Image Deblurring Using Robust Sparsity Priors

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Motion blur?

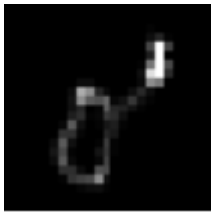
Motion blur model

Blurred image

=

Sharp image

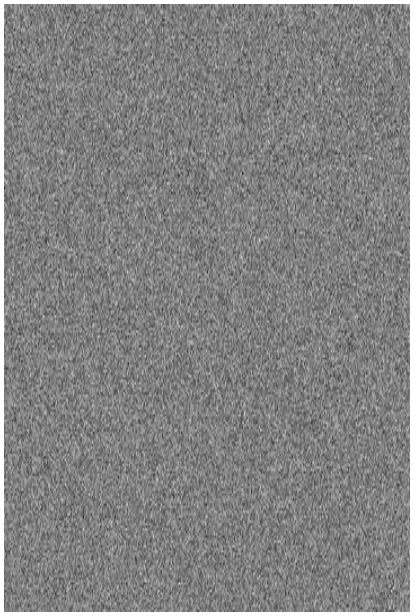
⊗



Blur kernel

Convolution operator

+



Noise

$$I = L \otimes k + N$$

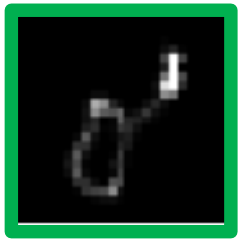
Motion blur model

Blurred image

=

Sharp image

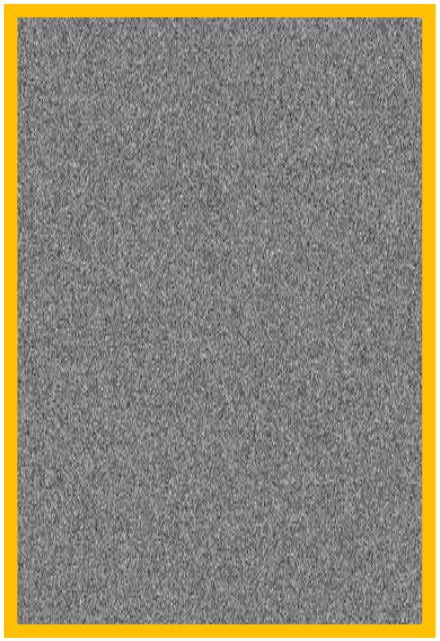
$\otimes$



Convolution operator

Blur kernel

+



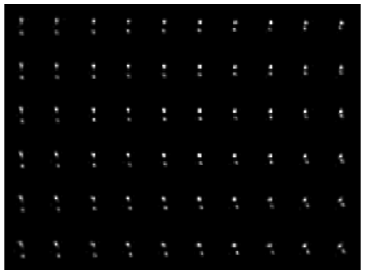
Noise

$$I = L \otimes k + N$$

Overview

- Related work
- The problem
- Robust blur kernel estimation
- Final latent image reconstruction
- Results
- Conclusion & Contributions

Related work



Non-uniform deblurring

Uniform deblurring

Deconvolution

~1970s

2006
Fergus *et al.*

2007
Jia *et al.*

Shan *et al.*

2008
Shan *et al.*

Tai *et al.*

2009
Levin *et al.*
Cho & Lee

2010
Xu & Jia

Joshi *et al.*
Gupta et al.

2011
Whyte *et al.*

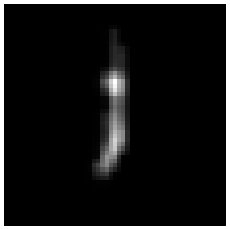
Hirsh *et al.*
Tai *et al.*

2012
Cho *et al.*

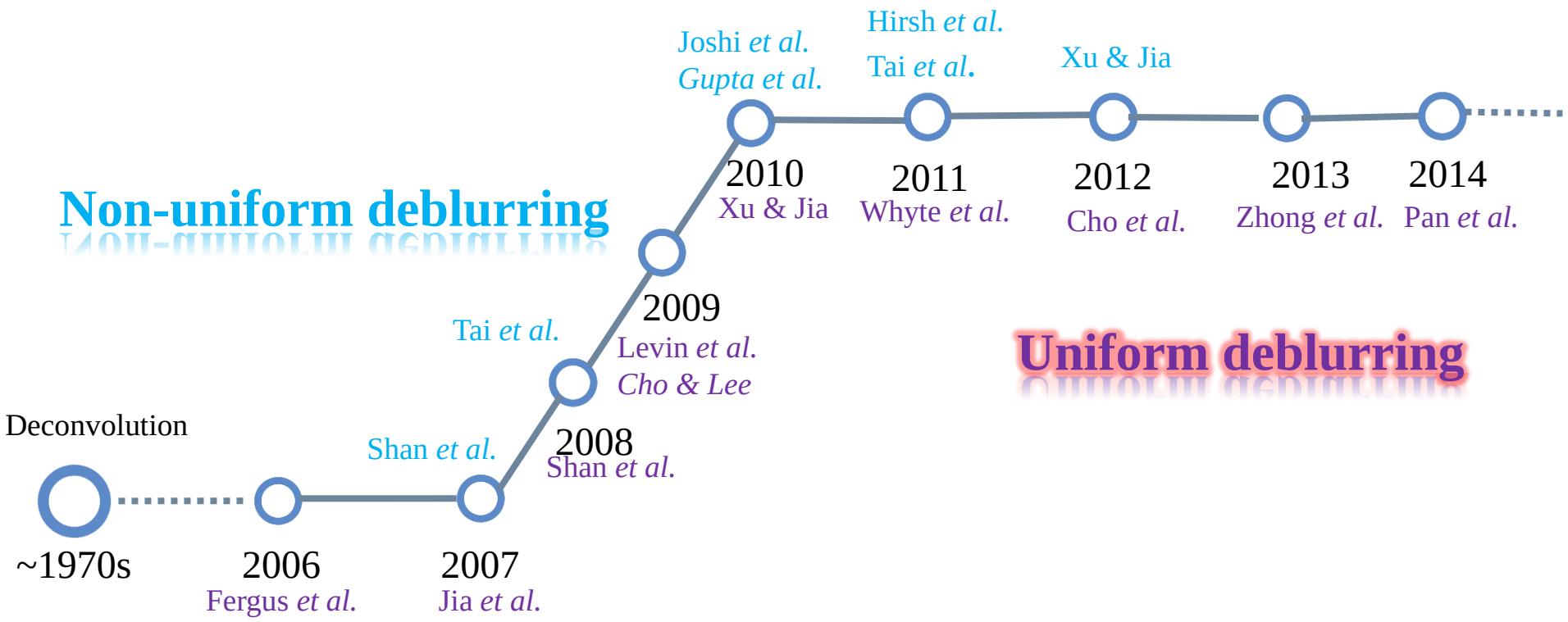
Xu & Jia

2013
Zhong *et al.*

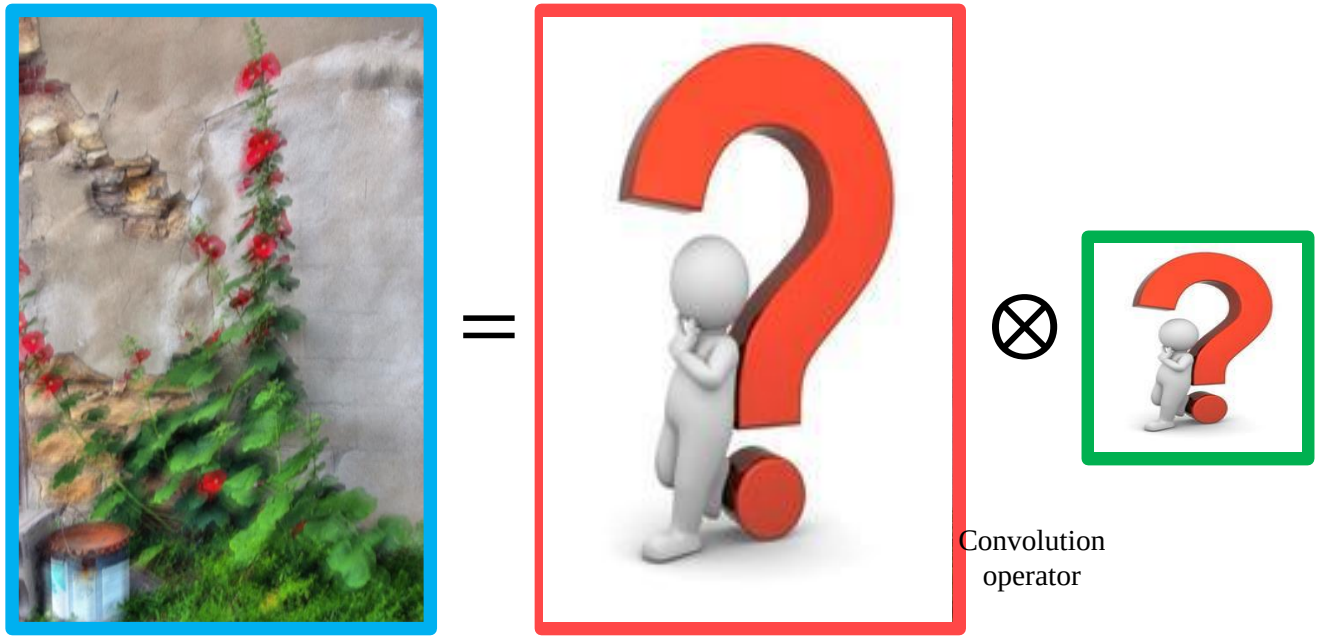
2014
Pan *et al.*



Related work



The problem



Convolution operator

Blurred image | Sharp image | Blur kernel

An ill-posed problem!

$$I = L \otimes k$$

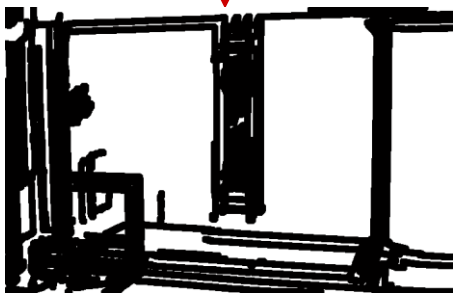
Priors

Motion deblurring

- Optimize L and k iteratively
  - Intermediate latent image estimation
  - Kernel estimation via salient edges
- Non-blind deconvolution

Intermediate latent image estimation

$$min\|L \otimes k - I\|_2^2 + \lambda_1 \|\nabla L\|^{0.5} \circ M + \lambda_1 \|\nabla L\|_2^2 \circ (J - M)$$



Kernel estimation via salient edges

Salient edge selection

- Relative Total Variation (RTV)

Iteration 1 Iteration 2 Iteration 3 Iterations Iteration n-1 Iteration n

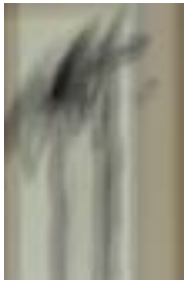
S 

Kernel estimation

$$min\|\nabla S \otimes \mathrm{k} - \nabla \mathrm{I}\|_2^2 + \gamma_1\|k\|_2^2 + \gamma_2\|\nabla k\|_2^2$$

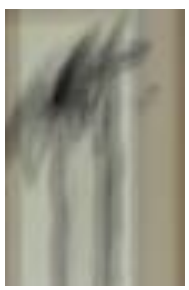
Kernel estimation via salient edges

- Kernel estimation
- $\min \|\nabla S \otimes \mathrm{k} - \nabla \mathrm{I}\|_2^2 + \gamma_1 \|k\|_2^2$



Kernel estimation via salient edges

- Kernel estimation
- $\min \|\nabla S \otimes \mathrm{k} - \nabla \mathrm{I}\|_2^2 + \gamma_1 \|k\|_2^2 + \gamma_2 \|\nabla k\|_2^2$



Final latent image reconstruction

- Non-blind deconvolution
  - Hyper-Laplacian model

$$\min_{L_1} \|L_1 \otimes k - \widetilde{I}\|_2^2 + \rho \|\nabla L_1\|^{\alpha}$$

  - TV-l_2 model

$$\min_{L_2} \|L_2 \otimes k - \widetilde{I}\|_2^2 + \mu \|L_2\|_{TV}$$

$$\|L_2\|_{TV} = \sqrt{(\partial_x L_2)^2 + (\partial_y L_2)^2}$$

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- Non-blind deconvolution
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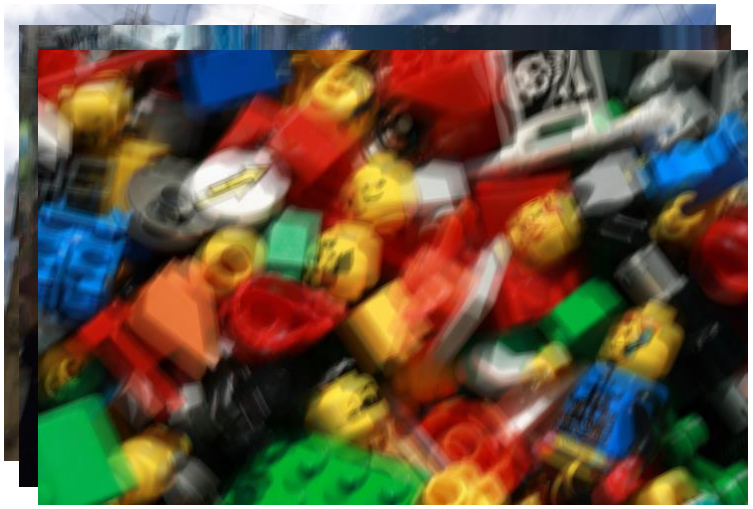
Results

- Objective evaluation on the synthetical dataset

40 sharp images



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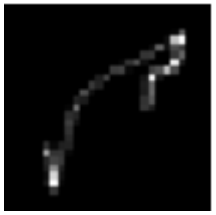
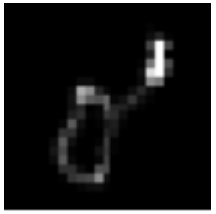
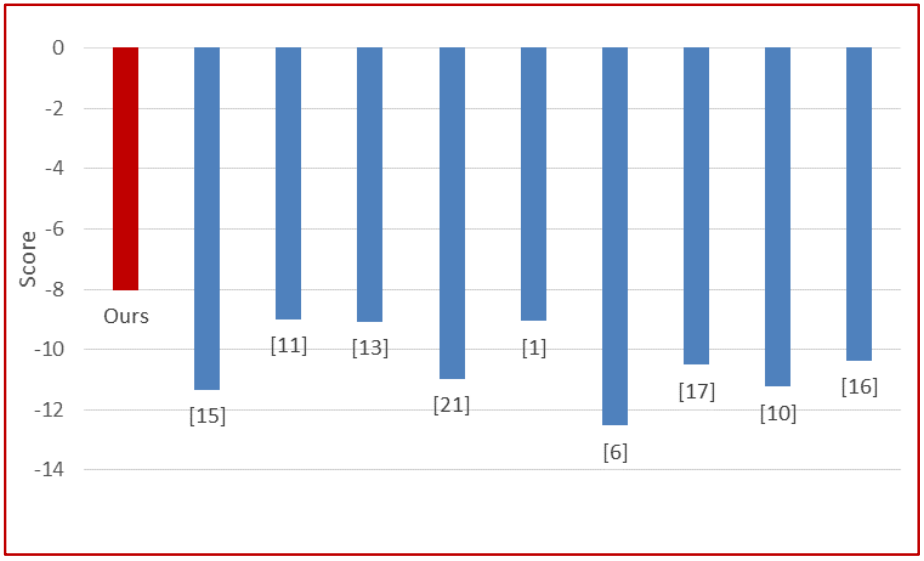


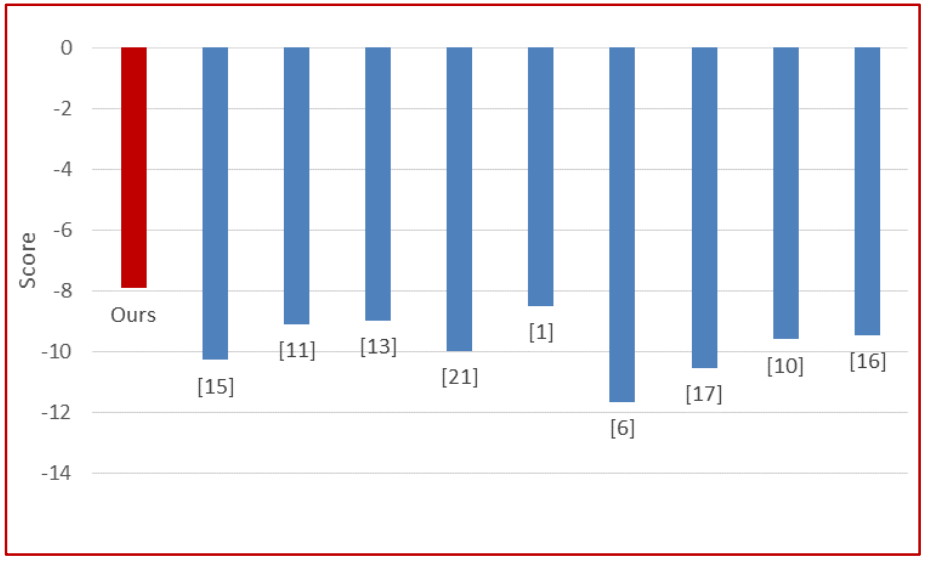
kernel 1



kernel 2



Average scores of results from images blurred with kernel 1



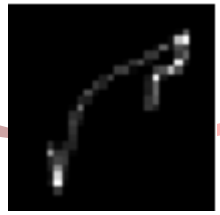
Average scores of results from images blurred with kernel 2

Results

- Objective evaluation on the synthetical dataset

Ground truth

Blurred image




-13.473
Cho and Lee SIGGRAPH Asia 2009


-10.708
Xu and Jia ECCV 2010


-10.634
Xu *et al.* CVPR 2013


-11.124
Zhong *et al.* CVPR 2013


-10.266
Pan *et al.* CVPR 2014


-13.326
Fergus *et al.* SIGGRAPH 2006

Results

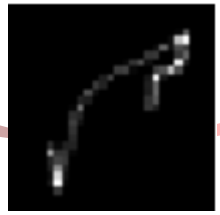
- Objective evaluation on the synthetic dataset

Results

- Objective evaluation on the synthetic dataset

Ground truth

Blurred image




-10.817
Cho and Lee SIGGRAPH Asia 2009


-8.893
Xu and Jia ECCV 2010


-8.994
Xu *et al.* CVPR 2013


-12.132
Zhong *et al.* CVPR 2013


-13.441
Pan *et al.* CVPR 2014


-12.418
Fergus *et al.* SIGGRAPH 2006

Results

- Objective evaluation on the synthetic dataset

Results

- Subjective evaluation on synthetic blurred images

Ground truth

Blurred image

Results

- Subjective evaluation on synthetic blurred images

Results

- Subjective evaluation on synthetic blurred images

Results

- Subjective evaluation on real blurred images


Blurred image


Cho and Lee SIGGRAPH Asia 2009


Xu and Jia ECCV 2010


Xu *et al.* CVPR 2013


Zhong *et al.* CVPR 2013


Pan *et al.* CVPR 2014

Results

- Subjective evaluation on real blurred images

Results

- Subjective evaluation on real blurred images

Blurred image

Cho and Lee SIGGRAPH Asia 2009

Xu and Jia ECCV 2010

Xu *et al.* CVPR 2013

Zhong *et al.* CVPR 2013

Pan *et al.* CVPR 2014

Results

- Subjective evaluation on real blurred images

Fergus *et al.* SIGGRAPH 2006

Shan *et al.* SIGGRAPH 2008

Krishnan *et al.* CVPR 2011

Pan and Liu
Signal Processing: Image Communication 2013

Ours

Conclusion & Contributions

- Robust sparsity priors
  - A mask is used to distinguish between the edge and smooth regions
  - Adopted an adaptive salient edge selection method
  - A gradient sparsity prior is used in kernel estimation model
- Final latent image reconstruction
  - Combination of the hyper-Laplacian model with the TV-l_2 model

THANK YOU