1 second)
- Window width = shutter speed
- Take average over window
- Plot maximum error
Maximum modulation error is roughly the same as the modulation of the light source. BUT only for compact digital cameras!
Contact sheet 1/500, taken with D200 DSLR. Due to the sliding mechanical shutter, flicker response is even less predictable than with a digital compact camera.
Flicker is Evil!

- If you specify LED lighting, do look into flicker
- Some references:
  - Poplawski: CALiPER Exploratory Study Highlights: Flicker & Dimming (PDF)
  - IEEE PAR1789: "Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers" (Web site)
Vignetting
Vignetting

- HDRs from RAW
- 10 deg steps
- Light source masked and extracted
- Quality not very good (light source not uniform, not properly centred, no temperature stabilisation, no dark room)
- We can still get some valuable clues from these measurements
False Colour Patches

F 2.8
F 3.2
F 5.6
F 11
F 22
Vignetting

 Polynomial Approximation

• Vignetting is commonly described with a higher-order polynomial; even orders only to achieve symmetry
• A polynomial representation is also handy for correcting vignetting in Radiance
• Cauwerts et al did not carry out a polynomial fit
• There are lens databases (both free and commercial) that include vignetting data for specific photographic lenses in polynomial form
• Sigma 4.5mm lens vignetting is fairly flat for apertures F 5.6 or higher but shows a sharp drop-off above 80 degrees.
• Polynomial >6th order is needed.
Even Order Polynomials

$$y(x) = a + bx^2 + cx^4 + dx^6 + ex^8 + fx^{10} + gx^{12} + hx^{14} + ...$$
For F3.2, a second order seems to work well: $y = a + b \ x^2$
To be useful with Radiance, this should be normalised so that $y(0) = 1$. This would remove the constant 'a' from the polynomial equation. This is not done on this plot and the following ones.
The quality of the raw data does not allow to say with certainty whether the 'wings' at about 80 degrees are a real phenomenon. If they are not, we can try a polynomial with a single higher order coefficient: $y(x) = a + fx^{10}$
Vignetting

... but if the 'wings' are real, two higher orders will work better e.g. $y(x) = a + dx^6 + ex^8$ or possibly $y(x) = a + cx^4 + ex^8$
If all (even) orders are used in the regression analysis, we might end up with some 'wobbles' that are probably not very correct, either. Again, this largely depends on the quality of the raw data, which is not particularly good here. Maybe a regression analysis on good quality data does not require so much tinkering and guesswork.
RAW vs JPG
RAW vs JPG

- EB sequence in RAW and JPG with 1/3 EV steps (G12)
- Extract values of 10 pseudo-randomly sampled points
RAW vs JPG

From RAW

Pixel Brightness vs Exposure Value

Diagram showing the comparison of RAW vs JPG in terms of pixel brightness versus exposure value.
RAW vs JPG

Consistent kinks in all pixels for certain exposures might indicate that the shutter speed recorded in the EXIF info is slightly different to the actual shutter speed.
RAW vs JPG

\[ EV = \log_2 \left( \frac{\text{Aperture}^2}{\text{Shutter Speed}} \times \frac{\text{ISO}}{100} \right) \]

Exposure value is a log2 function. Let's plot against ShutterSpeed...
RAW vs JPG

Nice and linear pixel response. Results can be a bit weird near saturation point. Pixel values were averaged over 10x10 area to cut down on noise.
RAW vs JPG

Same plot, same pixels from JPG (G12). Notice two things:
• non-linear response
• bug in camera firmware or processor means that no pixel is brighter than 251 (should be 255)
RAW vs JPG

Same JPGs, same pixels, this time with RSP applied. Curves are much straighter, but not as good as from RAW. G12 bug shows up again.

Q: Just how good is the RSP?
If we use RAW as baseline, we can plot an X/Y diagram with the pixel grey values.
Now apply RSP to JPG. X/Y chart should show a perfectly straight line. This particular RSP over-compensates for the unknown camera transformations. There appears to be no reliable way of knowing whether an RSP is good. Use RAW for most accurate results.
Whitebalance
Area of Interest
Calibration Factors

Nikon D200 - Calibration Factor vs WhiteBalance (2,800K)

- CF derived
- CF fixed
RSP Polynomials
Results suggest that RSP is not only dependent on camera's WB setting, but also on the predominant light source. This is bad news because it leads to many different combinations of WB and CCT that need to be looked at.
Whitebalance

• Creating a good RSP requires a non-chromatic scene with smooth gradients, as well as a fixed camera WB. This is old news.

• It is not clear how a good RSP can be created reliably.

• A good way of testing an RSP seems to be to compare pixel values against RAW data. This is a little awkward since we are trying to avoid capturing RAW (very large files sizes)

• A JPG vs RAW X/Y plot can show the fitness of an RSP. It could also be used to create an accurate RSP.

• CF is often used as the only means of calibration when some of the photometric inaccuracy actually lies with an improper RSP.
Conclusions
Conclusions

- Some variables that impact upon the accuracy of HDR images created from EB sequences have been presented.
- Those variables fall into one of three categories:
  - Those that can be determined accurately and compensated for (vignetting).
  - Those that can be measured but not corrected (flicker modulation error).
  - Those that cannot be fully known (whitebalance).
Conclusions

• A motorised head is very handy to have.
• Not all of the equipment was up to scratch, e.g. the 'pano head' and the light source.
• Nevertheless, the experiments still give us a good idea about some (but not all) of the variables that affect the accuracy of HDR photographs.
• This is work-in-progress. More work (and thinking) is required...
Acknowledgements

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