Optimising Aperture Shapes for Depth Estimation

- Anita Sellent, Paolo Favaro -
Institut für Informatik und angewandte Mathematik, Universität Bern, Schweiz

Depth from Defocus Blur

- Texture-Blur Ambiguity
  - two focus settings

  - two different aperture codes [3]

- Which aperture shapes are best?

Mask Optimization Criterion

- Maximize difference between blurred images of different depth levels

$$max_{\alpha,\beta} \left\| \begin{bmatrix} f_\alpha^{s_1} \\ f_\beta^{s_2} \end{bmatrix} - \begin{bmatrix} f_\alpha^{t_1} \\ f_\beta^{t_2} \end{bmatrix} \right\|_2^2$$

- Consider normalized images

$$\alpha_i \in [0,1] \quad \Sigma_i \alpha_i = 1$$

- Require open apertures

$$min_{\Sigma_i \alpha_i = 1} \ \lambda \|\alpha\|_2^2$$

- Solve quadratic problem efficiently [2]
  - MATLAB implementation on 2.95 GHz quad-core computer
  - 0.09 s for 11x11 depth from defocus mask
  - 2.40 s for 11x11 coded aperture pair

References

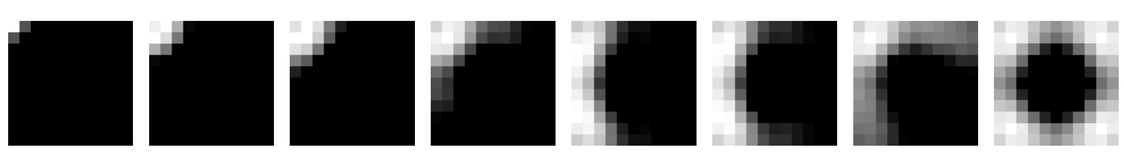
[1] P. Favaro, S. Soatto.: A geometric approach to shape from defocus. In T-PAMI 2005

[2] P. Gill, W. Murray, M. Saunders, M. Wright: Procedures for optimization problems with a mixture of bounds and general linear constraints. In TOMS 1984

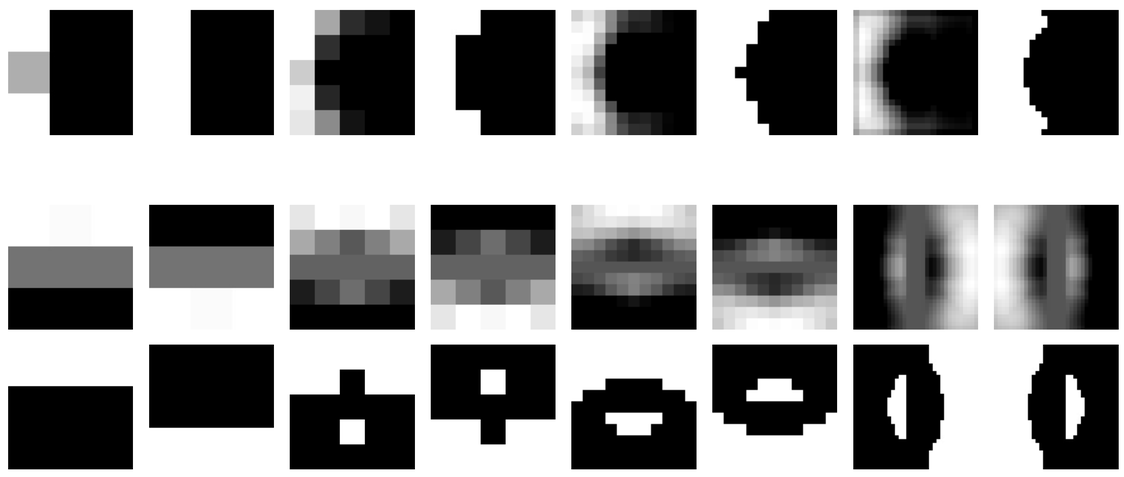
[3] C. Zhou, S. Lin, S. Nayar: Coded aperture pairs for depth from defocus. In Proc. ICCV 2009

Optimized Masks

- Masks depend continuously on parameter λ



- Increased resolution allows for smoother masks

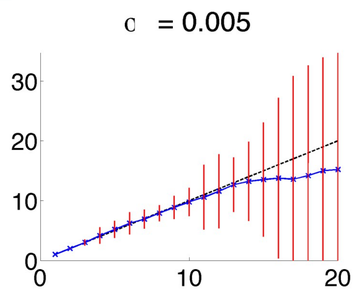


Depth Estimation

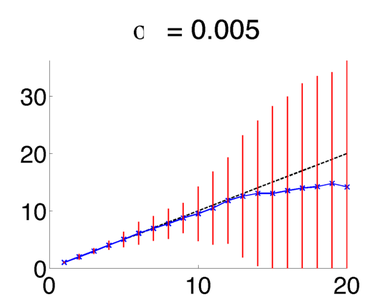
- Mask indifferent depth estimation algorithm [1] with constant parameters
- Optimized aperture shapes obtain more accurate depth estimates also on images with proportionally added noise

Depth from Defocus (depth estimation error)										
		3x3		5x5		11x11		21x21		full
Values	λ=0	cont	{0,1}	cont	{0,1}	cont	{0,1}	cont	{0,1}	{0,1}
σ = 0.000	0.30	0.30	0.30	0.25	0.22	0.26	0.26	0.24	0.20	1.02
σ = 0.001	0.38	0.31	0.31	0.27	0.23	0.28	0.28	0.26	0.22	1.02
σ = 0.005	6.52	1.15	0.92	1.61	1.08	1.37	0.91	1.69	0.88	1.31

Depth from Coded Aperture Pairs (depth estimation error)									
	3x3		5x5		11x11		33x33		
Values	cont	{0,1}	cont	{0,1}	cont	{0,1}	cont	{0,1}	Zhou
σ = 0.000	0.05	0.04	0.05	0.10	0.09	0.06	0.02	0.03	0.09
σ = 0.001	0.18	0.08	0.27	0.12	0.45	0.08	0.19	0.05	0.12
σ = 0.005	29.53	26.27	39.98	8.72	37.03	11.87	30.84	9.83	11.36



Our optimised mask



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