Joint Depth Estimation and Camera Shake Removal from Single Blurry Image

Zhe Hu[1], Li Xu[2], Ming-Hsuan Yang[1]

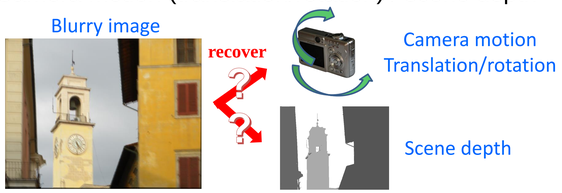
[1]University of California, Merced, [2]Lenovo R & T

Code Available at https://eng.ucmerced.edu/people/zhu/CVPR14_depthdeblur.html

Motivation

- Factors of motion blur effect:

Camera motion (translation/rotation) / scene depth



- Goal:

Single-image blur removal by estimating both camera motion and scene depth

- Challenging

Each sub-problem is challenging by itself

Single-image depth estimation

Non-uniform image deblurring

Problem Simplification

- Assumption:

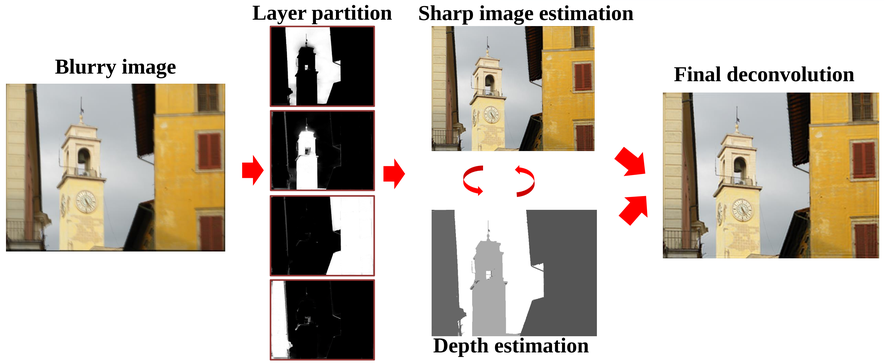
- The image can be split into several regions

latent image $x = \sum_{i=1}^{N} x_i$ blurry image $y = \sum_{i=1}^{N} y_i$

- Constant depth d_i for each region x_i, $D = \{d_i\}$

- Continuous depth value -> discrete depth value

Pipeline



Problem Formulation

$$y = \sum_{i=1}^{N} y_i = \sum_{i=1}^{N}\sum_{j=1}^{t} w_j(K(\theta_j, d_i)x_i) + n$$

Θ_j: camera pose

$W = (w_1, w_2, \ldots, w_t)$: weights at camera poses

$K(\theta_j, d_i)$: matrix that warps x_i to the transformed copy at pose θ_j

Consider marginal likelihood of the observed image

$$\log p(y, D|x, W) = \log p(y|x, W, D)p(D|x, W)$$

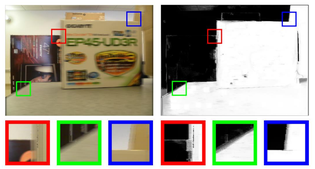
$$\propto -\frac{1}{2\eta^2}\sum_{i=1}^{N}\sum_{k=1}^{s}\alpha_{i,k}||y_i - \sum_{j=1}^{t} w_j K(\theta_j, v_k)x_i||^2.$$

$\alpha_{i,k}$: 1 or 0, indicating sampled depth value for d_i

- EM algorithm to estimate $\mathrm{E}[\alpha_{i,k}]$ and (x, w)

Image Partition

- Difficulty: ambiguity of the region boundary
- Matting: assign weights for pixels on the boundary



Depth Estimation Results

Blurry image Saxena et al. [2] Our method

- Synthetic example of depth estimation

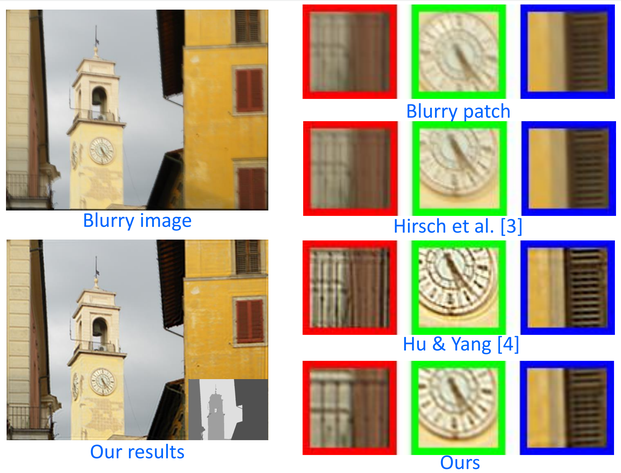
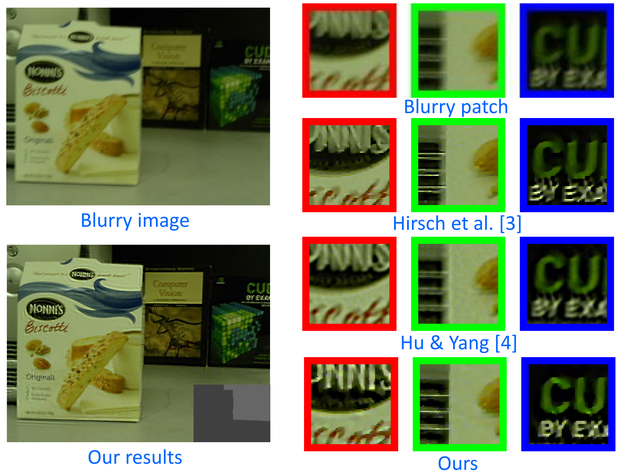
Blurry image

Ground-truth depth

Latent image prediction after smoothing

Our depth in 1st iteration

Reference

[1] Q. Chen, D. Li, and C.-K. Tang. KNN matting. In CVPR, 2012.
[2] A. Saxena, M. Sun and A.Y. Ng. Make3d: Learning 3d scene structure from a single still image. In PAMI, 2009.
[3] M. Hirsch,, C.J. Schuler, S. Harmeling and B. Scholkopf. Fast removal of non-uniform camera shake. In ICCV, 2011.
[4] Z. Hu and M.-H. Yang. Fast non-uniform deblurring using constrained camera pose subspace. In BMVC, 2012.

Qualitative Comparisons