Vignette Calibration for Fisheye Lenses

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Overview

- Motivation
- Lenses and Camera Models
- Vignetting
- Vignette Calibration
- Results
- Conclusion

Motivation

- Cameras and lenses: important tool in computer vision
- High image accuracy necessary for reproducable results
- Fisheye lenses provide huge field of view
- Vignetting compromises brightness information in outer regions

- Solution: Software calibration
- Radial approach due to radial nature of camera models and lenses

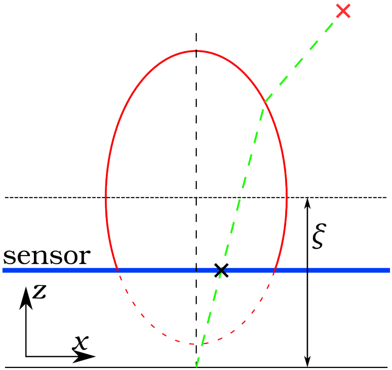
Fisheye Lenses

- Conventional lenses: small opening angle $\rightarrow$ small field of view
- Higher field of view $\rightarrow$ beneficial for motion tracking
- Development of lenses with field of view $> 180^\circ$
- "Fisheye lens" due to distortion similarity compared to a fish's eyes

Fisheye lens, image from `wikimedia.org` under CC license

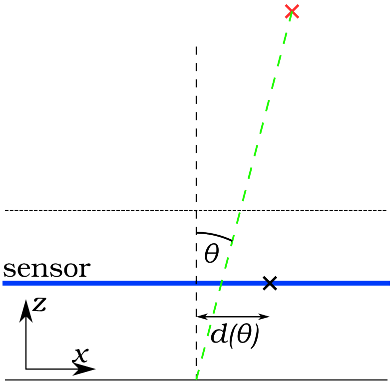
Camera Models: Extended Unified Camera Model

- Conventional camera model: pinhole
- Pinhole model insufficient for fisheye lenses
- Model suited for angles higher then 180° → Extended Unified Camera Model (2 additional parameters)



Camera Models: Kannala-Brandt Camera Model

- More complex model with 4 additional parameters
- Assumption: Distance between image center and projected point $\propto$ polynomial $d(\theta)$, θ: angle of incident ray to optical axis
- $d(\theta) = \theta + k_1\theta^3 + k_2\theta^5 + k_3\theta^7 + k_4\theta^9$



Vignetting

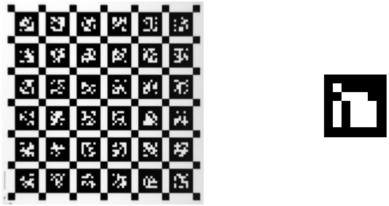
- Vignetting: light attenuation in edge regions
- Cause: Beam of light rays hitting some lenses in lens systems only partially
- Imaging model:

$$I(\boldsymbol{x}) = G(B(\boldsymbol{x})V(\boldsymbol{x})t) \tag{1}$$

- I: observed pixel value, G: camera response function, B: irradiance image, V: vignetting attenuation, t: exposure time
- B and V only known up to a scalar factor.

Vignette Calibration

- First step: record image sequences with AR markers on flat surface



AR markers; April (left), Aruco (right)

- Retrieve camera parameters via UPnP

Vignette Calibration

- Only well defined area around the markers taken for calibration

- With inverse response function $U = G^{-1}$, and C: surface irradiance, π_i: projection 3D→2D, formulate Maximum-Likelihood-Energy E:

$$E(C, V) = \sum_{i,\boldsymbol{x}\in\mathcal{S}} \left(t_i V\left(\pi_i(\boldsymbol{x})\right) C(\boldsymbol{x}) - U\left(I_i(\pi_i(\boldsymbol{x}))\right)\right)^2. \qquad (2)$$

Vignette Calibration

- Optimize $E(C, V)$ alternatingly, fixing one of the variables

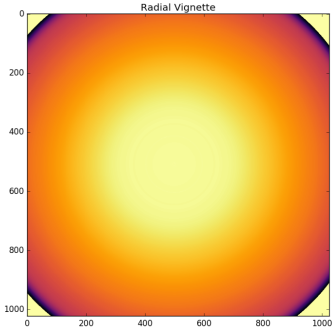
$$C^*(\boldsymbol{x}) = \operatorname*{arg\,min}_{C(\boldsymbol{x})} E(C, V) = \frac{\sum_i tV\left(\pi_i(\boldsymbol{x})\right) U\left(I_i(\pi_i(\boldsymbol{x}))\right)}{\sum_i \left(tV(\pi_i(\boldsymbol{x}))\right)^2}, \tag{3}$$

  and V in the same manner

- Radial Approach: $V(\boldsymbol{x}) \rightarrow V(r)$

Vignette Calibration

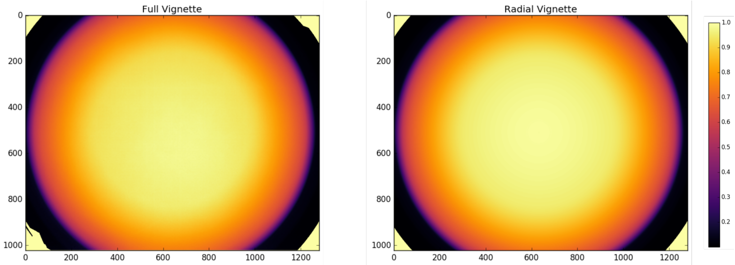
- Reconstructed surface and vignette:



- Further step: compare full (dense) model with radial one via 360 degree cuts

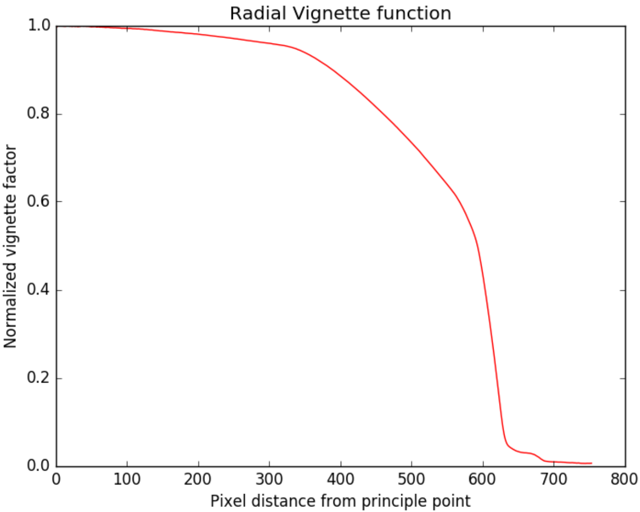
Results

- Huge datasets under ideal conditions:



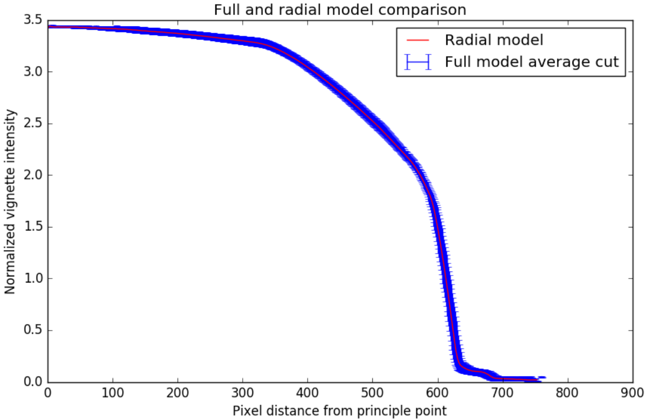
Comparison between full model (left) and radial model (right). False colors for better visualisation of graduations.

Results



Radial vignette function of the vignette shown on the previous slide

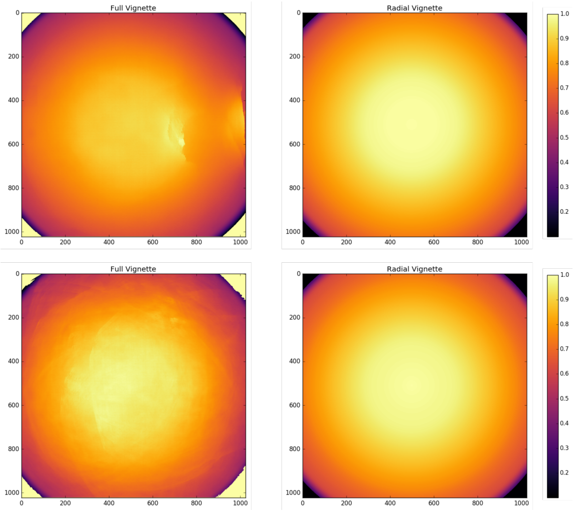
Results



Comparison between full model (averaged) and radial model

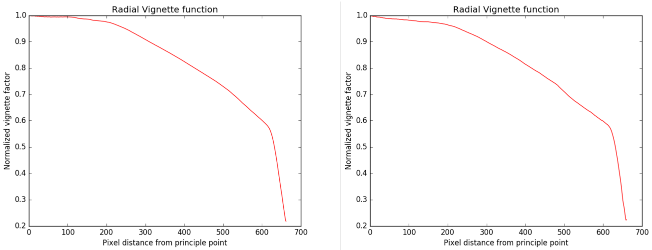
Results

- Datasets with less usable data points:



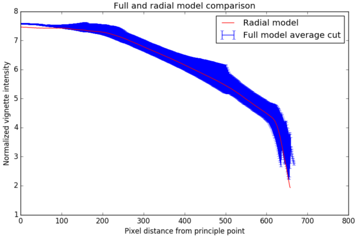
Comparison between full model (left) and radial model (right). False colors for better visualisation of graduations.

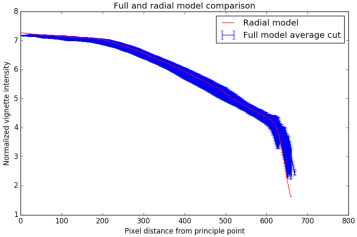
Results



Radial vignette functions of the vignettes shown on the previous slide

Results

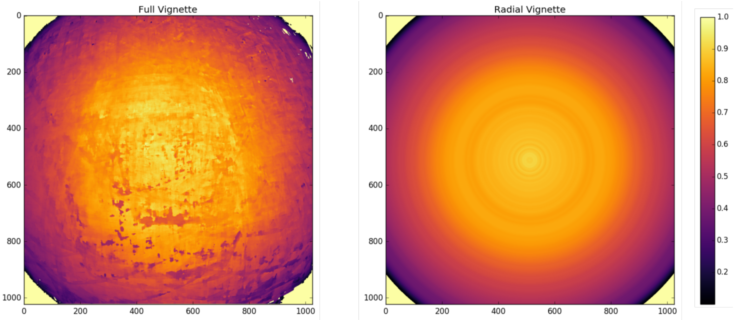




Comparison between full model (averaged) and radial model

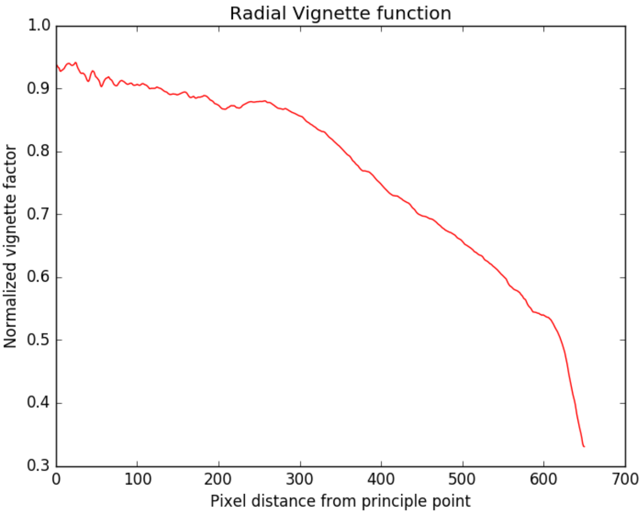
Results

- Dataset with few usable datapoints:



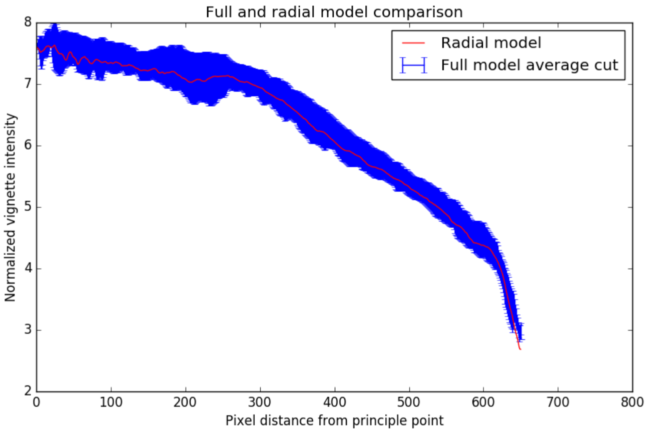
Comparison between full model (left) and radial model (right). False colors for better visualisation of graduations.

Results



Radial vignette function of the vignette shown on the previous slide

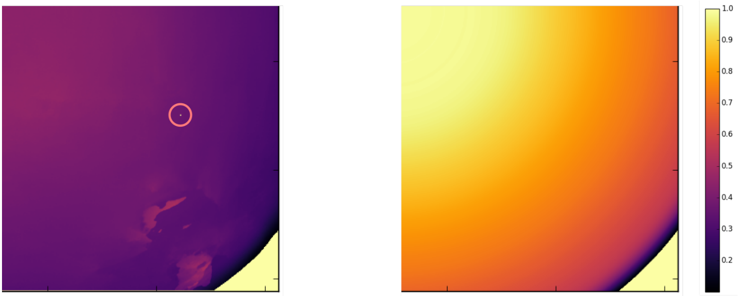
Results



Comparison between full model (averaged) and radial model

Results

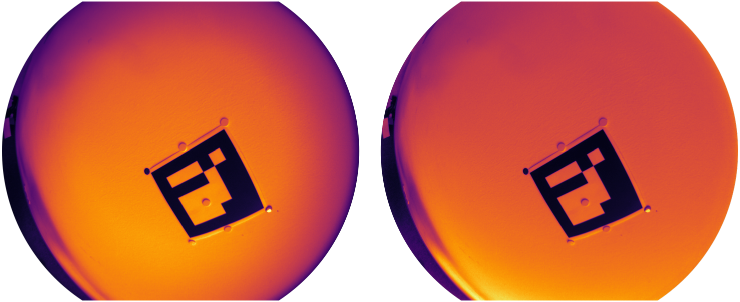
- Local anomalies are averaged out by the radial approach:



Local inconsistency in the full approach (left) removed in the radial approach (right)

Results

- Applying the calibrated vignette to one of the images from the sequence:



Comparison of original and vignette calibrated image in false colors. The right picture shows a much more uniform distribution over the flat wall's surface.

Conclusion

- Issues that arose:
  - Reflection on markers/surfaces
  - Lensflares
  - Shadows from camera/handler
  - Desyncronized flickering from artificial light source (flourescent tube)
- Results from radial model in good accordance to full vignette model
- Radial model less prone to inconsistencies and lack of data

Possible further work: Parametrization of radial function $\rightarrow$ increased robustness at cost of degrees of freedom.