THE HEADACHES OF IMAGE RESTORATION

Cha-Cha Group

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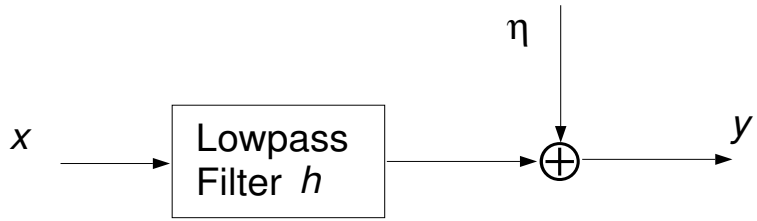
Outline

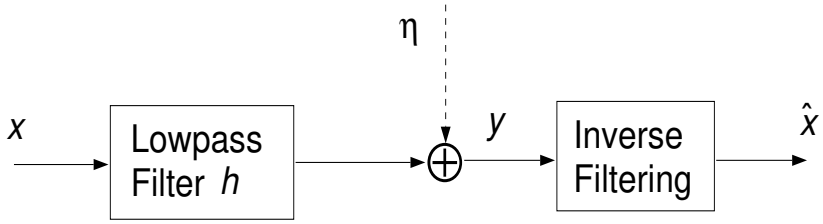
- Image degradation model
- Inverse filtering
- Wiener filtering
- Wavelet-based algorithms
- Blind deconvolution

Degradation Model



- Lowpass blurring h: misfocs, ...
- Additive Gaussian noise
- Unknown PSD (point spread function) h: blind deconvolution

Inverse Filltering



- Assume no additive noise, just deconvolution.

- In frequency domain, just invert the blurring, for singular PSD, generalized inverse introduced

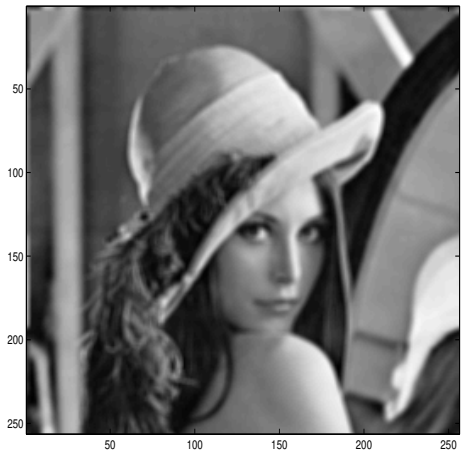
$$G_\gamma = \begin{cases} \frac{1}{H}, & |H| > \gamma \\ 0, & |H| \le \gamma \end{cases} \qquad G_\gamma = \begin{cases} \frac{1}{H}, & |H| > \gamma \\ \frac{1}{\gamma}\frac{|H|}{H}, & 0 < |H| \le \gamma \end{cases}$$

Pseudo-inverse filtering Generalized inverse-filtering

- Problem: for singular PSD, amplify noise, very sensitive to noise

Experimental Results: First Inverse Filtering Algorithm

Blurred



MSE = 204.1772

Inverted

MSE=9.6193

Blurred (noise)

MSE = 595.5884

Inverted

MSE = 445.6545

Inverse Filtering: Iterative Algorithm

- Frequency domain implementation, choosing threshold ...

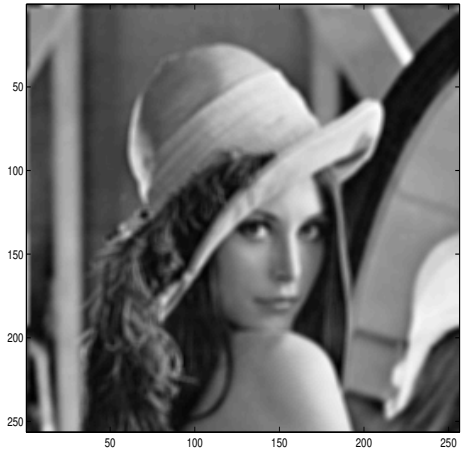
- Iteration algorithm: choose parameter $\lambda > 0$ to control the convergence

$$\begin{aligned} \widehat{x}_0[m,n] &= \lambda y[m,n] \\ \widehat{x}_{k+1}[m,n] &= \widehat{x}_k[m,n] + \lambda(y[m,n] - \widehat{x}_k[m,n] * h[m,n]) \end{aligned}$$

- Much more sensitive to noise

Experimental Results: Iterative Algorithm

Blurred



MSE = 204.1772

Inverted

MSE = 2363.4

Blurred (noise)

MSE = 595.5884

Inverted

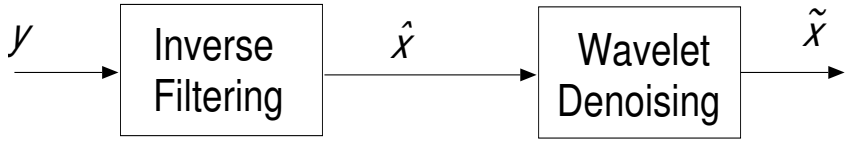
MSE = 1117.4

Wiener Filtering

$$\widehat{X} = \frac{H^* S_{xx}}{|H|^2 S_{xx} + S_{\eta\eta}} Y = \frac{1}{H} \frac{S_{yy} - S_{\eta\eta}}{S_{yy}} Y.$$

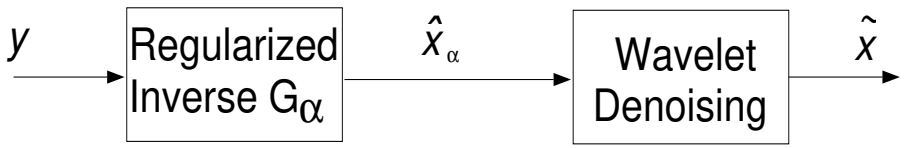
- Optimal linear MSE estimator, optimal tradeoff between inverse filtering and noise smoothing
- Implementation: inverse filtering part, and noise smoothing part (need to estimate S_{xx} and $S_{\eta\eta}$)
- Problem: noise amplified, and amplified noise unattended

Wavelet-based Restoration Algorithms



- Separate operations: inverse filtering in frequency domain and noise removing in wavelet domain
- Frequency domain: inverse filtering, Wiener filtering or regularized inverse filtering
- Wavelet domain: threshold small wavelet coefficients to remove noise

WaRD: Wavelet-based Regularized Deconvolution Algorithm



- Introduce a parameter α in Wiener filter

$$\widehat{X} = \frac{H^* S_{xx}}{|H|^2 S_{xx} + \alpha S_{\eta\eta}} Y.$$

- Choose optimal α to minimize the cumulative MSE

- Threshold wavelet coefficients using scale-dependent thresholds

WaRD: Experimental Results

Blurred

MSE = 1120.23

Wiener

MSE = 673.45

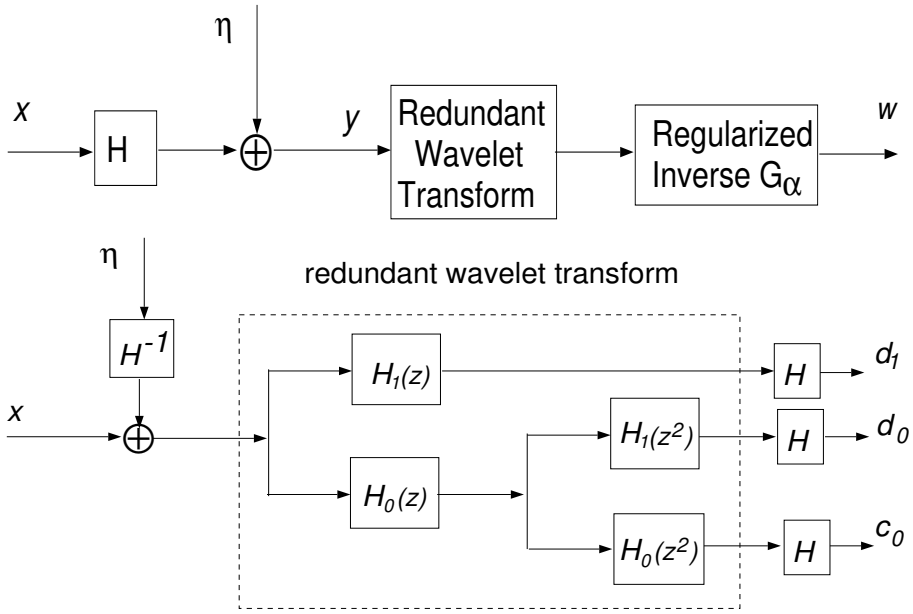
Donoho's

MSE = 445.78

WaRD

MSE = 234.67

Wavele-based Restoration: A New Algorithm



- Both inverse filtering and denoising in wavelet domain. Better estimation of power spectrum of wavelet coefficients

- For different subband use different regularized parameter α. Increase computational complexity

Experimental Results: New Algorithm

Blurred

MSE = 1120.23

WaRD

MSE = 234.67

Subband

MSE = 226.32

- Improved in terms MSE, however, deconvolution is not satisfactory
- How to optimally choose parameters α for each subband? Reseacrh topic.

Blind Deconvolution - Jain Approach

- An approach from Jain proposes the following estimate of H

$$\log |H| = \frac{1}{M} \sum_{k=1}^{M} [\log |V_k| - \log |U_k|].$$

  where U_k and V_k are obtained by breaking the input u and degraded v into M smaller blocks and computing their spectral densities.

- H is then used with S_{nn} and S_{uu} to compute the Wiener Filter

- Method only computes Magnitude of H, so its best for phaseless LSI filters. Phase is zero or unimportant in cases where H represents: Camera Misfocus, uniform Motion (linear phase),atmospheric Turbulence. Method comes from Homomorphic ideas

Blind Deconvolution - Jain Approach

- S_{nn} and S_{uu} assumed known. Image Broken into Sixteen 64x64 pixel Blocks

- Noise is Zero Mean AWGN with Variance 80

Lenna after Blurring Plus Nois

MSE = 3093.7

Lenna restored using Blind Deconvolution

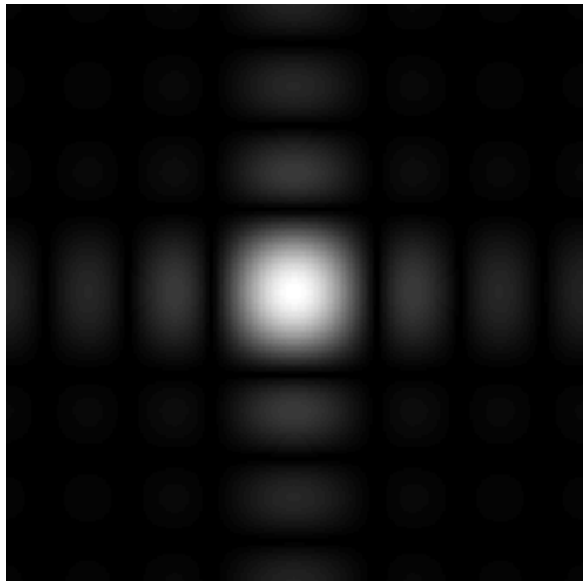
MSE = 264.88

Blind Deconvolution - Jain Approach

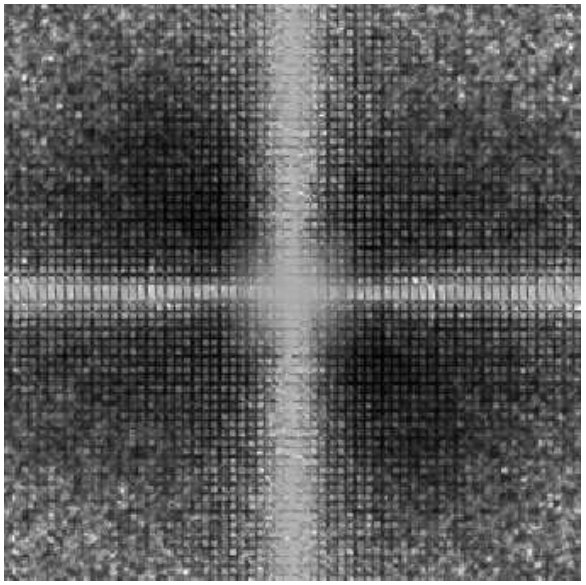
- S_{nn} and S_{uu} assumed known. Image Broken into Sixteen 64x64 pixel Blocks

- Noise is Zero Mean AWGN with Variance 80

Magnitude Plot of Blurring Filter



Magnitude Plot of Estimated Blurring Filte



Conclusions

- Inverse filtering, Wiener filtering are very much sensitive to noise
- Regularized inverse filtering followed by wavelet denoising minimize the cumulative MSE
- Blind Deconvolution is a very difficult problem. It is effective under specific conditions and even then may yield poor restoration quality.
- Homomorphic processing allows us to use statistical estimation to simplify calcuations, but many iterations are needed for convergence. This may require many image snapshots or sub-blocks, which could be unfeasible..