QUALITY ASSESSMENT OF COMPRESSION TECHNIQUES FOR SYNTHETIC APERTURE RADAR IMAGES

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INTRODUCTION

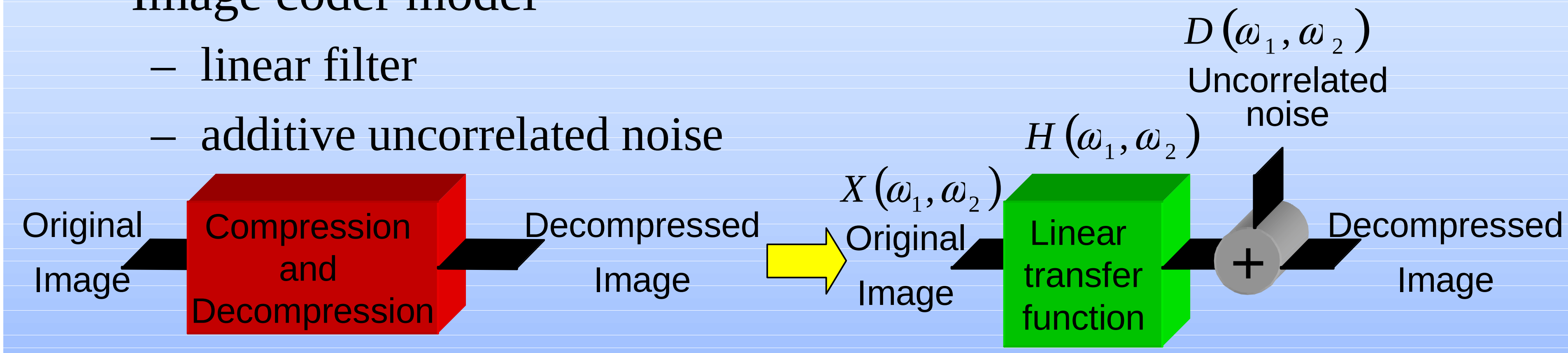
- Synthetic Aperture Radar (SAR)
  - active remote sensing system
  - applications in agriculture, oceanography, target recognition, etc.
- Compression of SAR images
  - limited storage capacity
  - limited downlink capacity on mobile platforms
- Difference between SAR and optical images
  - speckle noise
  - high frequency components
- Commonly used quality measures (for both optical and SAR)
  - mean squared error (MSE)
  - peak signal-to-noise ratio (PSNR)

MOTIVATION AND CONTRIBUTIONS

- Assumption for MSE and PSNR
  - distortion is independent noise
- Distortion caused by compression algorithms
  - linear distortion
  - nonlinear distortion
  - additive noise
- No quality measure quantifies these distortions independently
- Contributions
  - Decouple and quantify linear distortion and additive noise
  - Introduce an edge correlation measure to quantify edge distortion
  - Apply to assess the quality of JPEG and SPIHT coders

BACKGROUND

- Image coder model
  - linear filter
  - additive uncorrelated noise



- Distortion transfer function
  - Deviation of the filter response from an all-pass response: $1\text{-}H(\omega_1,\omega_2)$
- Contrast sensitivity function $C(\omega_1,\omega_2)$
  - frequency response of a human visual system model
  - weight the distortion measures with the contrast sensitivity function

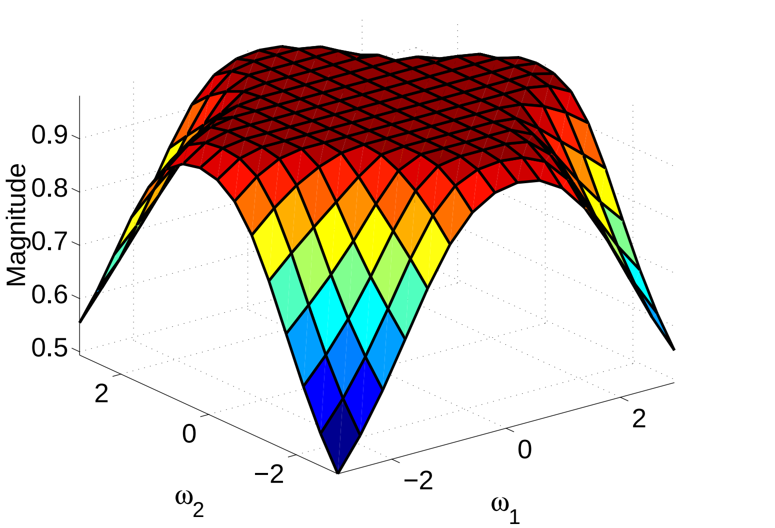
DISTORTION MEASURES

- Linear distortion
  - Linear distortion measure (LDM)

$$\text{LDM} = \frac{\sum_{\omega_1}\sum_{\omega_2}\left|C(\omega_1,\omega_2)\right|\left|1-H(\omega_1,\omega_2)\right|}{\sum_{\omega_1}\sum_{\omega_2}\left|C(\omega_1,\omega_2)\right|}$$

- Noise injection
  - Weighted signal-to-noise ratio (WSNR)

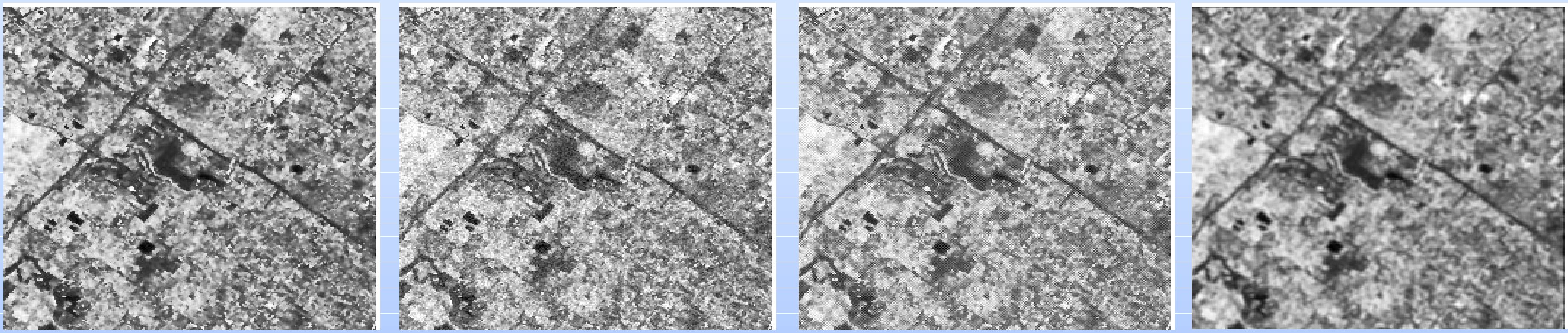
$$\text{WSNR} = 10\log_{10}\left(\frac{\sum_{\omega_1}\sum_{\omega_2}\left|X(\omega_1,\omega_2)C(\omega_1,\omega_2)\right|^2}{\sum_{\omega_1}\sum_{\omega_2}\left|D(\omega_1,\omega_2)C(\omega_1,\omega_2)\right|^2}\right)$$



contrast sensitivity function

- Nonlinear distortion
  - edge correlation measure
    - nonlinear distortion is hidden in the uncorrelated noise
    - appears as blocking effect and mosquito noise
    - predominantly high frequency effects

EXAMPLE



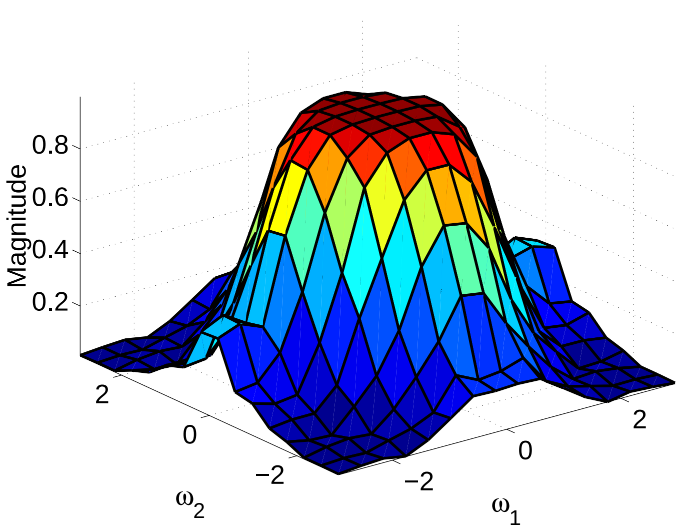
original image	white noise added	high-pass noise added	filtered (no noise)
PSNR	23.1 dB	23.1 dB	23.1 dB
correlation with error	0.0089	0.0082	0.5919
WSNR	21.5 dB	26.8 dB	41.0 dB
correlation with error	1×10^{-6}	5×10^{-8}	9×10^{-6}
linear distortion measure	0.009	0.008	0.819
edge correlation	0.74	0.73	0.42

- Same PSNR for all three distorted images
- Proposed scheme gives different WSNR and quantifies the noise
- LDM quantifies the linear distortion
- Edge correlation quantifies the preservation of edge information

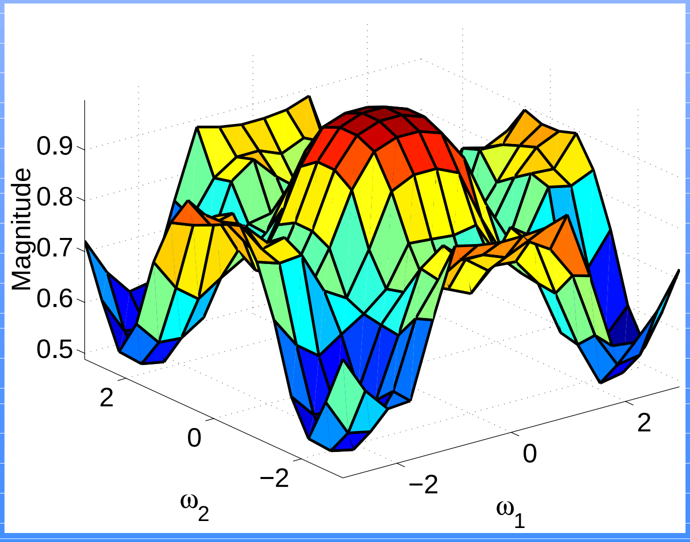
ESTIMATION OF LINEAR MODEL

- Divide the input and the output images into non-overlapping blocks of 64x64 in the DFT domain
- Rearrange the pixels for every input-output block pair to form the vectors **x** and **y**
- Estimate a constant frequency response for every block using

$$\mathbf{e}^H \mathbf{x} = (\mathbf{y} - \mathbf{H}\mathbf{x})^H \mathbf{x} = 0 \quad \Rightarrow \quad \mathbf{H} = \frac{\mathbf{y}^H \mathbf{x}}{\mathbf{x}^H \mathbf{x}}$$

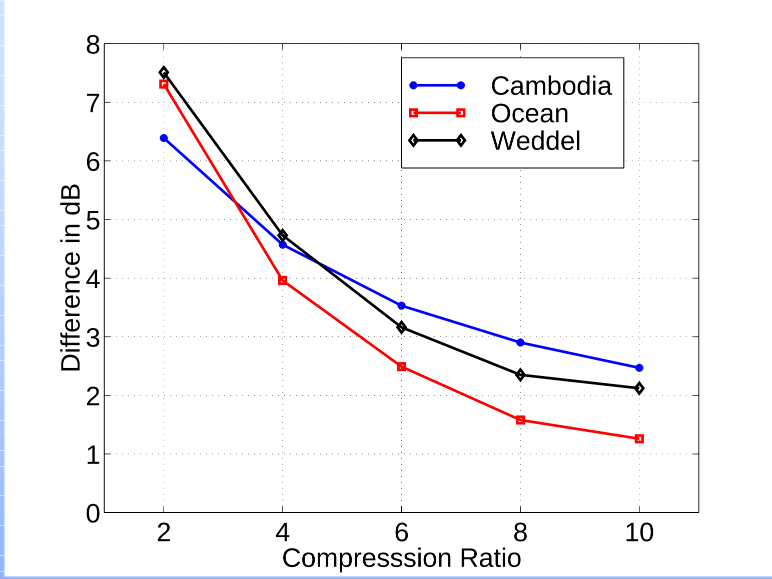


linear model for JPEG

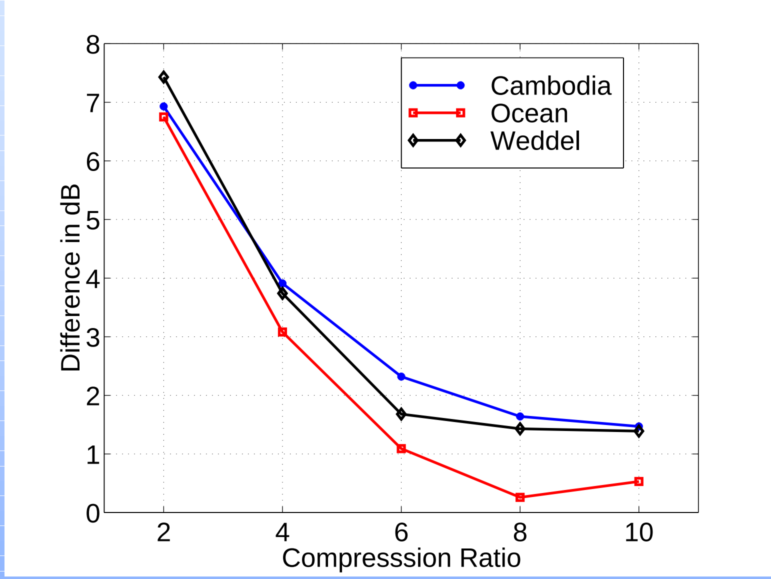


linear model for SPIHT

JPEG vs. SPITH



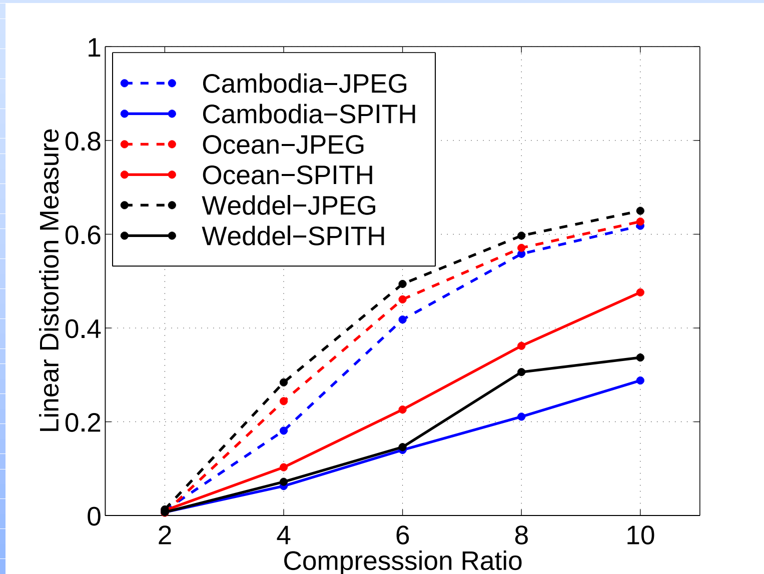
$PSNR_{SPIHT}$ - $PSNR_{JPEG}$



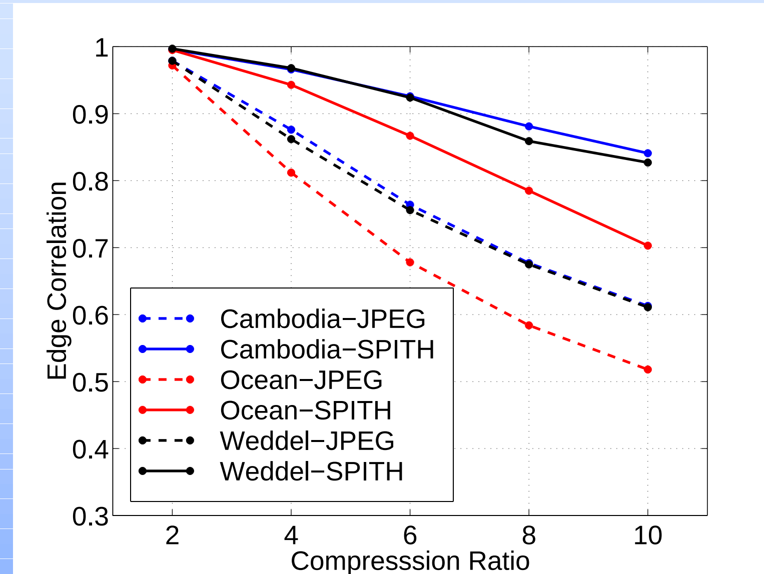
$WSNR_{SPIHT}$ - $WSNR_{JPEG}$

- Both PSNR and WSNR shows that SPIHT outperforms JPEG
- For high compression ratios the performance difference is not as high as PSNR suggests
- PSNR does not give any other information

JPEG vs. SPITH



linear distortion measure



edge correlation

- Similar performance for compression ratios close to two
- JPEG distorts more than SPIHT for high compression ratios
- Combining the results: SPIHT outperforms JPEG
  - due to less noise injection at low compression ratios
  - due to less linear and edge distortion at high compression ratios

CONCLUSION

- Lossy image compression subjects an image to
  - linear distortion
  - non-linear distortion
  - noise injection
- To measure these distortions we model a compression scheme as a linear filter followed by uncorrelated noise injection.
- We measure the non-linear distortion using edge correlation.
- We assess the visual impact of all three distortions in SAR images compresses by JPEG and SPIHT image coders.
- Our result is that SPIHT outperforms JPEG in all three measures.