Removing Camera Shake from a Single Photograph

by Rob Fergus, et al.

Michał Zapotoczny

Instytut Informatyki
Uniwersytet Wrocławski

Computational Photography Course

This is a problem...

...this is how standard software solves it...

...and this is how we will solve it

Assumptions

- No significant parallax
- Any image-plane rotation of camera is small
- No parts of the scene are moving relative to one another

Image model

$$\mathbf{B} = \mathbf{K} \otimes \mathbf{L} + \mathbf{N} \tag{1}$$

$$\mathbf{N} \propto \mathcal{N}(0, \sigma^2) \tag{2}$$

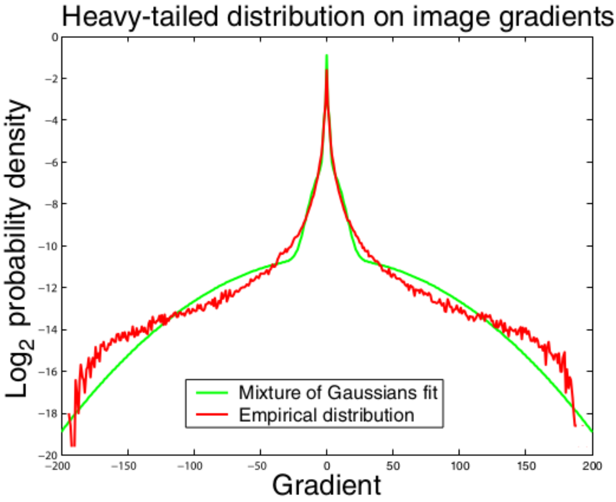
B is a blurred input image

K - blur kernel

L - true image

N - noise

Distribution of gradients of natural, non-blurred images



A priori assumptions about images

- Prior $p(\nabla P)$ is a mixture of C zero-mean Gaussians (with variance v_c and weight π_c)
- Prior $p(K)$ is a mixture of D exponential distributions (with scale factors λ_d and weights π_d). It encourages zero values in the kernel, and requires all entries to be positive.

Algorithm

User supplies:

- Blurred image **B**
- A rectangular patch **P** within the **B**
- An upper bound on the size of **K**
- Initial guess on the orientation of **K**

We convert **P** to linear color space and grayscale.

Estimating blur kernel

Given the grayscale blurred patch $\mathbf{P}$, we estimate $\mathbf{K}$ and the latent patch image $\mathbf{L_p}$ by finding the values with highest probability, guided by a prior on the statistics of $\mathbf{L}$.

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So posterior distribution will be:

$$
\begin{aligned}
p(\mathbf{K}, \nabla \mathbf{L_p} | \nabla \mathbf{P}) &\propto p(\nabla \mathbf{P} | \mathbf{K}, \nabla \mathbf{L_p}) p(\mathbf{K}) p(\nabla \mathbf{L_p}) \\
&= \prod_i \mathcal{N}(\mathbf{P}(i) | (\mathbf{K} \otimes \nabla \mathbf{L_p}(i)), \sigma^2) \\
&\prod_i \sum_{c=1}^{C} \pi_c \mathcal{N}(\nabla \mathbf{L_p}(i) | 0, v_c) \\
&\prod_j \sum_{d=1}^{D} \pi_d exp(\mathbf{K}_j | \lambda_d)
\end{aligned}
$$

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- MAP objective function attempts to minimize all gradients (even large ones)
- Whereas we expect natural images to have some large gradients.
- The algorithm yields a two-tone image (virtually all gradients are zero)
- When we reduce the noise variance then we have no deblurring

Solution #2

Approximate the full posterior distribution $p(\mathbf{K}, \nabla \mathbf{L_p} | \nabla \mathbf{P})$, then compute the kernel $\mathbf{K}$ with **maximum marginal probability**. This method selects a kernel that is most likely with respect to the distribution of possible latent images, thus avoiding the overfitting that can occur when selecting a single "best" estimate of the image. I won't show here details of the algorithm.

Multi-scale approach

- Previous section is subject to local minima, particularly for large blur kernels
- Hence, we perform estimation in a coarse-to-fine manner, starting with a 3x3 kernel.
- Initial kernel is picked by user from 2 possibilities: vertical or horizontal line.
- Initial estimate for the $\nabla \mathbf{L_p}$ is produced by running the inference scheme, while holding K fixed
- Then we work back up, upsampling $\mathbf{K}$ and $\nabla \mathbf{L_p}$ from previous pass to use as initialization for inference at current scale.

Image reconstruction

- Standard non-blind deconvolution methods produce unacceptable levels of artifacts.
- Inferring whole **B**, while holding **K** fixed and then using Poisson image reconstruction was no better than previous attempt
- In the end Richardson-Lucy deconvolution algorithm gave best results

Results


睇到女人定係
愛斯基摩人?


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