M2 Internship Position
Unsupervised Learning for Imaging Inverse Problems

Keywords Imaging inverse problems, deep learning, unsupervised methods, scale invariance

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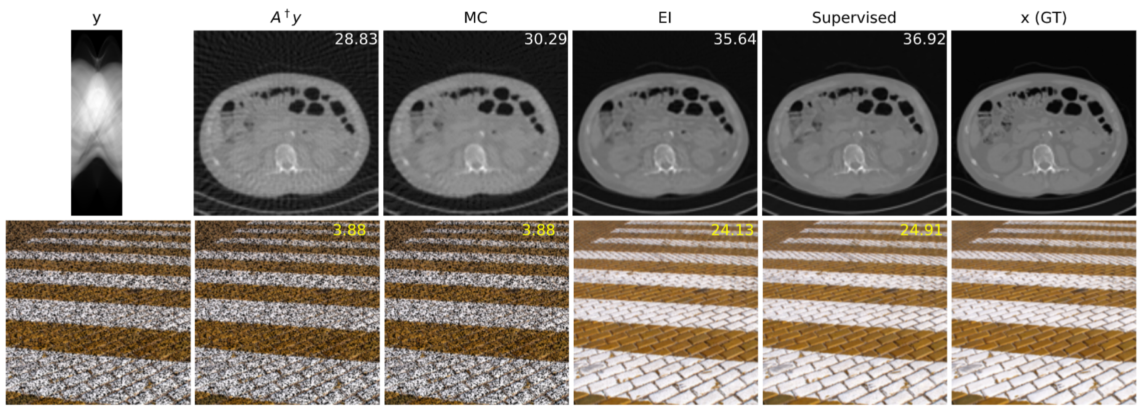

Figure 1: **Learning to image from only measurements [1]**. Training an imaging network through just measurement consistency (MC) does not significantly improve the reconstruction over the simple pseudo-inverse ($A^\dagger y$). However, by enforcing invariance in the reconstructed image set, *equivariant imaging* (EI) performs almost as well as a fully supervised network. **Top**: sparse view CT reconstruction, **Bottom**: pixel inpainting. PSNR is shown in top right corner of the images.

Context In recent years, deep neural networks have obtained state-of-the-art performance in multiple imaging inverse problems, such as computed tomography [2] and image super-resolution [3]. Networks are generally trained with supervised pairs of images and associated measurements. However, in various imaging problems, we usually only have access to incomplete measurements of the underlying images, thus hindering this learning-based approach. Learning from measurement data alone is impossible in general, as the incomplete observations do not contain information outside the range of the sensing process.

Recent advances in self-supervised learning methods have highlighted the possibility of learning from measurement data alone if the underlying signals are invariant to groups of transformations such as translations or rotations [4]. The potential of these unsupervised methods has been demonstrated on various inverse problems, including computed tomography and magnetic resonance imaging [1, 5]. However, invariance to translations and/or rotations are not enough for various band-limited inverse problems appearing in practice such as image deblurring or super-resolution [4]. This project will explore the use of scale invariance [6] to tackle such problems, investigate their theoretical properties and propose practical unsupervised learning algorithms using deep learning.

Subject The main goals of the internship will be:

1. Understand the challenges and fundamental limitations of unsupervised learning in the context of inverse problems.

2. Propose new practical deep learning-based unsupervised learning algorithms that enforce scale equivariance.

3. Study theoretical guarantees for learning from measurement data alone under scale invariance assumptions.

Skills The applicant should have a strong background on signal processing and machine learning and be proficient in Python programming. Knowledge of PyTorch and compressed sensing is a plus, although not mandatory.

Application Potential applicants are invited to write Julián with any question about the project or even to meet us at the physics department of ENS de Lyon. Applicants can contact us at `julian.tachella@ens-lyon.fr` and `patrice.abry@ens-lyon.fr`. Please include a CV and a statement of interest in your application email.

References

[1] Dongdong Chen, Julián Tachella, and Mike E Davies. Equivariant imaging: Learning beyond the range space. In *Proceedings of the IEEE/CVF International Conference on Computer Vision (ICCV)*, pages 4379–4388, October 2021.

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[6] Patrice Abry, Paolo Goncalves, and Jacques Lévy Véhel. *Scaling, fractals and wavelets.* John Wiley & Sons, 2013.