Fusion for Image Restoration

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Traffic surveillance - can we read the license plates?
Empirical observation

• **One image is not enough**
  – ill-posed problem

• **Solution**
  – strong prior knowledge of blurs and/or the original image
  OR
  – more images
  – techniques how to combine them
Realistic multiframe imaging

registration

image restoration
Superresolution

Goal: Obtaining a high-res image from several low-res images
Traditional superresolution

Method: interpolating LR images on a HR grid
Fusion for image restoration

• **Idea**: Each image consists of “true” part and “degradation”, which can be removed by fusion

• Types of degradation:
  – additive noise: image denoising
  – blurring: blind deconvolution
  – resolution decimation: superresolution

Realistic acquisition model

\[ D \left( \left[ u \ast h_k \right](x, y) \right) + n_k(x, y) = z_k(x, y) \]
Decimation operator $D$

- Convolution with the sensor PSF
  - Modeling CCDs
- Registration
  - Adjusting sensor PSFs
- Downsampling
  - e.g. take every second pixel
- Masking
  - Eliminating erroneous pixels
    (e.g. registration is inaccurate or impossible)
Misregistration

- Optimization with respect to registration parameters
- Marginalization (eliminating registration parameters)

- Incorporating between-image shift

\[ [u * h_k](\tau_k(x, y)) + n_k(x, y) = z_k(x, y) \]

\[ [u * g_k](x, y) + n_k(x, y) = z_k(x, y) \]
Blind superresolution

• System of integral equations
  (ill-posed, underdetermined)

\[ z_k(x) = D[h_k \ast u](x) + n_k(x) \]

• Energy minimization problem (well-posed)

\[
E(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^{K} \|D[h_i \ast u] - z_k\| + \lambda Q(u) + \gamma R(\{h_k\})
\]
Image Regularization

- $Q(u)$ captures local characteristics of the image $\Rightarrow$ Markov Random Fields

- Identity: $\int_{\Omega} |u|^2$

- Tichonov (GMRF): $\int_{\Omega} |\nabla u|^2$

- Variational integral: $\int_{\Omega} \phi(|\nabla u|)$

- Huber MRF, bilateral filters, …
PSF Regularization

\[ z_1 = h_1 \ast u \]

\[ u \ast h_2 = z_2 \]

\[ z_1 \ast h_2 = u \ast h_1 \ast h_2 \]

\[ h_2 \ast h_1 \ast u = h_1 \ast z_2 \]

\[ R(\{h_i\}) = \frac{1}{2} \sum_{1 \leq i, j \leq K} \|z_i \ast h_j - z_j \ast h_i\|^2 \]

with one additional constraint \[ 0 \leq h_i(x) \leq 1, \quad \forall x, i \]
AM algorithm

- Alternating minimizations of $E(u, \{h_k\})$
- Input: blurred LR images and estimation of PSF size
- Output: HR image and PSFs
- **Blind deconvolution in the SR framework**

$$E(u, \{h_k\}) = \frac{1}{2} \sum_{k=1}^{K} \| D[h_i * u] - z_k \| + \lambda Q(u) + \gamma R(\{h_k\})$$
Taking pictures in a museum
Long-time exposure
Moving car

Still car & moving camera

rough registration

Superresolved image (2x)

Optical zoom (ground truth)

Superresolution with High Factor

Input LR frames

interpolated

SR

Original frame

Webcam images

LR input frame  Superresolution image (2x)

Reprinted from Sroubek et al., “Imaging for Detection and Identification”, NATO Advance Study Institute, 2006
Video sequence

160x120, 30fps
Video sequence

original
LR video

reconstructed
HR video
Challenges
Challenges

- 3D scene
- objects having different motion
- improving registration
- space-variant deblurring
- motion field
- minimization over registration param.
Matlab GUI
Any questions?
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