BLIND DEBLURRING OF NATURAL IMAGES

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Summary

- We present a blind deblurring method which only requires weak assumptions on the blurring filter.
- The method reaches satisfactory reconstruction of various images degraded by various blurs and noise levels.
- Filter estimates are close to true blurs.
- Improvements are achieved in real blurred photos and in synthetic blurs.

Blind image deconvolution

Degradation model: $y = Hx + n$

x - original image, H - linear blurring operator

n - noise, y - degraded image (blurred and noisy).

(y, x, n are vectorized in lexicographic order)

Aim: recovering x from y.

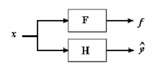
Ill-posed problem: infinite number of solutions, blur operator typically ill-conditioned.

Applications: Photography, medical imaging, astronomy.

Assumptions (weak)

- Original image edges: sparse, sharp
- Blur operator: limited support, low pass nature.

Cost function



F - edge extractor

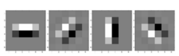
f - image edges

Cost function: $C(x, H) = \|y - Hx\|_2^2 + \lambda R(F(x))$

$R(\bullet)$ - Favors sparse distributions.

Edge detector

Combines directional filters: $f = \sqrt{\sum_\theta g_\theta^2}$ $\quad F_{\theta=0} = \begin{bmatrix} 1 & 2 & 2 & 1 \\ -1 & -2 & -2 & -1 \end{bmatrix} / 12$



f - edge image.

g_θ - output of filter with direction θ.

Image prior/regularizer

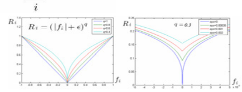
$p(f) \propto e^{-k(f+\epsilon)^q} \quad 0 \leq f$

$R(F(x)) = \sum_i (f_i + \epsilon)^q,$

q - sparsifying parameter (0<*q*<*1*)

k - scaling parameter

ϵ - small parameter



Guided optimization

- λ is initially set to a large value and is slowly decreased over iterations:
  - Initially, the main features/details are estimated. Smaller details are progressively considered as λ decreases.
  - The filter estimate improves over iterations.
- q can be initialized with a large value, being progressively decreased over iterations.

Algorithm

Initialization:

1 – Set H to the identity operator.
2 – Set x equal to y.
3 – Set λ and the prior's sparsity to the initial values of the corresponding sequences.

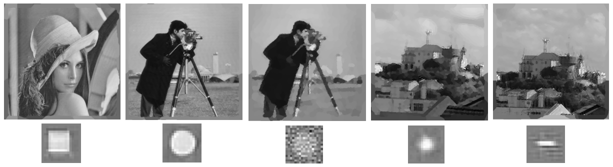
Optimization loop:

4 – Find new x estimate: $x = \mathrm{argmin}_x\ C(x, H)$ (H fixed).
5 – Find new H estimate: $H = \mathrm{argmin}_H\ C(x, H)$ (x fixed).
6 – Set λ and the prior's sparsity to the next values in sequence.
7 – If $\lambda \geq \lambda_{min}$ go back to 4; otherwise stop.

Degraded images

9x9 uniform blur | Circular blur (11 pixel diameter) | Circular blur 25 dB additive noise | Actual photo Camera out-of-focus | Actual photo Camera moving

Image and filter estimates



Conclusions

- We present a blind deblurring method which only requires weak assumptions.
- Results: Satisfactory reconstruction of various images degraded by various blurs and noise levels. Filter estimates close to true blurs. Improvements achieved in real photos.
- The method is also able to estimate parameterized blurs.