Determining Lens Vignetting with HDR Techniques

Axel Jacobs
Low Energy Architecture Research Unit (LEARN)
London Metropolitan University
<a.jacobs@londonmet.ac.uk>

Bulgarian National Lighting Conference
Varna, 10–12 June 2007
High Dynamic Range Images

- Data is stored in photometric units, i.e. cd/m²
- Depending on image format, very large dynamic range, e.g. RADIANCE RGBE format: $10^{76}$ with 1% accuracy
- Inexpensive consumer digital camera can be used to measure luminance distribution
- Image calibration required. More calibration for higher accuracy...
Calibration

- LDR images
  - Response curve calibration
    - HDR image
      - Luminance calibration
        - photometrically correct HDR image
          - Spatial calibration
            - photometrically correct HDR image + Lens correction
HDR Images

WebHDR Luminance Map

Please read the text below the image before using the interactive luminance reader!

(219,29): L=44cd/m2

<table>
<thead>
<tr>
<th>cd/m2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1415.391</td>
</tr>
<tr>
<td>709.626</td>
</tr>
<tr>
<td>355.655</td>
</tr>
<tr>
<td>178.250</td>
</tr>
<tr>
<td>89.336</td>
</tr>
<tr>
<td>44.774</td>
</tr>
<tr>
<td>22.440</td>
</tr>
<tr>
<td>11.246</td>
</tr>
<tr>
<td>5.636</td>
</tr>
<tr>
<td>2.825</td>
</tr>
</tbody>
</table>
Vignetting

Source: wikipedia.org
Determining Vignetting

- Difficult to determine
- Option 1: Compute from a series of overlapping photographs
  - inaccurate
- Option 2: Compute from one photograph of an evenly lit wall
  - not suitable for fish-eye lenses, integrating spheres not widely available
- New approach: HDR and Pan-and-tilt head
CoolPix 990 with Fish-eye Lens
Motorised Pan-and-tilt Head
Software Control Panel

[Image of software control panel interface]

Resolution: Normal
Focus Mode: Normal
Aperture: 0
White Balance: Auto
Zoom: 10

Shutter Speed: 1/1000

Show Grid
Erase Last
Erase All
Download All

Take Snapshot

Query Camera

PhotoPC Control Panel for CoolPix 990

D:\axel\projects\labview\camera\lib>photopc -u shutter 8000
Starting in folder "\DCIM\100Nikon"
High-tech Light Source
Exposure-bracketed Sequence
Automated Image Capture

- 61 steps corner-to-corner
- Shutter speed from 1/1000 to 2 s (12 exposures)
- Resolution 2048 x 1532 pixels
- Full-frame fish-eye, no black border
- 61 x 12 = 732 images
- 750 MB in total
- HDR generation with `hdrgen` and `pfstools` for comparison
Photograph

Light Source

Photograph
False-colour HDR Image
Remove Hot Pixels

CoolPix990 Dark Noise (Fine 2048x1536)

Number of noisy pixels

Threshold [%]

1/971 sec
1/493 sec
1/248 sec
1/124 sec
1/60 sec
1/30 sec
1/15 sec
1/8 sec
1/4 sec
0.5 sec
1 sec
2 sec
4 sec
8 sec
Patch Luminance

- Patches are darker near the corner, brighter at the image centre
- Pixels below a certain threshold set to black so that only light source is left
- Pixels forming the light source are averaged
- Radius assumed zero at image centre, one at corner
- Plot source luminance against radius...
Images Thresholded

Detail
hdrgen vs pfshdrcalibrate
Vignetting

- Vignetting described with polynomial (even order only)
  \[ f(r) = a + b*r^2 + c*r^4 + d*r^6 \]

- Results from *hdrgen* and *pfsHDRcalibrate* match

- Additional absolute calibration of image luminance required

- Correction done with RADIANCE's *pcomb* program
Luminance vs Radius

Angular Intensity CoolPix990+FC-E8 (hdrgen)

Luminance [cd/m²]

Relative distance from centre

'angular_intensity.dat'
f(x) = a*x**2 + b
g(x) = c*x**4 + d*x**2 + e
h(x) = f*x**6 + g*x**4 + h*x**2 + i
Software

- WebHDR
  http://luminance.londonmet.ac.uk

- jpegpixi
  http://www.zero-based.org/software/jpegpixi/

- pfsHDRcalibrate
  http://www.mpi-inf.mpg.de/resources/hdr/calibration/pfs.html

- hdrgen
  http://www.anyhere.com

- RADIANCE
  http://radsite.lbl.gov/radiance/

Thank You