

Efficient covariance matrix estimation for imaging inverse problem with deep learning

– M.Sc. proposal in machine learning and signal/image processing –

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Context

Reconstructing a clean image from a degraded signal is an important problem in computer vision, which arises in numerous applications, including medical sciences, astrophysics or computational photography. It is typically an ill-posed inverse problem, so that there might exist several realistic solutions consistent with one given observation. In applications such as medical imaging where the recovered image is used to support a decision process, it is necessary to inform on the potential sources of uncertainty in order to enable the practitioner to produce the best and most reliable diagnostic.

Adopting a probabilistic framework, the uncertainty on the solution is fully characterized by the posterior distribution of the solution conditioned on the degraded observation. In particular, the covariance matrix associated with the posterior distribution provides valuable information on the uncertainty of the solution, as it can offer an interpretable visualization of the uncertain components in the solution, and it can be used to construct compact credible interval to perform uncertainty quantification [1, 2, 3]. However, estimating and manipulating the covariance matrix for large images is impractical because of its very-high dimensionality (for an image of n by n pixels, the covariance matrix is of size $n^2 \times n^2$).

This internship will investigate on how to obtain efficiently a compact approximation of the posterior covariance matrix in imaging inverse problems. The intern will review methods recently proposed to solve image inverse problems using learning-based regularization, and investigate how those methods can be extended to estimate the covariance matrix. One possible research direction would be to focus on methods parameterizing the posterior distribution by a conditional variational autoencoder [4, 5]. Another approach would be to adopt the *plug-&play* framework, which integrate a deep denoising neural network within an optimization or a sampling scheme in order to generate solutions [6, 7, 8, 9].

Keywords

Machine learning, signal & image processing, deep generative models, plug-&play image restoration.

Objectives

1. Make a brief review of the literature on algorithms for solving imaging inverse problem with deep learning and deep generative models.
2. Under the supervisors guidance, design a method to obtain an interpretable approximation of the posterior covariance matrix and visualize the uncertainty in the solution.
3. Implement the proposed method for a toy example, using Python.

Scientific environment

The M.Sc. student will benefit from a favorable context and will be able to rely on the most recent results and advances in machine learning and signal & image processing. He/she will integrate the [Signal and Communication team](#) of the IRIT lab, and will be mainly co-advised by the following researchers :

- [Jean Prost](#), Associate Professor at Toulouse-INP/ENSEEIH
- [Nicolas Dobigeon](#), Professor at Toulouse-INP/ENSEEIH and AI Research Chair at ANITI

Practical details

This internship shall take place in 2026, from February for a 6-month duration. The precise starting and ending dates can be adjusted according to the availability of the selected candidate.

The student will be hosted in the INP-ENSEEIH premises of the IRIT lab, located in the charming Saint-Aubin district of Toulouse city center.

The grant is about of 620 euros per month.

A **Ph.D. position** can be considered as a possible continuation of this M.Sc. training period, depending of the intern profile and internship outcomes.

Profile & requirements

Master or Engineering school students with major in applied mathematics, computer science or electrical engineering.

The knowledge needed for this work includes a strong background in **machine learning or data science, signal & image processing**. Good scientific programming skills (e.g., Python) and good communication skills in English, both written and oral are also expected.

Contact & application procedure

Applicants are invited to send (as pdf files)

- a detailed curriculum,
- official transcripts from each attended institution (in French or English).

to the co-advisors

- Jean Prost (email : jean.prost@toulouse-inp.fr)
- Nicolas Dobigeon (email : nicolas.dobigeon@toulouse-inp.fr)

Applicants will be contacted if their profiles meet the expectations. Review of applications will be closed when the position is filled.

References

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