Adaptive Medical Image Denoising over Multiple Anatomical Regions with Edge and Texture Preservation

59th AAPM Annual Meeting & Exhibition

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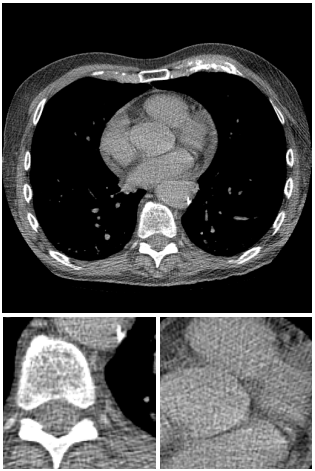
- Cynthia H. McCollough
- Juan Carlos Ramirez-Giraldo

- TCGA-BLCA research group

Introduction: Low-dose CT denoising

- Multiple sources of image degradation[1,2,3]
- Low-dose CT denoising is more challenging
  - Signal and noise
    - correlate
    - no longer reside in separate frequencies



Display range: [800, 1300] HU
Data source: TCIA: TCGA-BLCA collection
DOI:10.7937/K9/TCIA.2016.8LNG8XDR

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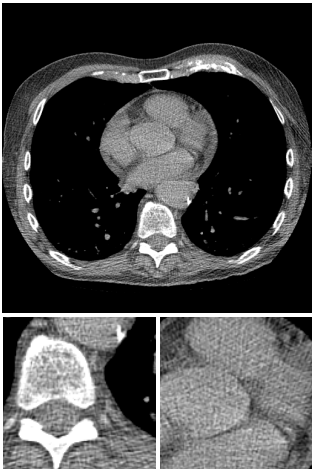
- Multiple approaches
  - Li et al., Med Phys, 2014
  - Zhang et al., Med Phys, 2017



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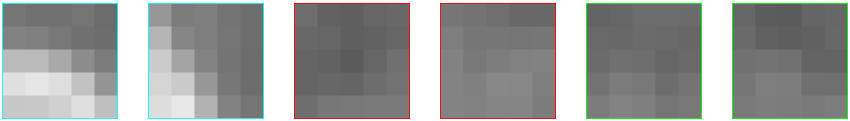
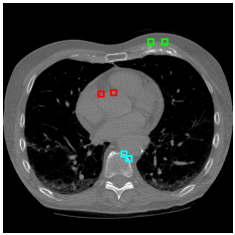
Introduction: Non-local means filtering

Patch: texture element (local signal structure and noise statistics)





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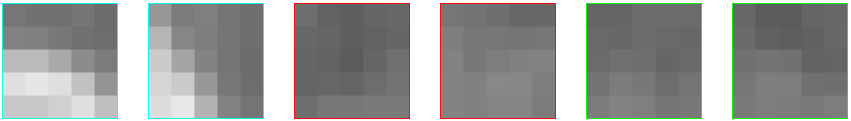

Each image patch is filtered by a weighted mean of similar patches[1]

$$\widehat{\mathbf{P}}_i = \sum_{j \in \mathcal{S}_i} w_{ij} \mathbf{P}_j \qquad w_{ij} = \frac{1}{Z_i} \exp\left\{ \frac{\|\mathbf{P}_i - \mathbf{P}_j\|_2^2}{\sigma^2} \right\}$$

$\mathbf{P}_i$: patch around i-th pixel

σ: noise level | denoising strength

Z_i: weight normalization

$\widehat{\mathbf{P}}_i$ denoised patch around i-th pixel

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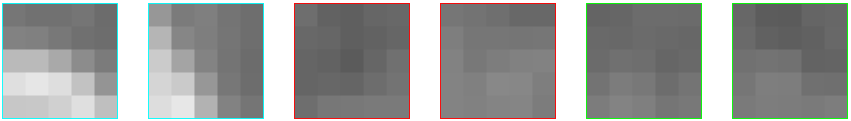

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- Different search strategies for similar patches
  - Entire image domain

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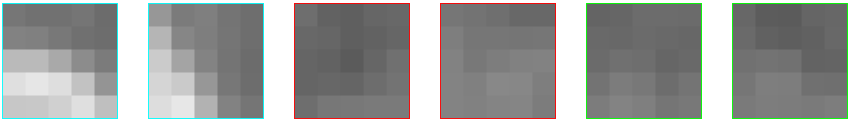

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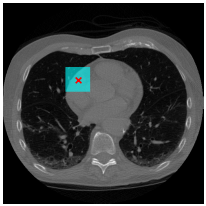

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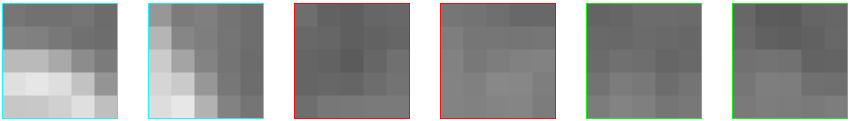

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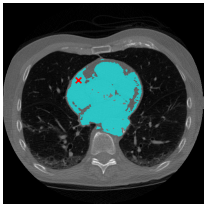

- Different search strategies for similar patches
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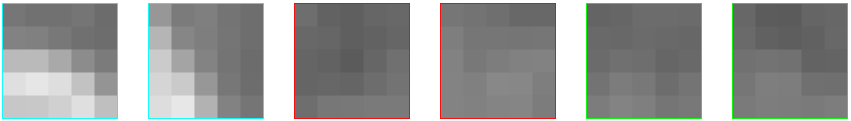

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adaptive denoising strength

- Different search strategies for similar patches
  - Entire image domain
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  - ⋆ Irregular region of homogeneous texture

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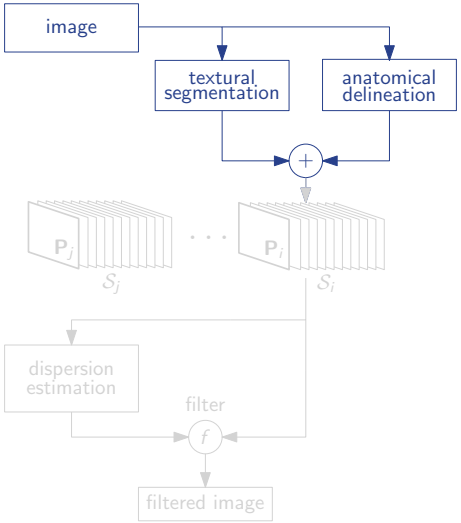
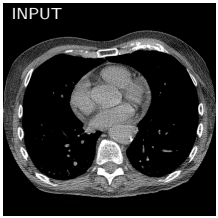
Purpose

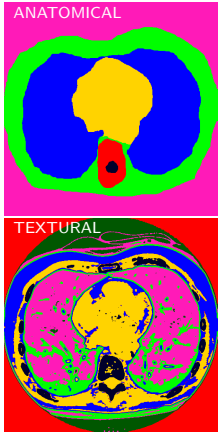
⋆ **ETA**-NLM: **E**dge- & **T**exture-**A**daptive Non-Local Means

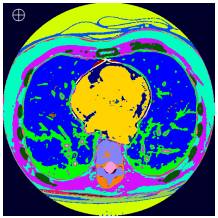
- Reduction of heteroskedastic noise in CT
- Preservation of edges and textures

Methods: Anatomical & textural segmentation





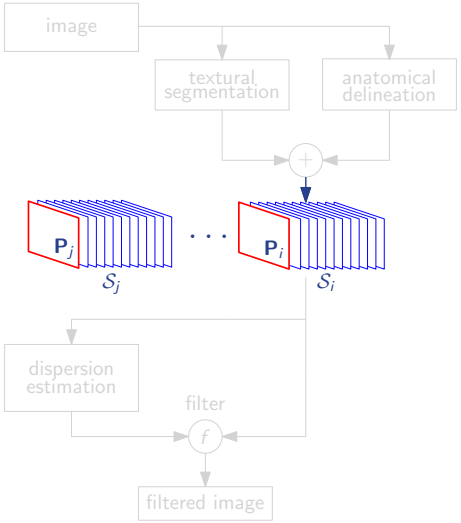




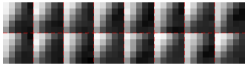
color denotes region label

⋆ Liu et al., SNAP talk SU-K-201-14, 59th AAPM AM, 2017

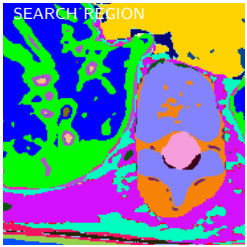
Methods: Similarity stacks over segmented regions

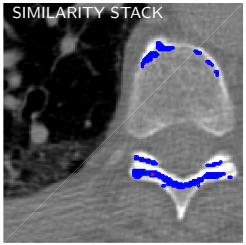


noisy patches in stack

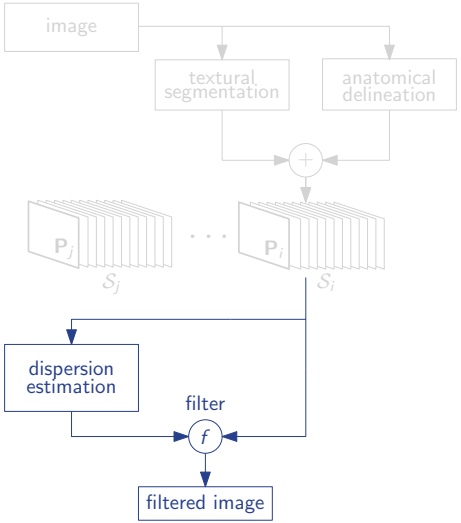


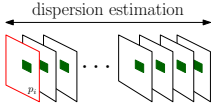
$\mathcal{S}_i$





Methods: Noise level estimation & filtering





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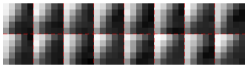
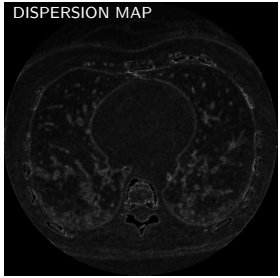
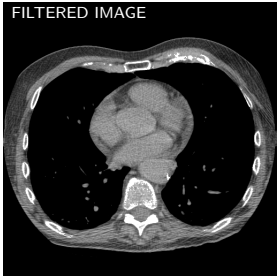






Materials & methods: Case study and evaluation

Comparison between *ETA-NLM* and NLM[1], BM3D[2]

- Equal values of relative residual image energy
- Quantitative measures
  - image standard deviation (STD)
  - structural similarity index (SSIM)[3]

The results shown here are in whole based upon data generated by the TCGA Research Network[4]

[1] Buades et al., Multiscale Model Simul, 2005

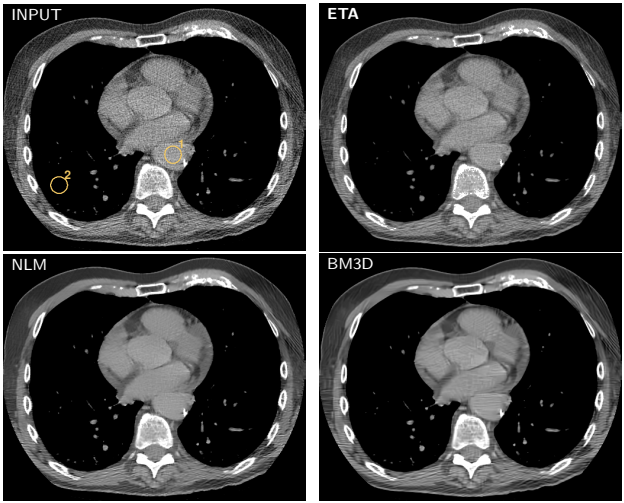
[2] Dabov et al., IEEE TIP, 2007

[3] Wang et al., IEEE TIP, 2004

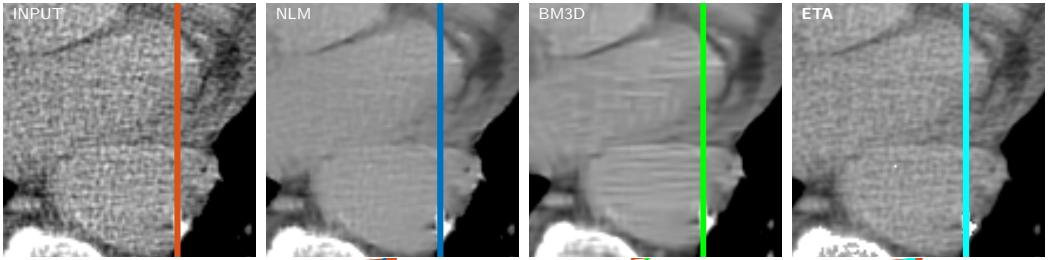
[4] Clark et al., Multiscale Model Simul, 2013; Kirk et al., Multiscale Model Simul, 2016; http://cancergenome.nih.gov/

Results: Multiple anatomical regions

	ROI-1		ROI-2	
	STD	SSIM	STD	SSIM
INPUT	38.92	1.000	50.58	1.000
NLM	9.27	0.316	26.85	0.495
BM3D	15.24	0.143	36.92	0.504
ETA	28.74	0.760	38.15	0.832



Results: Multiple anatomical regions – ROI



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ETA-NLM for low-dose CT denoising

- Extract and exploit anatomical structure and textures
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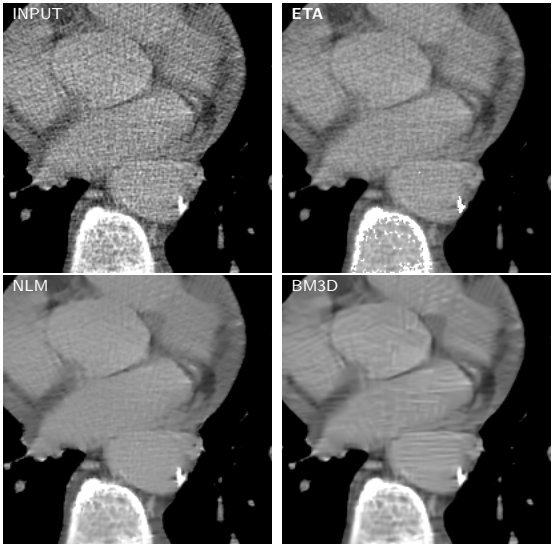

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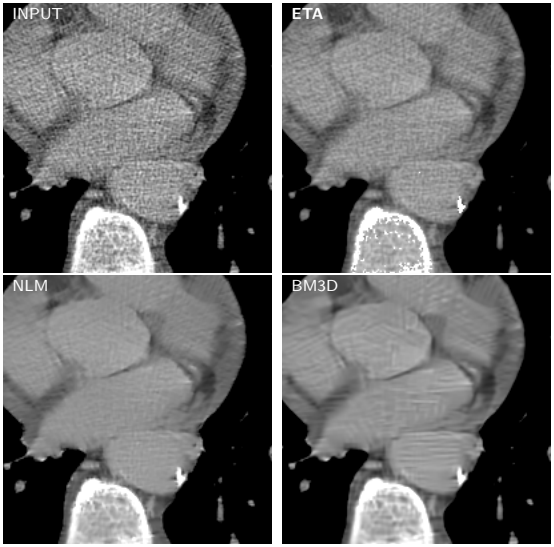

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⋆ Work in progress: *streak artifact removal*

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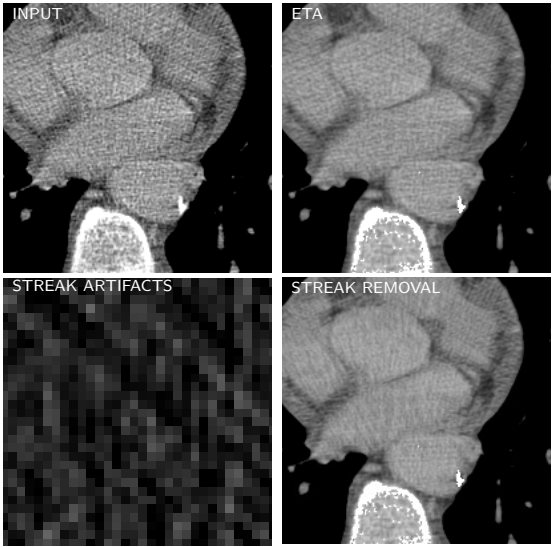

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