Solving Inverse Problems with Deep Learning

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CS & Physics Meet-Up by Lamarr & B3D - 30th November 2023

technische universität
dortmund

What is an Inverse Problem?

Inverse Problems

Reconstruct a signal $x \in \mathbb{R}^n$ from measurements

$$y = \mathcal{A}(x) + \epsilon \in \mathbb{R}^m,$$

where $\mathcal{A}$ is some (non-) linear measurement function and ε is noise.

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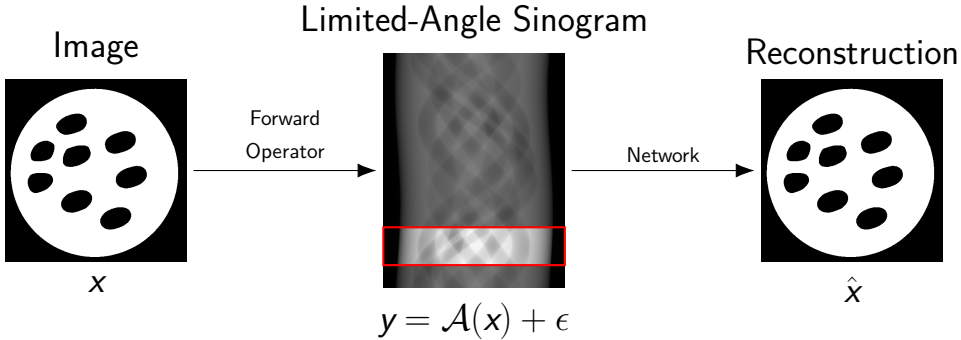
Examples:

- Denoising, Deconvolution, Inpainting
- Limited-angle tomography, phase retrieval
- Very-long-baseline interferometry (VLBI) imaging
- And many more...

Limited-Angle X-Ray Computed Tomography

Team: T. Germer, J. Robine, S. Konietzny, S. Harmeling, T. Uelwer

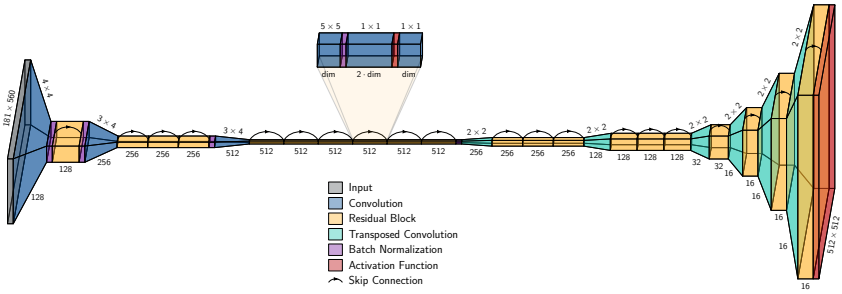


End-to-end Learning on Synthetic Data for CT Reconstruction [1]

Step 1 Generate synthetic images

Step 2 Simulate sinograms from images using ASTRA [2]

Step 3 Train reconstruction network for sinograms of similar images

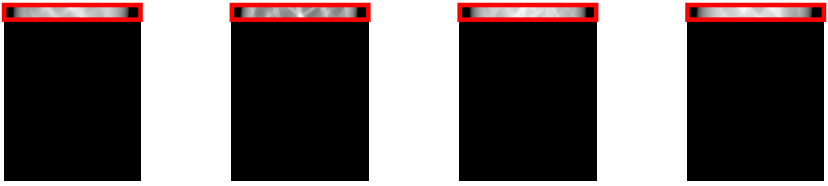


[1] Germer T, Robine J, Konietzny S, Harmeling S, Uelwer T. Limited-angle tomography reconstruction via deep end-to-end learning on synthetic data. Applied Mathematics for Modern Challenges. 2023

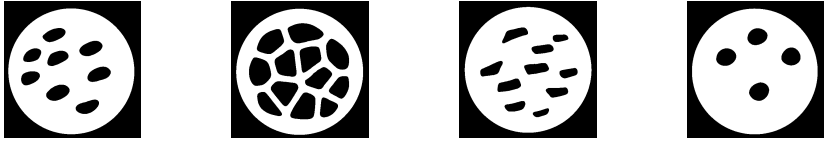
[2] Wim van Aarle, Willem Jan Palenstijn, Jeroen Cant, Eline Janssens, Folkert Bleichrodt, Andrei Dabravolski, Jan De Beenhouwer, K. Joost Batenburg, and Jan Sijbers. Fast and flexible X-ray tomography using the ASTRA toolbox. Optics Express, 24(22):25129--25147, 2016

End-to-end Learning on Synthetic Data for CT Reconstruction [1]

Limited angle sinogram



Limited angle reconstruction



Error to ground truth

Distributed Acoustic Sensing (DAS)

Team: S. Konietzny, V.H. Lai, T. Uelwer, M. Miller, J. Townsend, S. Harmeling

Measures ground motion as **strain rates** in the direction of a **fiber-optic cable**

Haast Pass Highway, New Zealand.

Distributed Acoustic Sensing (DAS)

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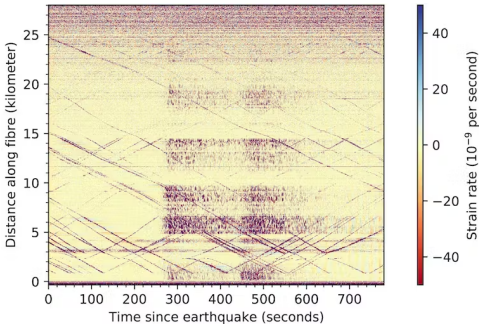
Measures ground motion as **strain rates** in the direction of a **fiber-optic cable**

- **Backscattered light pulses** are sent through the cable
- Observe **change in particle displacements** along the cable

Haast Pass Highway, New Zealand.

Distributed Acoustic Sensing (DAS)



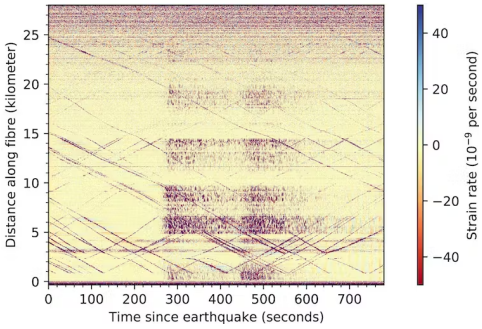
DAS recording of an M7 earthquake.

Distributed Acoustic Sensing (DAS)

Tasks:

- Remove coherent and incoherent noise
- Recover the underlying earthquake signal

Unlabeld data: evaluation relies on **synthetic data**



DAS recording of an M7 earthquake.

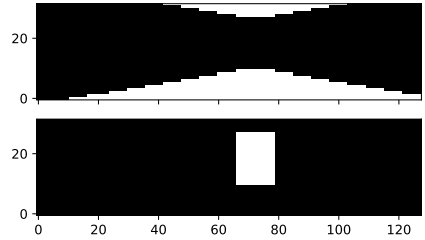
Denoising DAS Data using Self-Supervised Learning

Current approach is based on Noise2Self [3]:

- Define fixed **hourglass masks** m_h that can only process earthquake signals
- Predicting vehicle signals in **center regions** m_c using only region masked by the hourglass masks is not possible
- Minimize

$$\mathbb{E}_{(m_c, m_h)} \| m_c \cdot (g_\theta(m_h \cdot x) - x) \|_2^2, \qquad (1)$$

where g_θ is a parameterized function



Example 32×128 **hourglass mask** m_h (top) and its corresponding **center mask** m_c (bottom).

[3] Batson J, Royer L. Noise2self: Blind denoising by self-supervision. CoRR, abs/1901.11365, 2019

Thank you for your attention! Questions?

References

[1] Thomas Germer, Jan Robine, Sebastian Konietzny, Stefan Harmeling, and Tobias Uelwer. Limited-angle tomography reconstruction via deep end-to-end learning on synthetic data. *Applied Mathematics for Modern Challenges*, pages 0--0, 2023.

[2] Wim van Aarle, Willem Jan Palenstijn, Jeroen Cant, Eline Janssens, Folkert Bleichrodt, Andrei Dabravolski, Jan De Beenhouwer, K. Joost Batenburg, and Jan Sijbers. Fast and flexible X-ray tomography using the ASTRA toolbox. *Optics Express*, 24(22):25129--25147, 2016.

[3] Joshua Batson and Loïc Royer. Noise2self: Blind denoising by self-supervision. *CoRR*, abs/1901.11365, 2019.