NON-PARAMETRIC SUB-PIXEL LOCAL PSF ESTIMATION

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Overview

- We prove formally that the non-parametric sub-pixel point spread function (PSF) estimation problem is well-posed with a single well chosen observation.
- Near-optimal accuracy achieved with a Bernoulli(0.5) noise calibration pattern.
- Local PSF estimated by solving a well conditioned linear system that does not require regularizers.
- Relative estimation error of 2% to 5%.
- Such a regularization and model free subpixel PSF estimation scheme is the first of its kind, to our knowledge.

Motivation

Image blur can be a consequence of :

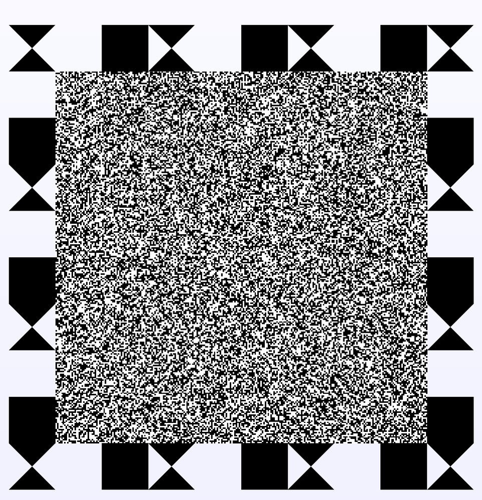
- Camera misusing or scene configuration
  - Wrongly setting the camera focus
  - Only an specific interval of depths in focus
  - Camera shake
  - Scene motion
- Physical camera phenomena
  - Light diffraction
  - Sensor averaging
  - Lens aberrations
  - Optical anti-aliasing filter

Our Goal
Accurately estimate a function, called point spread function -PSF, that models the blur due to intrinsic camera phenomena. Image ideally obtained from a null-area point light source (impulse response).

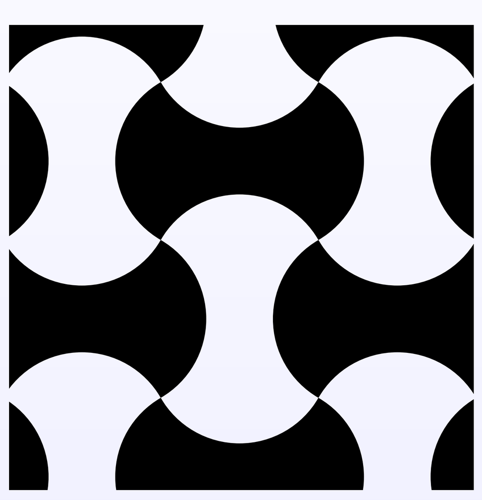
Difficulties
Most medium to high quality digital cameras (DSLR) acquire images at a spatial rate which is below the ideal Nyquist rate. Only aliased versions of the cameral point-spread function (PSF) can be directly observed.

Our Approach

- Non-parametric non-blind local subpixel PSF estimation.
- Noise target specially designed for PSF estimation. (local blur information)



Proposed



Joshi et al. ("knife-edge") [2]

Mathematical Formulation

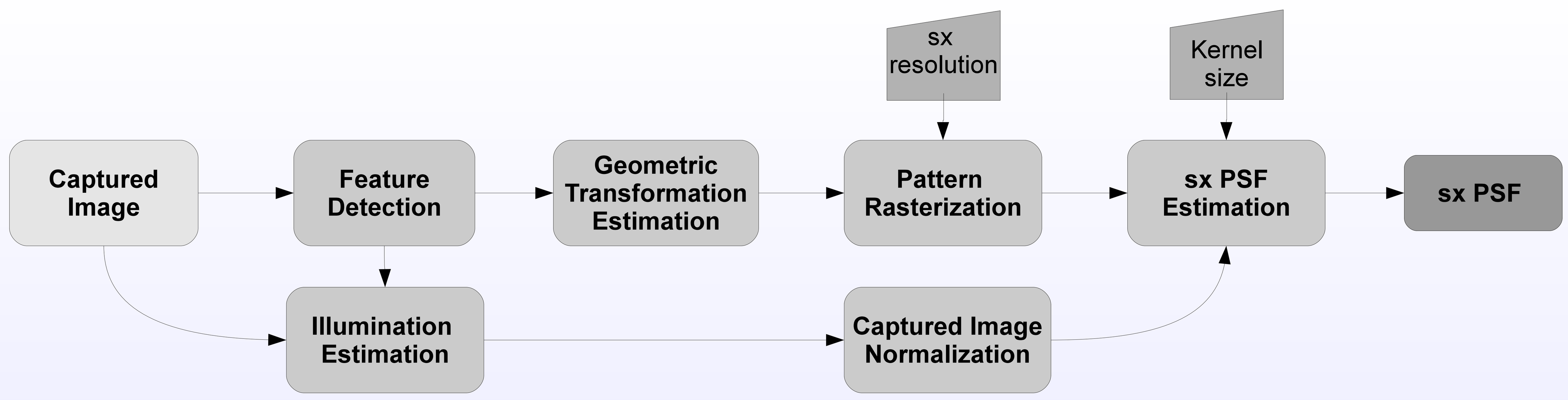
- Solve inverse problem
- Extremely weak a priori assumption: small spatial support of the PSF. No regularization term needs to be added to the forward problem.
- Estimate $\mathbf{h}$: samples of h at a rate $\delta\times$ higher than the camera sampling (e.g $4\times$)

Choose $\mathbf{h}$ to minimize the functional:

$$\arg\min_{\mathbf{h}} \|\mathcal{S}_\delta\left(\tilde{\mathbf{u}}_D * \mathbf{h}\right) - \mathbf{v}\|^2 \quad \text{s.t. } \mathbf{h} \geq 0$$

- $\tilde{\mathbf{u}}_D$ HR sharp distorted pattern image
- $\mathbf{v}$ blurred LR observed image ($1\times$).
- $\mathbf{h}$ discrete HR PSF - can be spatial variant (strictly not a convolution).
- $\mathcal{S}_\delta$: Subsampling operator: takes HR and generates LR

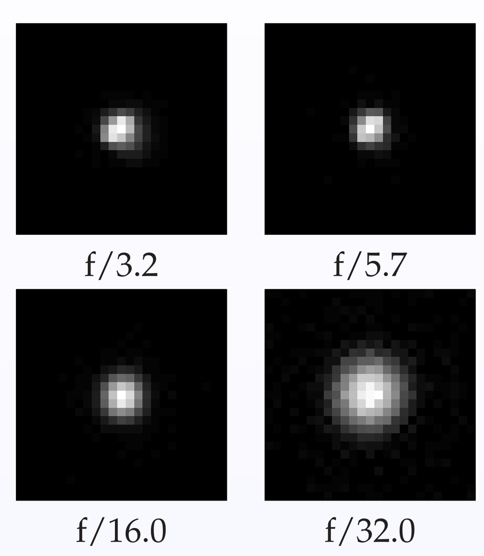
Algorithm Description

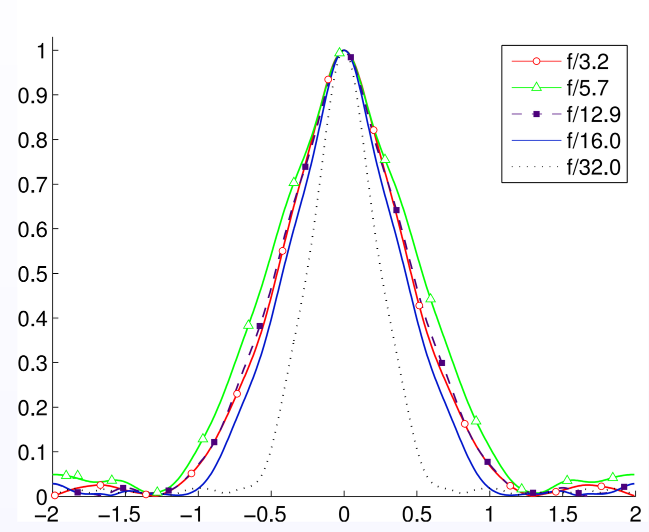


Results: Real camera examples

Canon EOS 400D - Tamron AF 17-50mm F/2.8 XR Di-II lens. Taken at 100 ISO, 50mm
RAW Green channel (half), $4\times$ estimation.

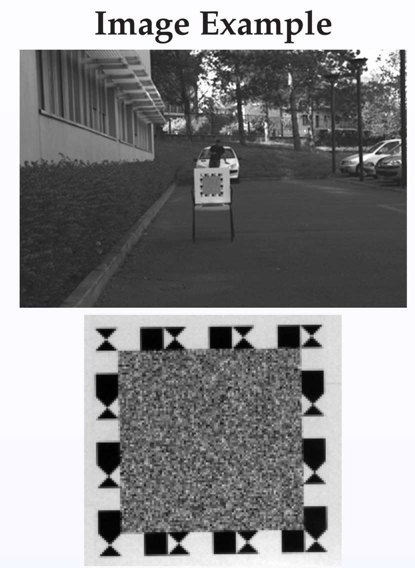
Different Apertures





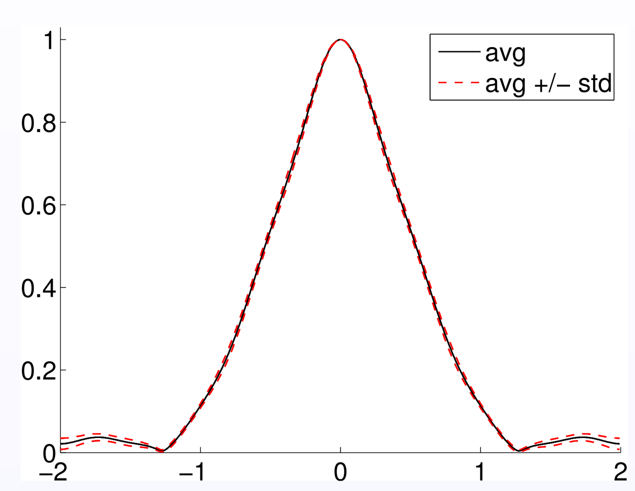
Horizontal profile MTF $= |\mathbf{F}\ (\text{PSF})|$

Image Example



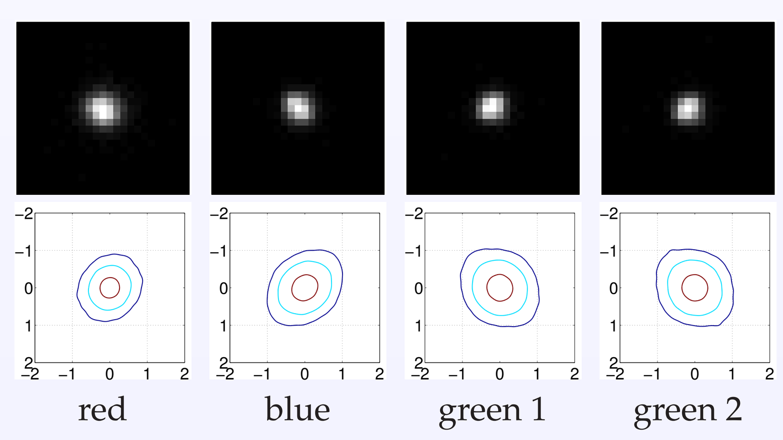
Observed pattern
110×110 pixels

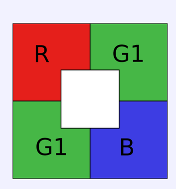
Stability



Average and standard deviation images from 13 estimations

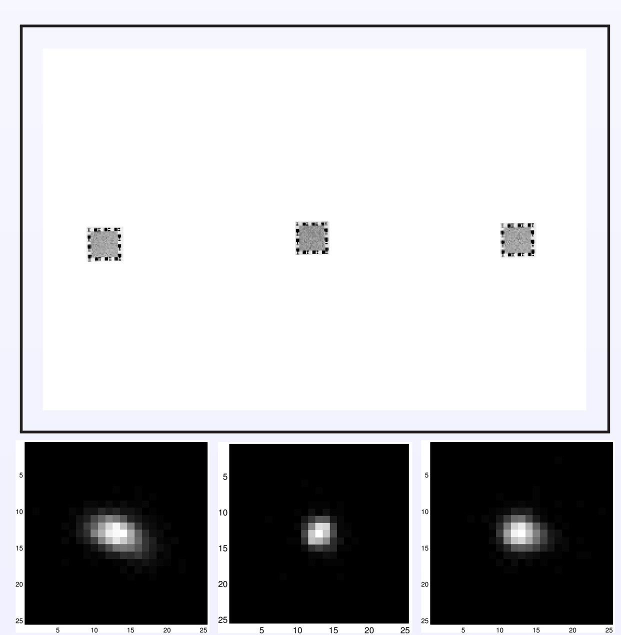
Color Estimation Bayer RAW camera output





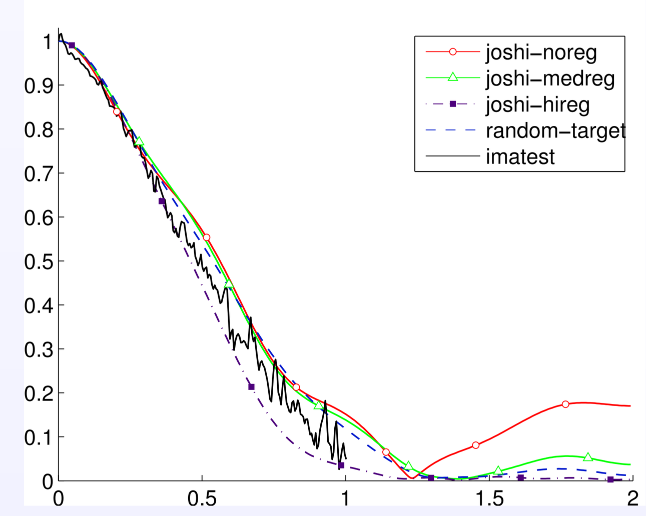
Active Area L-shaped

Different Locations



Lens aberrations in image borders.

Comparison of several methods



Joshi et al. (non-blind), Imatest and Proposed
LF: all algorithms very similar
HF: Joshi estimation depends on regularization level

DEMO & References

Test it online IPOL: Image Processing On Line
`http://www.ipol.im/pub/algo/admm_non_blind_psf_estimation/`

[1] Delbracio M., Musé P., Almansa A., Morel JM. The non-parametric sub-pixel local point spread function estimation is a well posed problem, to appear in *IJCV*, 2011

[2] Joshi N., Szeliski R., Kriegman DJ. PSF estimation using sharp edge prediction. in *CVPR*, 2008