Physics-inspired machine learning for joint reconstruction and unmixing in spectral medical imaging

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1 Presentation

1.1 Context

Spectral imaging is gaining popularity within the medical imaging community, specifically in the field of optical and X-ray imaging. This is due to the ability of spectral information to provide insight into the chemical composition of samples. Spectral cameras operating in the visible range enable optical biopsy in vivo, allowing surgeons to detect fluorescent markers on the brain surface, indicating the presence of cancerous cells.

1.2 Challenges

Most medical imaging modalities require the reconstruction of an image from an incomplete, noisy dataset. This is an ill-posed problem that typically necessitates prior knowledge of the solution, see Figure 1. Finding an effective prior for accurate reconstruction is generally challenging [4]. A related problem in spectral imaging is spectral unmixing [1], which involves estimating the spectra of the components of interest (such as fluorescent markers) to perform a soft classification of pixels in the image [3].

The proposed Ph.D. project aims to address the reconstruction and unmixing problems jointly. In particular, low-rank factorization typically used for spectral unmixing is anticipated to be an effective prior for image reconstruction. Joint spectral unmixing and image reconstruction is a challenging nonconvex multivariate optimization problem, whose solutions depend heavily on the chosen prior information. The project will explore recent data-driven (e.g., unrolled, plug-and-play) algorithms that bridge the gap between deep learning and handcrafted prior optimization and enable the learning of effective priors while benefiting from theoretical garantees. All algorithms will be evaluated on experimental measurements acquired by our in-house computational acquisition device. Lastly, the project will explore strategies to make use of the partial knowledge of spectra (knowledge is partial because the fluorescent spectrum depends on the local environment) [2].

2 Work environment

The PhD candidate will be part of the Myriad team in the CREATIS laboratory in Lyon/Villeurbanne. The PhD director will be Denis Friboulet, professor in team Myriad, and the thesis will be mainly supervised by Jeremy Cohen, CNRS researcher in team Myriad, and Nicolas Ducros, assistant professor in team TOMORADIO in CREATIS. Existing ANR projets LoRAiA and ULHYB provide sufficient funds to cover publication expenses, conference fees and potential international exchanges.

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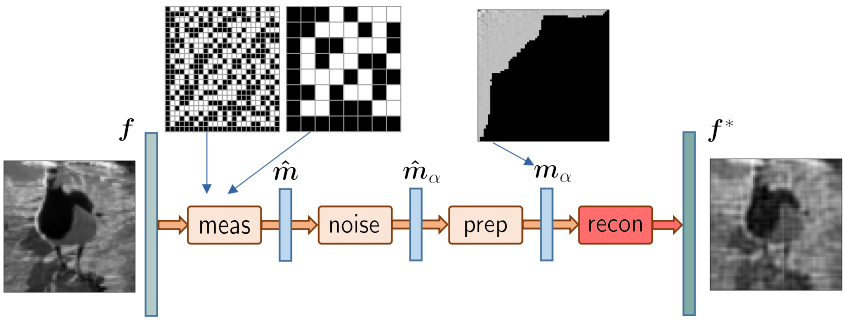

Figure 1: A graphical representation of the monochromatic single-pixel imaging system. An image $\mathbf{f}$ is measured by a linear filter consisting of Hadamard patterns (black and white matrices with squares). It is then affected by multiplicative noise, yielding a raw measurement vector $\hat{\mathbf{m}}_\alpha$. This measurement vector is preprocessed into $\mathbf{m}_\alpha$. Finally, we are left with the difficult task of reconstructing the image knowing the hadamard matrices and the measurements. In the context of spectral imaging, each pixel to reconstruct is in fact a full fluorescence spectrum.

3 Funding

The candidate will have to apply to the funding program of the doctoral school EEA, which is competitive. The PhD fundings are awarded primarily based on the candidate's academic results and his or her presentation of the project in front of the doctoral school's board.

4 Salary

The salary will follow the national standard, 2044€ bruts per month.

5 Skills requirement

Because of the intrinsic interdisciplinary nature of the project, the PhD candidate is expected to have prior knowledge in

- Linear algebra and Inverse Problems,
- Numerical optimisation and real-valued function analysis in general,
- Scientific programming languages such as Matlab or Python, and development in general,
- Machine learning paradigms.

Prior knowledge on image processing, in particular spectral unmixing or image reconstruction, is a plus.

Main qualities for the PhD candidate will be curiosity and creativity within formal aspects of inverse problems and learning in general, but also rigor in the experimental design and tests. The candidate should finally have a strong desire to produce reproducible research.

6 How to apply

Please contact Jeremy Cohen (jeremy.cohen@cnrs.fr) and Nicolas Ducros (nicolas.ducros@insa-lyon.fr) with a CV, a motivation letter and university grades.

References

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