JEDI: Joint Enhancement and Denoising of Images for SAR

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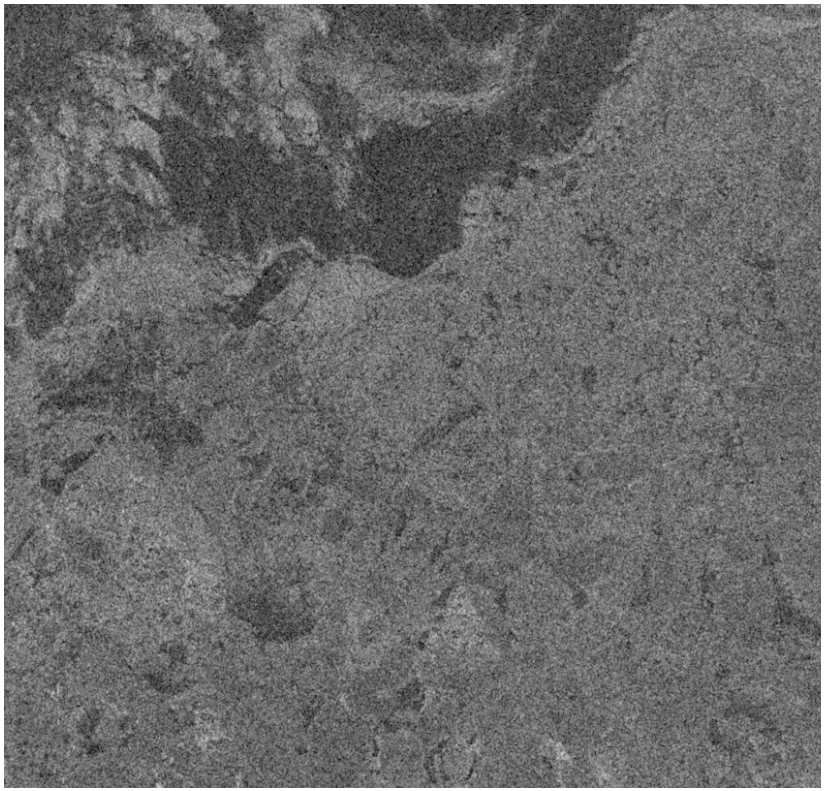
Motivation

- Speckle is a noiselike pattern produced by coherent imaging methods such as SAR
- Degrades visual quality
- Hinders automatic segmentation



Background

- Despeckling methods
  - LLSE, local statistics: Lee, Frost, Kuan filters
  - Gamma-MAP
  - Anisotropic diffusion
  - Adaptive weighted median filter
  - Wavelet domain methods
- Issues:
  - Insufficient speckle reduction
  - Edge preservation, but not enhancement

Speckle Model

- Multiplicative noise model:

$$g(\mathbf{x}) = f(\mathbf{x}) \cdot n(\mathbf{x})$$

- Assuming noise and signal and uncorrelated:

$$\begin{aligned} E\left[g(\mathbf{x})\right] &= E\left[f(\mathbf{x}) \cdot n(\mathbf{x})\right] \\ &= E\left[f(\mathbf{x})\right] \cdot E\left[n(\mathbf{x})\right] \\ &= E\left[f(\mathbf{x})\right]. \end{aligned}$$

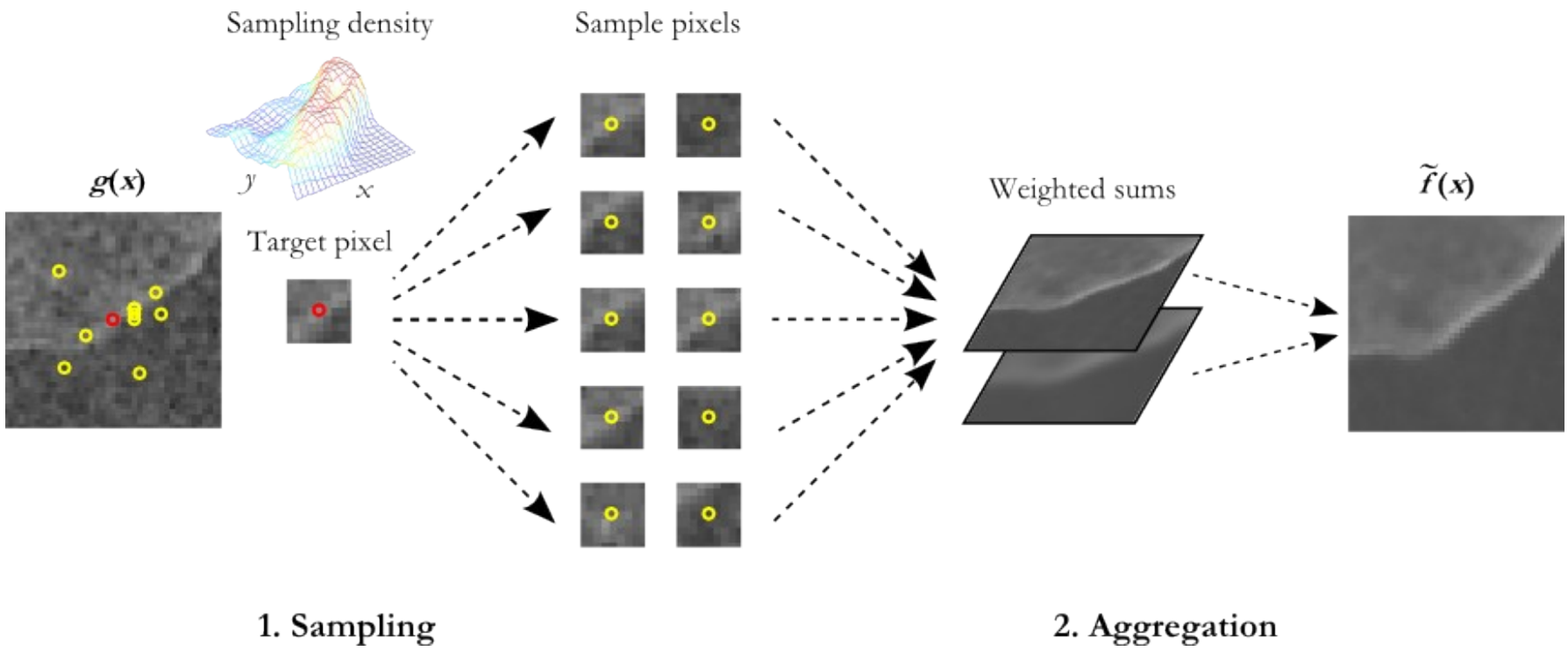
- The noise “averages out”

Estimation Framework

- Cannot take multiple measurements of the same location
- Make use of redundant information within the same image with spatial averaging:

$$\hat{f}(\mathbf{x}) = \frac{1}{W(\mathbf{x})} \sum_{\xi \in \Omega_{\mathbf{x}}} w(\mathbf{x}, \xi) g(\xi),$$

JEDI Overview



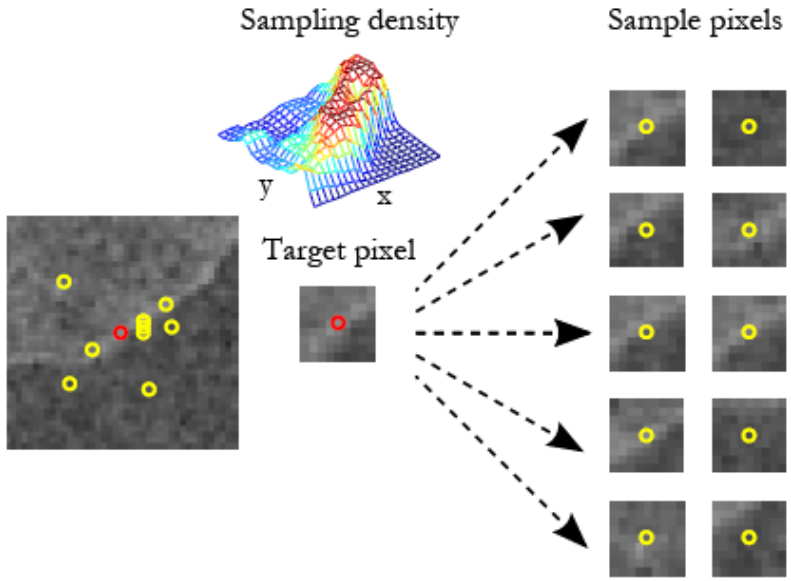
1. Sampling

- Sampling density a function of:
  - Proximity: Euclidean distance to target
  - Perceptual similarity: local image variance

$$p(\xi|\mathbf{x}_c) = \frac{1}{C(\xi, \mathbf{x}_c)} e^{-\alpha|\mathbf{x}_c - \xi|^2 \left(\sigma^2(\xi) - \sigma^2(\mathbf{x}_c)\right)^2}$$

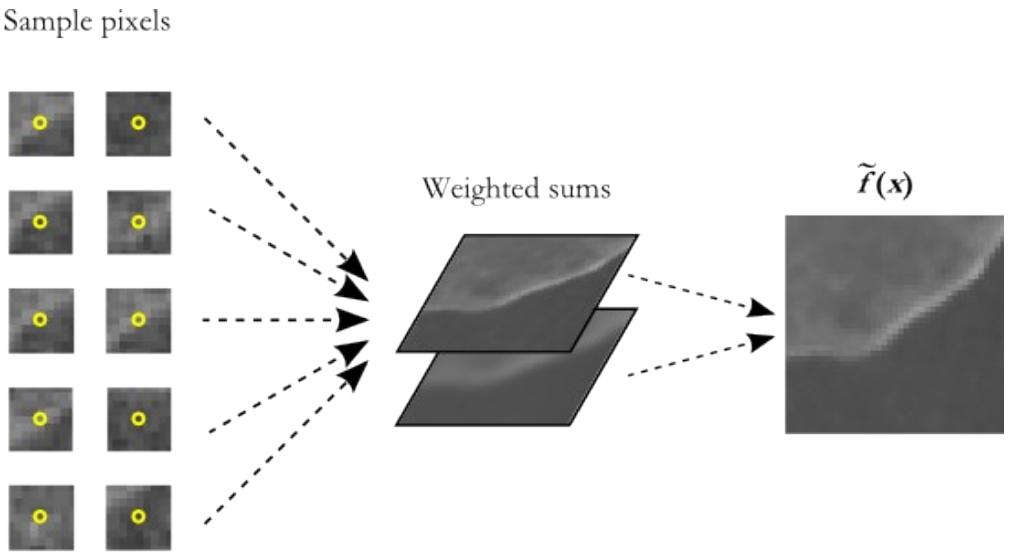
1. Sampling cont'd

- Samples are chosen with higher likelihood of providing information redundancy

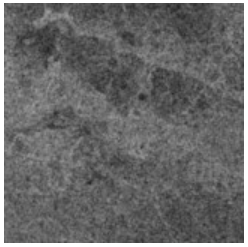


2. Aggregation

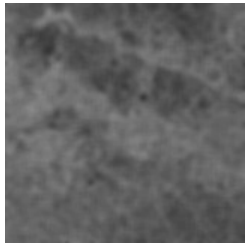
- Weights are based on differences between neighbourhoods around target pixel and sample pixel



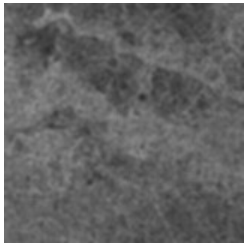
$$\hat{f}_{enh}(\mathbf{x}_c) = \frac{\theta}{W_1(\mathbf{x}_c)} \sum_{i=1}^{m} e^{-\frac{\Phi(\mathbf{x}_c,\xi_i)}{h^2}} g(\xi_i) - \frac{\theta - 1}{W_2(\mathbf{x}_c)} \sum_{i=1}^{m} e^{-\frac{\Phi(\mathbf{x}_c,\xi_i)}{\beta^2 h^2}} g(\xi_i),$$



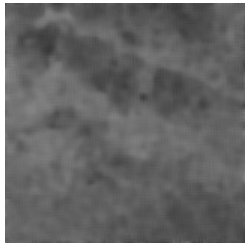
SAR Test Image 1



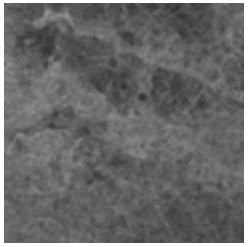
Frost



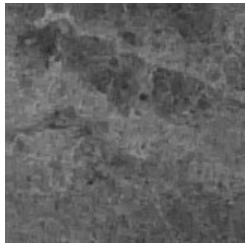
Gamma-MAP



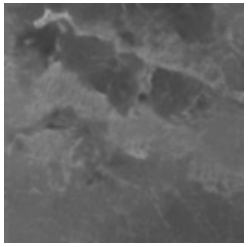
SRAD



Median



GenLik



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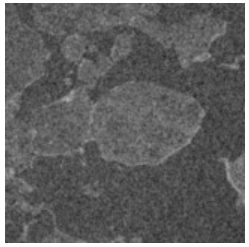
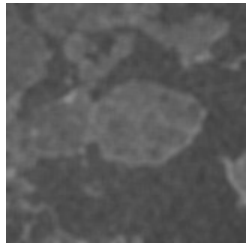
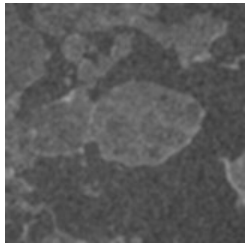


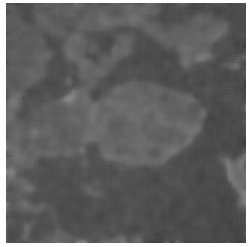
SAR Test Image 2



Frost



Gamma-MAP



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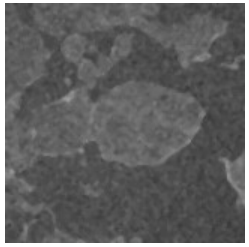
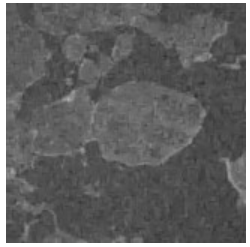


Median



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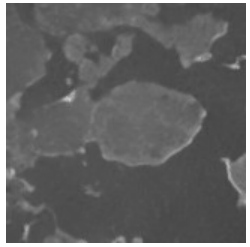

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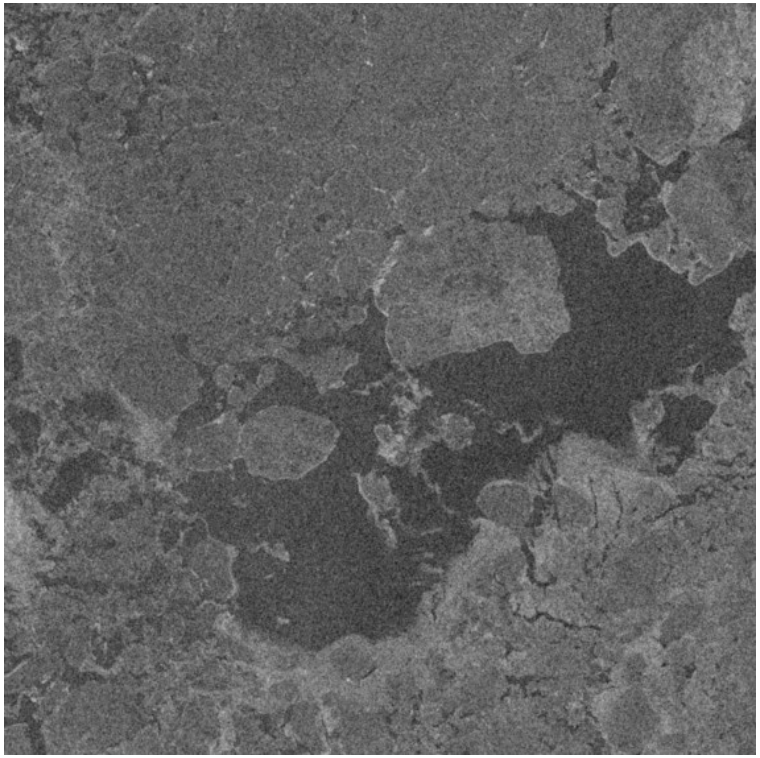
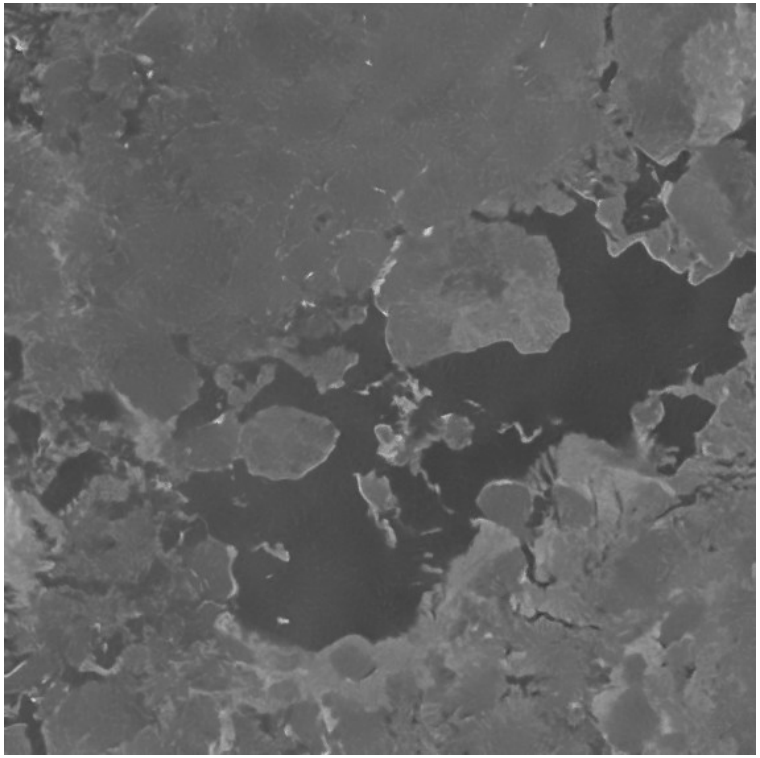
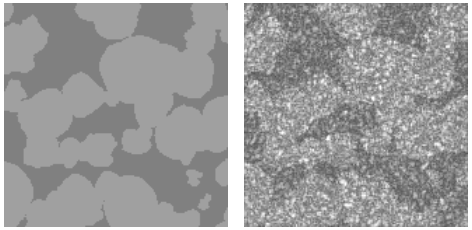
Full SAR Image



RADARSAT-2 Image

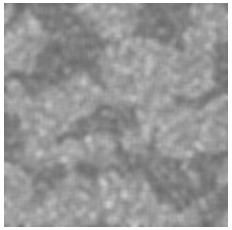


Processed with JEDI

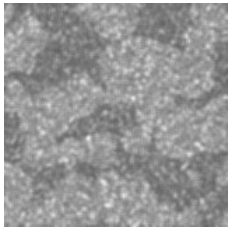


Reference image

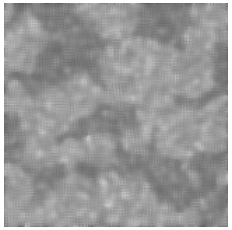
Simulated speckle



Frost



Gamma-MAP



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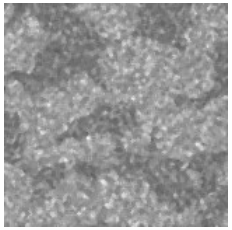

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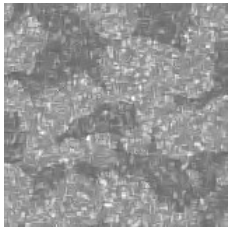

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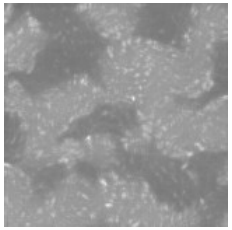

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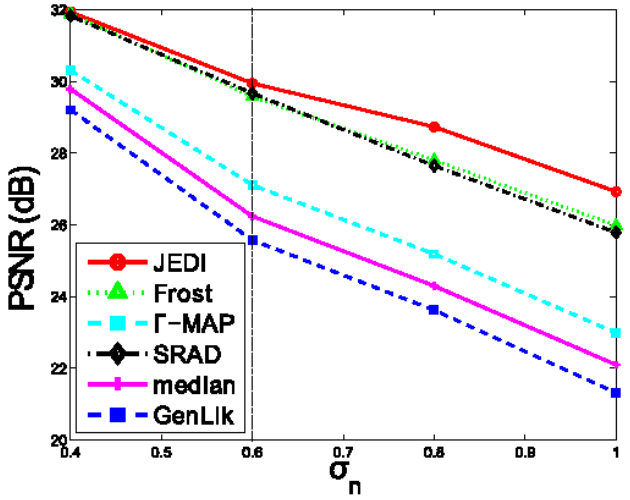

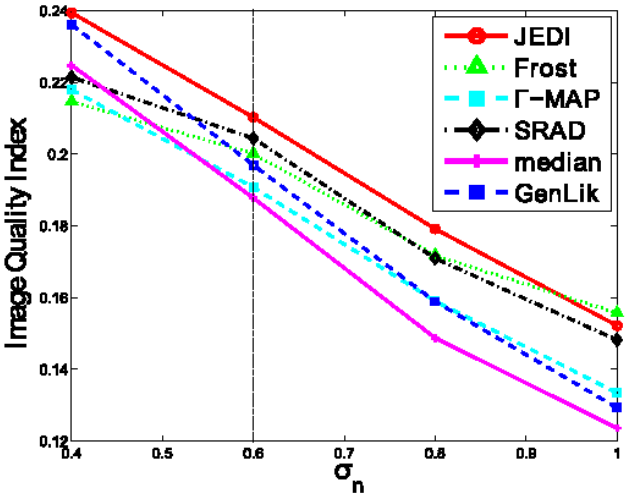

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Summary

- Stochastic estimation technique
- Efficiently utilizes information redundancy by sampling
- Aggregation method jointly denoises and enhances
- Improves appearance of edge detail
- Outperforms popular despeckling methods