Blind Image Deblurring Using Dark Channel Prior

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Their Work

- Dark channel prior
- Theoretical analysis
- Applications

Dark channel [He et al., CVPR 2009]

$$D(I)(x) = \min_{y \in N(x)} \left(\sum_{c \in \{r,g,b\}} I^c(y) \right)$$

- Compute the minimum intensity in a patch of an image

- Our model
  - Add the dark channel prior into standard deblurring model

$$\min_{I,k} \| I * k - B \|_2^2 + \gamma \| k \|_2^2 + \mu \| \nabla I \|_0 + \lambda \| D(I) \|_0$$

  - How to solve?
    - L0 norm and non-linear min operator

- Algorithm skeleton

$$\min_{k} \| I * k - B \|_2^2 + \gamma \| k \|_2^2$$

$$\min_{I} \| I * k - B \|_2^2 + \mu \| \nabla I \|_0 + \lambda \| D(I) \|_0$$

  - L0 norm
    - Half-quadratic splitting method
  - Non-linear min operator
    - Linear approximation

Optimization

- Update latent image I:

$$\min_{I} \| I * k - B \|_2^2 + \mu \| \nabla I \|_0 + \lambda \| D(I) \|_0$$

Half-quadratic splitting [Xu et al., SIGGRAPH Asia 2011, Pan et al., CVPR 2014]

$$\min_{I,u,g} \| I * k - B \|_2^2 + \alpha \| \nabla I - g \|_2^2 + \beta \| D(I) - u \|_2^2 + \mu \| g \|_0 + \lambda \| u \|_0$$

- Update latent image I:
  - I sub-problem

min operator

$$\min_I \| I * k - B \|_2^2 + \beta \| D(I) - u \|^2 + \mu \| \nabla I - g \|^2$$

  - Our observation

$$D(I) = \mathrm{MI}$$

    - Let $y = \mathrm{argmin}_{z \in N(x)} I(z)$, we have

$$\mathrm{M}(x, z) = \begin{cases} 1, & z = y, \\ 0, & \text{otherwise.} \end{cases}$$

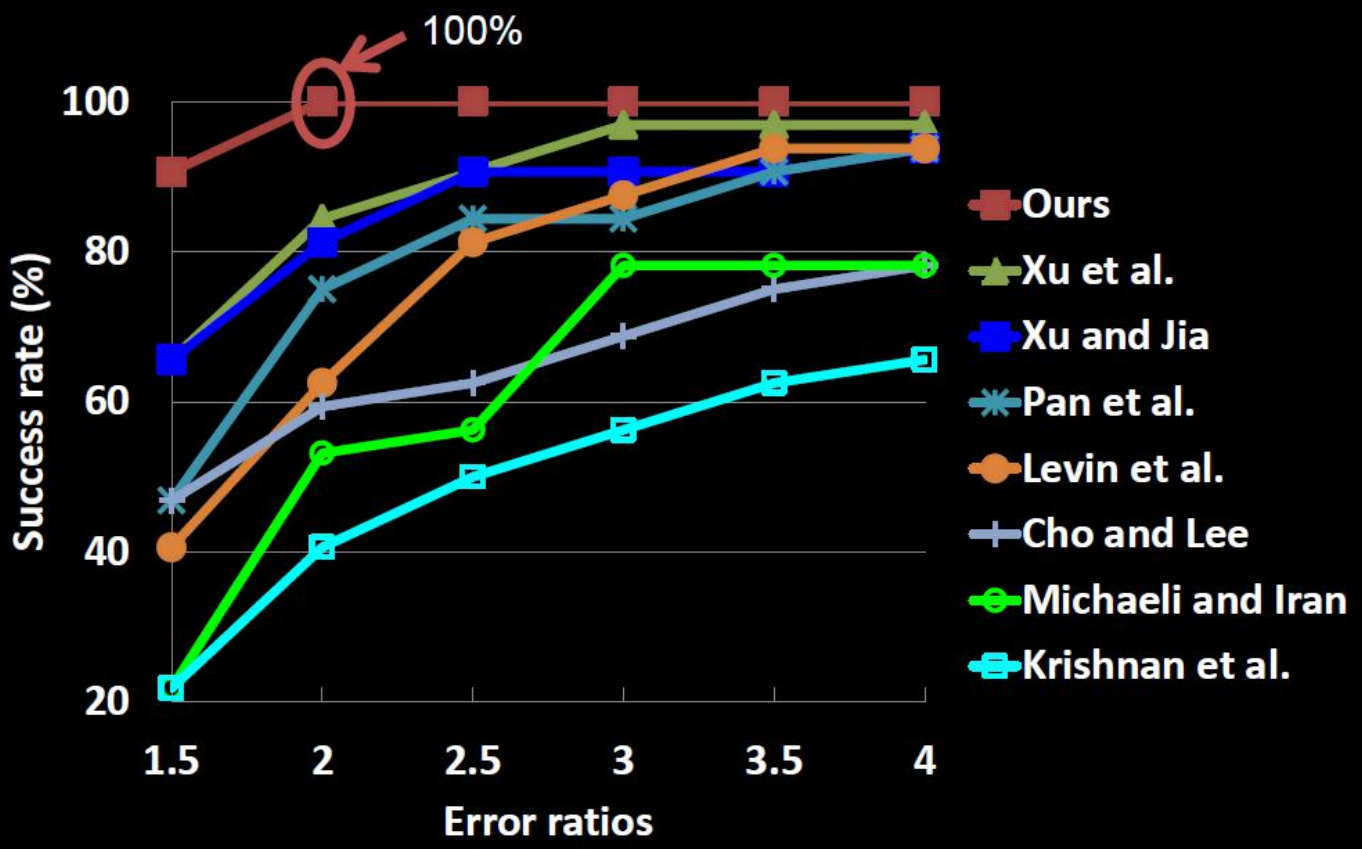
Experimental Results

- Natural image deblurring
- Specific scenes
  - Text images
  - Face images
  - Low-light images
- Non-uniform image deblurring

Natural Image Deblurring Results

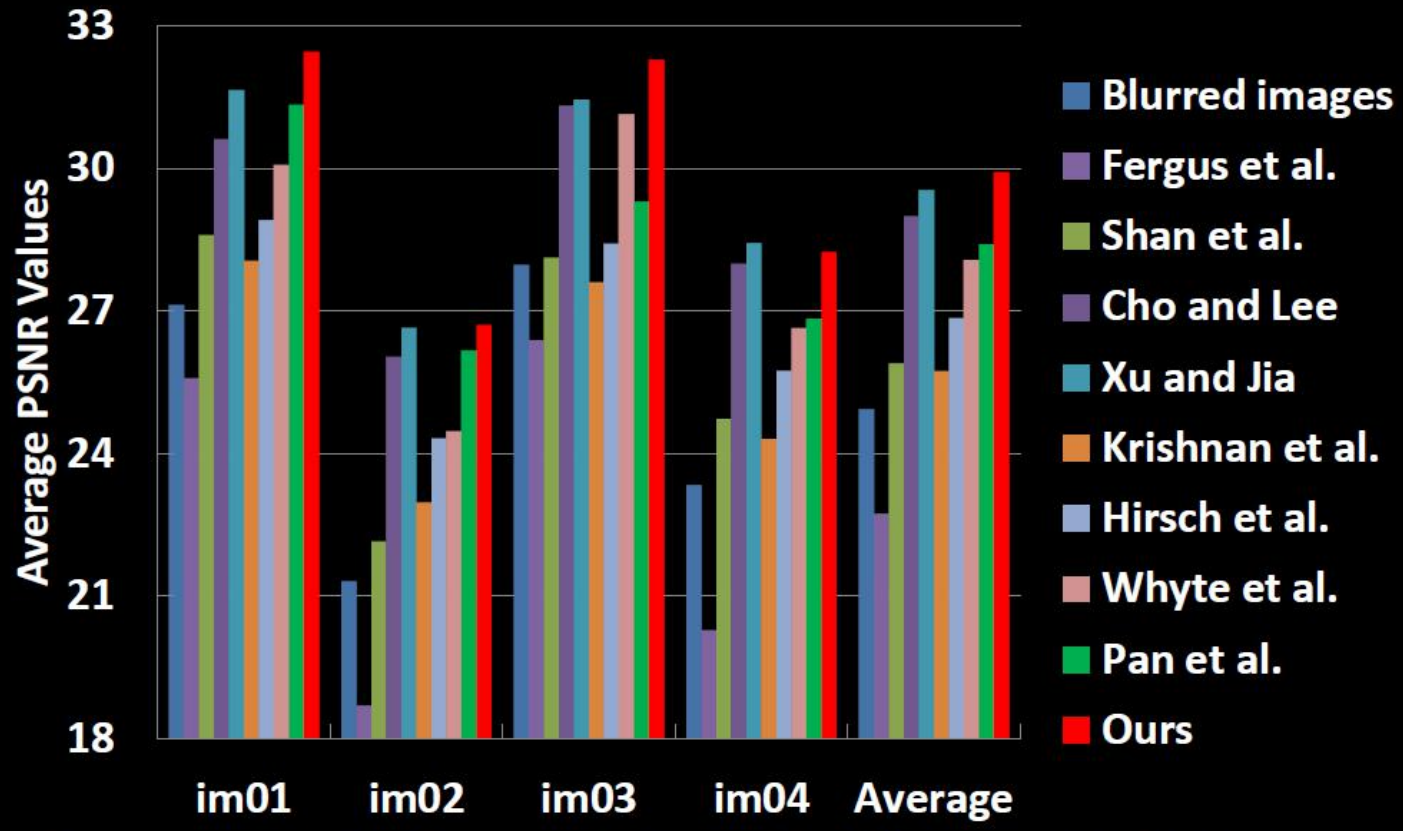
- Quantitative evaluation
  - Levin et al., CVPR 2009
  - Köhler et al. ECCV 2012
  - Sun et al., ICCP 2013

Natural Image Deblurring Results



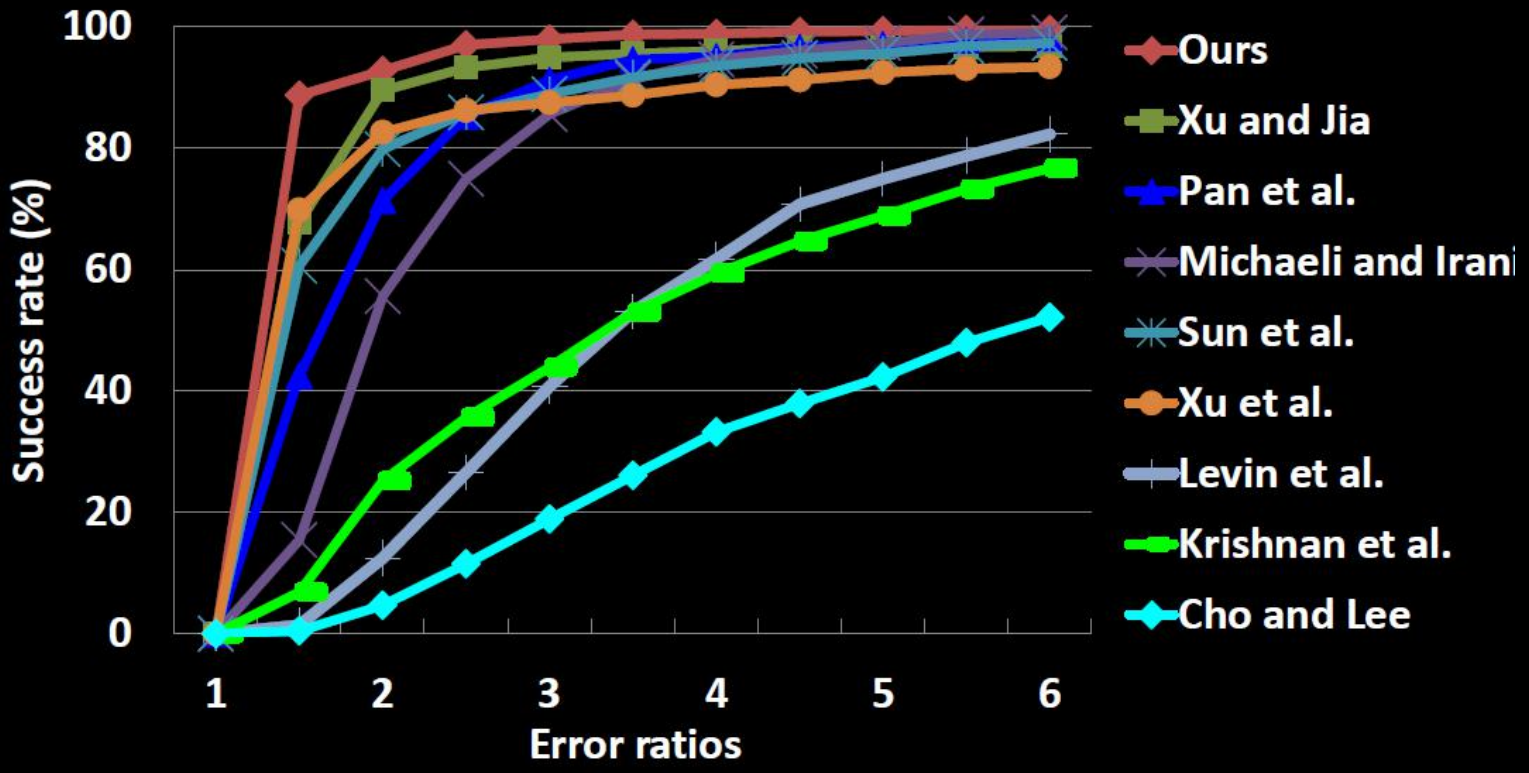
Quantitative evaluations on the dataset by Levin et al., CVPR 2009

Natural Image Deblurring Results



Quantitative evaluations on the dataset by Köhler et al. ECCV 2012

Natural Image Deblurring Results



Quantitative evaluations on the dataset by Sun et al. ICCP 2013

Natural Image Deblurring Results

Blurred image

Krishnan et al., CVPR 2011

Xu et al., CVPR 2013

Pan et al., CVPR 2014

Ours without D(I)

Ours

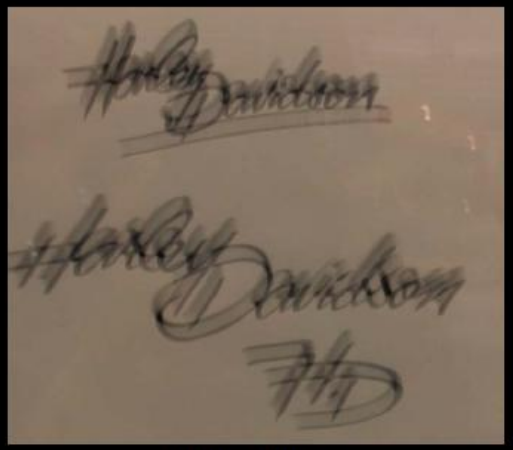
Text Image Deblurring Results

	Average PSNRs
Cho and Lee	23.80
Xu and Jia	26.21
Krishnan et al.	20.86
Levin et al.	24.90
Xu et al.	26.21
Pan et al.	28.80
Ours	27.94

Natural image debluring methods

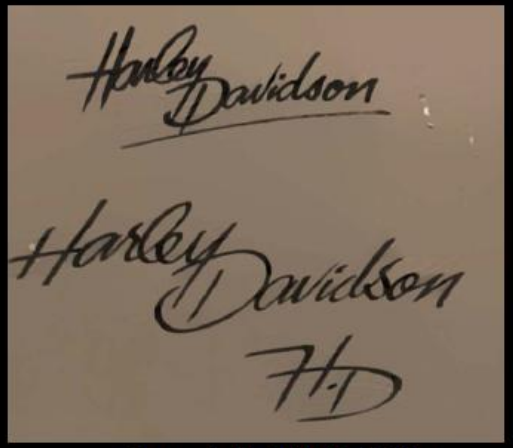
Quantitative evaluations on the text image dataset by Pan et al., CVPR 2014

Text Image Deblurring Results

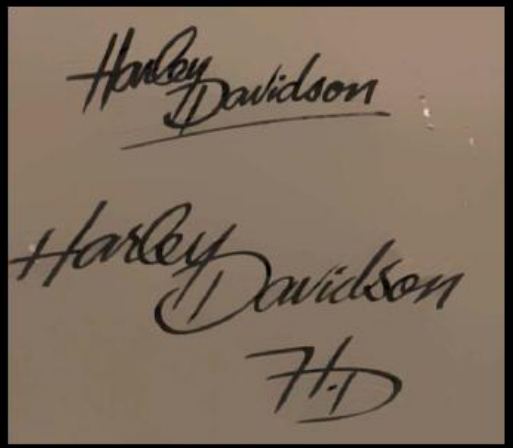


Blurred image

Xu et al., CVPR 2013



Pan et al., CVPR 2014



Ours

Saturated Image Deblurring Results

Blurred image

Xu et al., CVPR 2013

Pan et al., CVPR 2014

Ours

Face Image Deblurring Results

Blurred image | Xu et al., CVPR 2013 | Pan et al., ECCV 2014 | Ours

Non-Uniform Deblurring

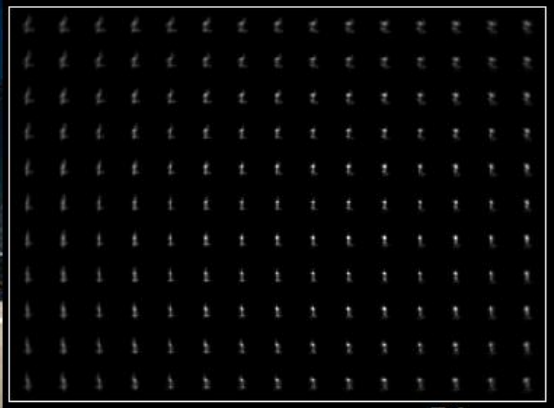
Blurred image

Krishnan et al., CVPR 2011

Whyte et al., IJCV 2012

Xu et al., CVPR 2013

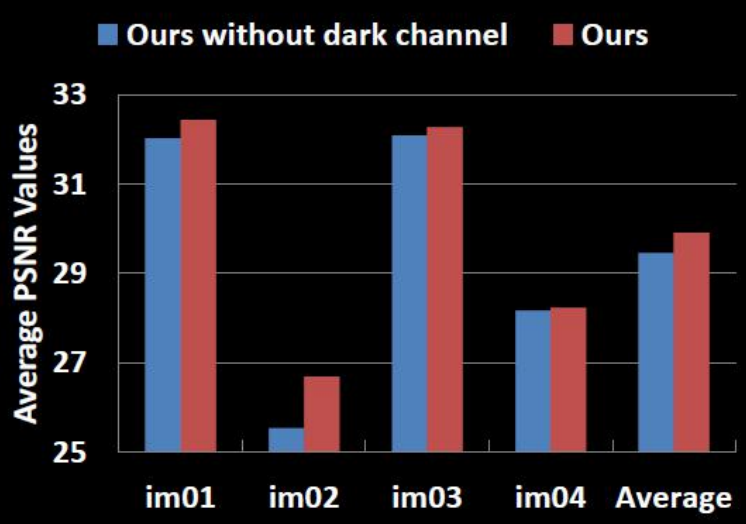
Ours



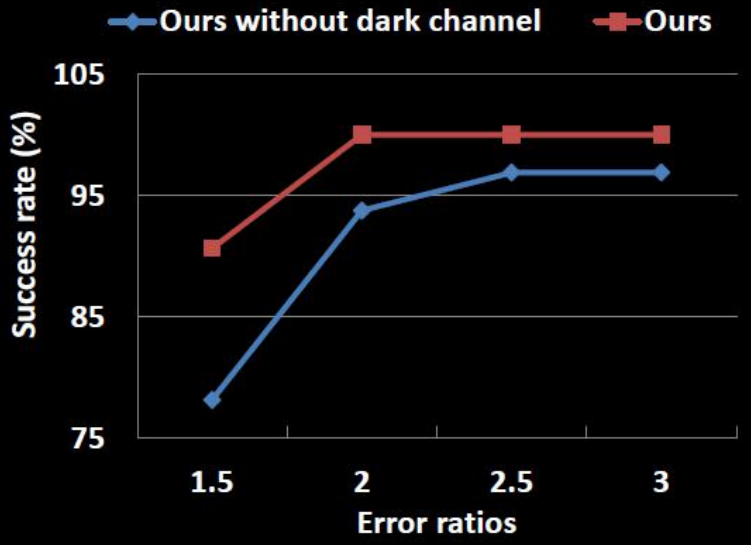
Our estimated kernels

Analysis and Discussions

- Effectiveness of dark channel prior



Results on the dataset by Köhler et al. ECCV 2012



Results on the dataset by Levin et al. CVPR 2009

Limitations

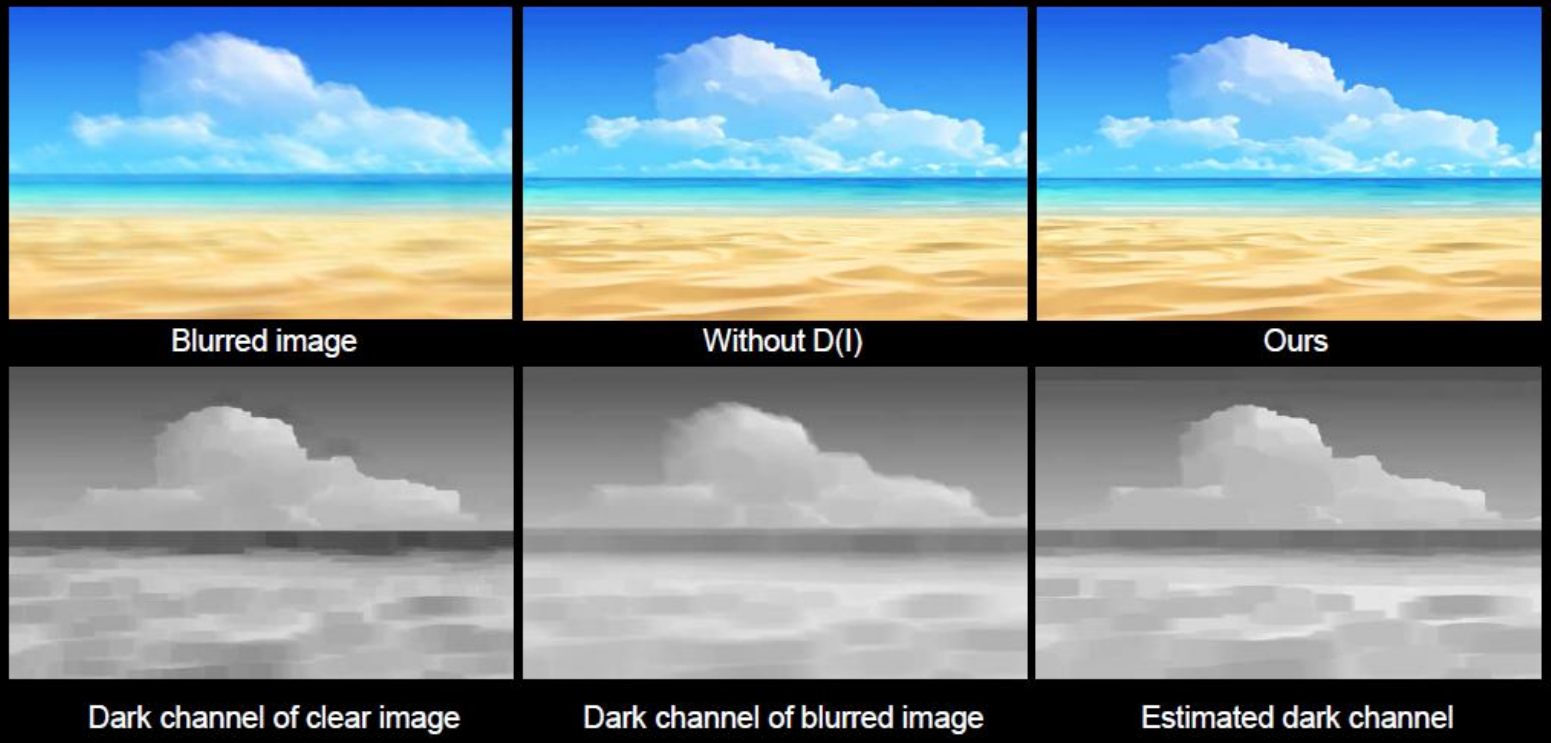
- The dark channel of clear image does not contain zero-elements

$$\| D(B) \|_0 = \| D(I) \|_0$$

  - Property 2 does not hold
  - Dark channel prior has no effect on image deblurring

Limitations

- The dark channel of clear image does not contain zero-elements



Limitations

- Images containing noise

Blurred image

Limitations

- Images containing noise

Without D(I)

Limitations

- Images containing noise

With D(I)

Thank You!