Explorable Data Consistent CT Reconstruction

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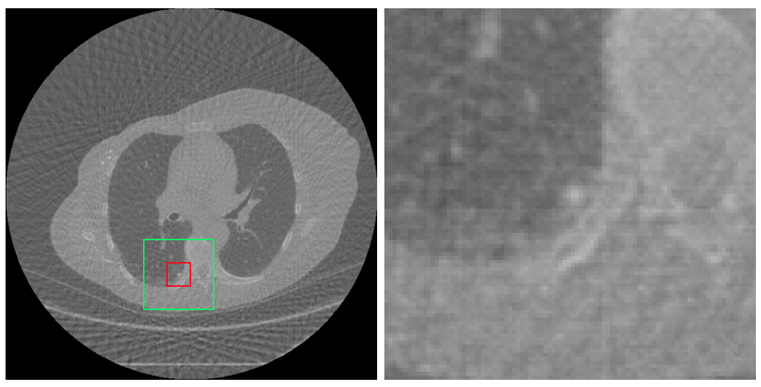
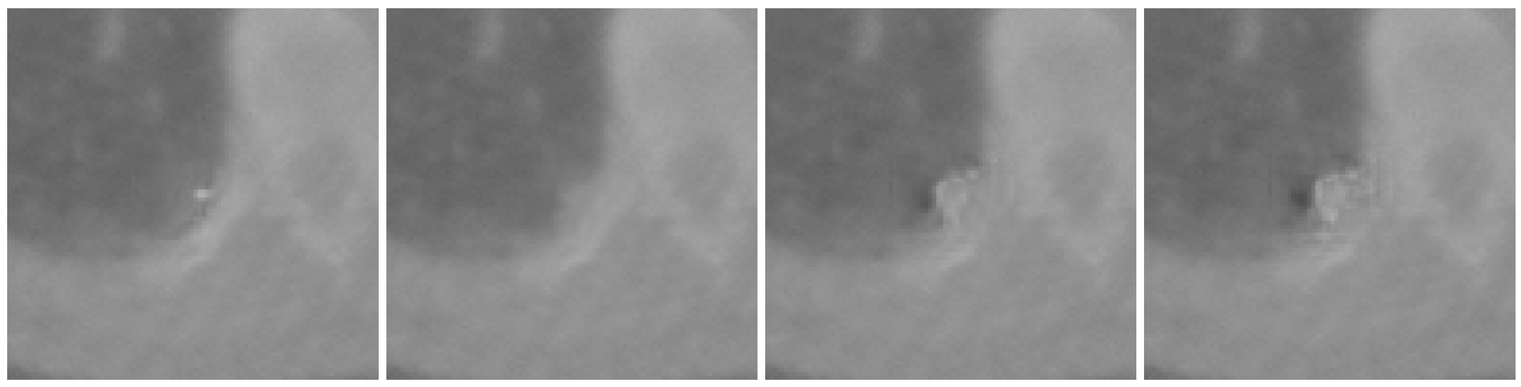


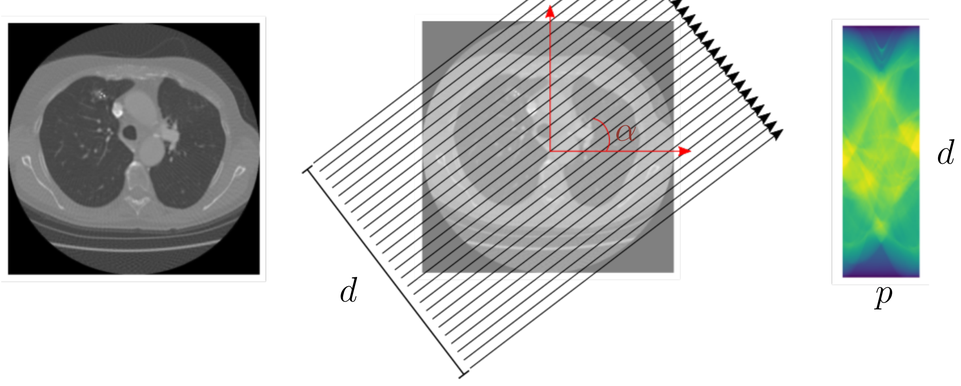
Reconstruction by Filtered Backprojection



Data Consistent Reconstructions (our approach)

Motivation & Idea

- Computed Tomography (CT):
  - ✓ Diagnosing various health conditions and devising treatment plans
  - ✗ Health risks such as cancer due to exposure to the X-ray radiation

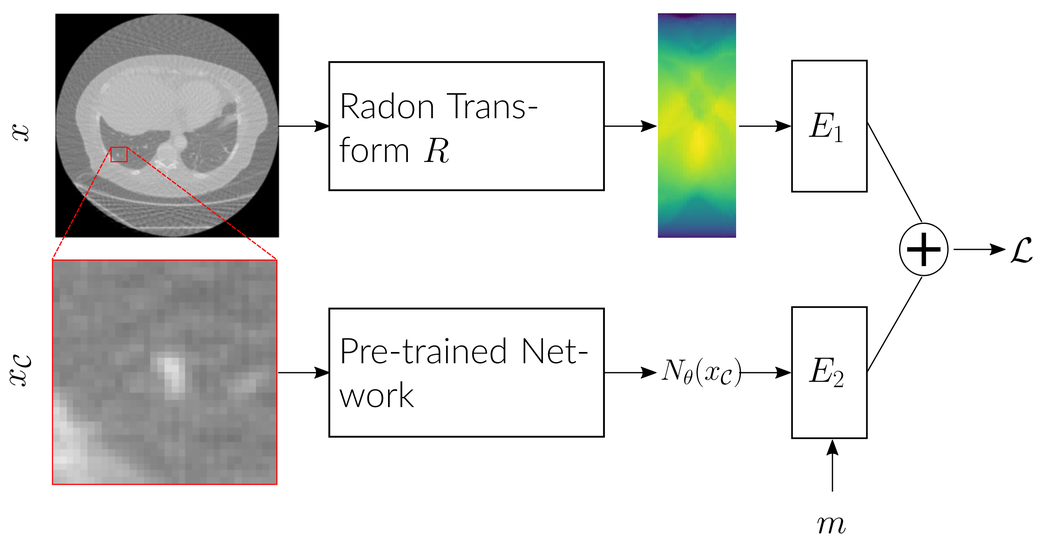


- *Sparse-view CT*: the target is radiated with fewer projection angles
- Reconstruction of a tomographic image x from a measured sinogram f

$$f = Rx + n,$$

- Exploration of the space of consistent reconstructions
  - Radon transform matches with the measured sinogram
  - Corresponding to semantically different interpretations, obtained from a pre-trained CT image classifier

Method



- Data Consistent Reconstruction:

$$\min_{x\in[0,1]^N} \frac{1}{pd}\|Rx - f\|^2 + \lambda H_\epsilon(N_\theta(x_{\mathcal{C}}) - m)$$

- **Transformations:** Utilize transformed (scaling, rotation) versions $T_j(x_{\mathcal{C}})$, to produce realistically looking CT reconstructions

$$\hat{x}(m) = \arg\min_{x\in[0,1]^N} \underbrace{\frac{1}{pd}\|Rx - f\|^2}_{=E_1(x)} + \underbrace{\lambda_1 \frac{1}{J}\sum_j H_\epsilon(N_\theta(T_j(x_{\mathcal{C}})) - m) + \lambda_2 TV(x_{\mathcal{C}})}_{=E_2(x)}$$

- **Soft Cropping:** To avoid visible artifacts in around the cropping boundary, the gradient descent update can be written as

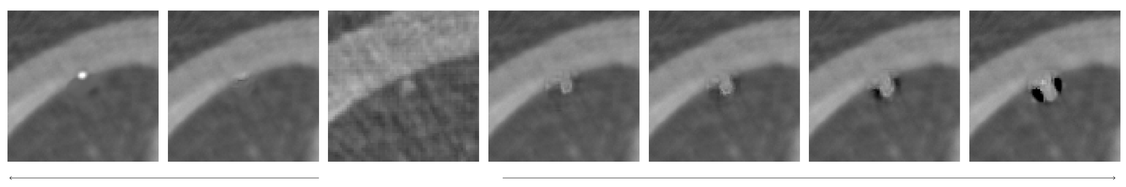
$$x^{i+1} = x^i - \tau(\nabla E_1(x^i) + G \odot \nabla E_2(x^i))$$

- **Training Suitable Classification Network:** Training of a classification network N_θ adversarially using the *Fast Gradient Sign Method*

CT data taken from Armato III, Samuel G., et al. "The lung image database consortium (LIDC) and image database resource initiative (IDRI): a completed reference database of lung nodules on CT scans." Medical physics 38.2 (2011): 915-931.

Realistic Solution Space

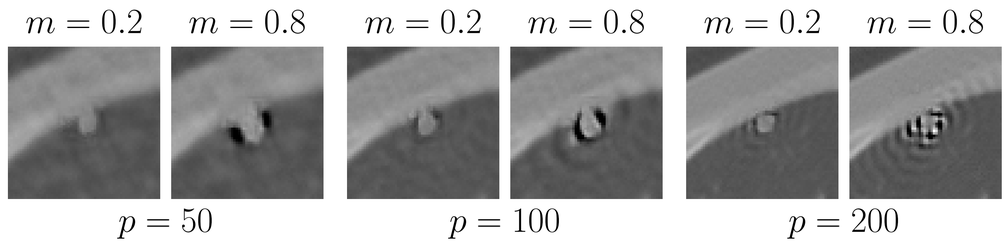
- Reconstructions of different malignancies (controlled by m)
- Space of underdetermined CT reconstructions ($p = 50$)



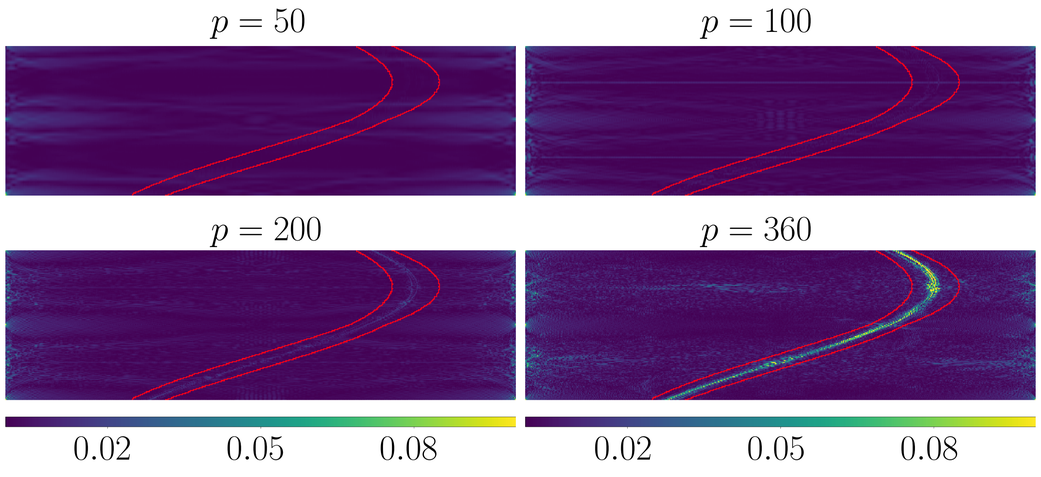
- Strong changes of m: visually unrealistic
- Small changes of m: realistic images & significant changes in the appearance of the nodule

Investigation on the Residuals

- Reconstruction: Tendency to allow larger variations in the reconstruction for fewer projection angles. For many projections, strong deviations can lead to severe artifacts.



- Residual: A modification in the nodule is easier to recognize for more projection angles. For fewer projection angles it is possible to modify the nodule without any sign of the exploration.



- Data consistency loss & the distance of the interior and the exterior error $(e_i - e_o)$ increase with increasing number of angles p

	set	p	$\frac{1}{pd}\|Rx - f\|^2 \cdot 10^5$	$N_\theta(x)$	$(e_i - e_o) \cdot 10^5$
optimizing for small N_θ	$S^{\mathcal{M}}$	50	2.09	0.003	-1.50
		100	3.36	0.099	-1.63
		200	30.16	0.423	309.01
		360	62.15	0.526	658.71
optimizing for large N_θ	$S^{\mathcal{B}}$	50	5.58	0.960	-3.73
		100	3.30	0.957	-1.26
		200	5.82	0.922	9.40
		360	13.45	0.802	86.85
FBP	$S^{\mathcal{B}} \cup S^{\mathcal{M}}$	50	$5.23 \cdot 10^5$	0.54	$-1.00 \cdot 10^5$
		100	$2.73 \cdot 10^5$	0.55	$-1.72 \cdot 10^5$
		200	$2.52 \cdot 10^5$	0.55	$-1.81 \cdot 10^5$
		360	$2.52 \cdot 10^5$	0.55	$-1.82 \cdot 10^5$