Solving Inverse Problems with Deep Learning

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technische universität
dortmund

What is an Inverse Problem?

Inverse Problems

Reconstruct a signal ² R^j from measurements

$$´ = A(²) + \mathrm{R}^h,$$

where A is some (non-) linear measurement function and ε is noise.

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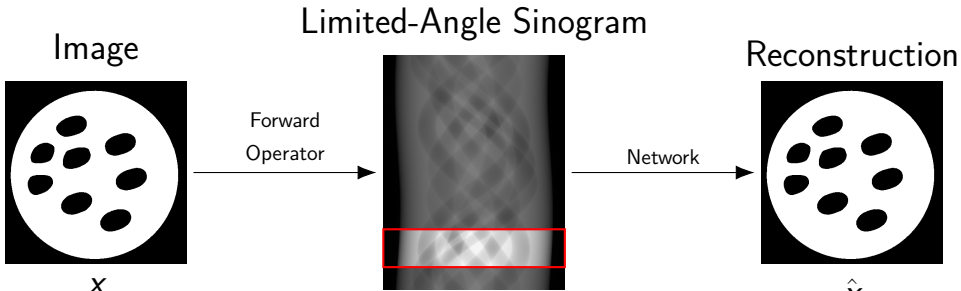
Examples:

- 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

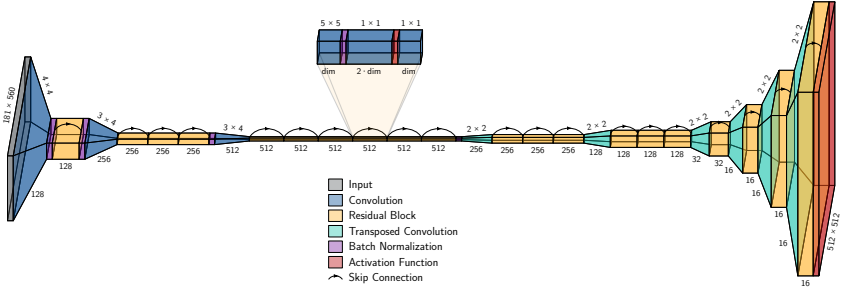


End-to-end Learning on Synthetic Data for CT Reconstruction [1]

Step 1 Generate synthetic images

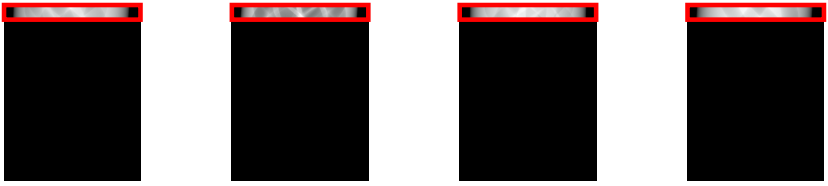
Step 2 Simulate sinograms from images using ASTRA [2]

Step 3 Train reconstruction network for sinograms of similar images

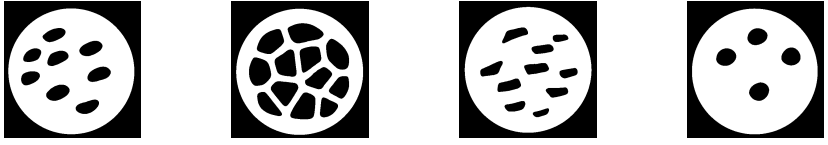


End-to-end Learning on Synthetic Data for CT Reconstruction [1]

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.

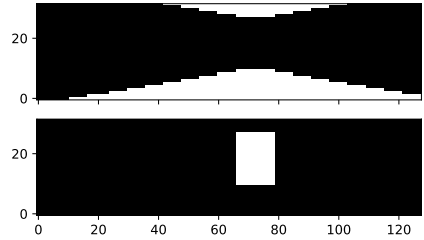
Denoising DAS Data using Self-Supervised Learning

Current approach is based on Noise2Self [3]:

- Define fixed **hourglass masks** $h_{\setminus}$ that can only process earthquake signals
- Predicting vehicle signals in **center regions** h_H using only region masked by the hourglass masks is not possible
- Minimize

$$\mathrm{E}_{(h_H, h_{\setminus})} \; h_H \cdot (X_\theta(h_{\setminus} \cdot ²) - ²) \; \overset{©}{©}, \qquad (1)$$

where X_θ is a parameterized function



Example 32 × 128 **hourglass mask** $h_{\setminus}$ (top) and its corresponding **center mask** h_H (bottom).

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. *8qqe_0L g 9§\0h 9§_H Tn} g nL0}j G\9ee0jX0* , 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. *mq§_H N²q}0* , 24(22):25129--25147, 2016.

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