DesCartes program: Research Fellow 1 year (WP3)

DesCartes Program is looking for one RF position in Optimization-driven hybrid AI.

1 Descartes program

The DesCartes program[1] is developing a hybrid AI, combining Learning, Knowledge and Reasoning, which has good properties (need for less resources and data, security, robustness, fairness, respect for privacy, ethics), and demonstrated on industrial applications of the smart city (digital energy, monitoring of structures, air traffic control). The program brings together 80 permanent researchers (half from France, half from Singapore), with the support of large industrial groups (Thales SG, Edf SG, ESI group, CETIM Matcor, ARIA etc.). The research will take place mainly in Singapore, at the premises of CNRS@CREATE.

WP3 aims at supporting the whole Descartes program in order to develop advanced optimization-based solutions in the context of hybrid AI. Any AI system or machine learning algorithm ultimately involves a formulation with an objective or loss function to be minimized. The modelling of the problem as well as the chosen objective function and optimization algorithm are crucial to the success of the overall AI task. This is all the more crucial in the context of hybrid AI, which seeks to integrate physics-inspired models with machine learning algorithms. We will address this problem from two complementary angles, namely optimization-based methods and machine learning-based methods.

2 Research objectives

Context Traditional approaches for the resolution of inverse problems (i.e, recovering x from noisy data $y = Ax + \varepsilon$) are usually based on solving optimization problems of the form

$$\arg\min_{x} \; \mathcal{D}(Ax; y) + \lambda \mathcal{R}(x) \tag{1}$$

where $\mathcal{D}$ measures the discrepancy between the model Ax and the data y, $\mathcal{R}$ imposes prior knowledge on the solution sought, and $\lambda > 0$ controls the trade-off between these two terms. Traditionally, the regularizer $\mathcal{R}$ was defined from a model-based perspective, provided the prior knowledge we have on the solution. Alternatively, modern approaches aim at learning the regularizer directly from the data. This can be achieved in several ways. For instance, plug-and-play (P&P) approaches [3] replace proximal (i.e., denoising) steps in optimization algorithms by state-of-the-art denoisers that can be specifically trained for the considered problem. Unrolled approaches [4], on their side, leverage the structure of optimizations algorithms for (1) in order to define neural network architectures. P&P and unrolled approaches fall within the scope of hybrid AI and are currently establishing themselves as the methods of choice for the resolution of inverse problems [3, 2, 6, 5].

Objectives Although the choice of the regularizer $\mathcal{R}$ has a significant impact on the quality of the computed solution, the measure of fit $\mathcal{D}$ should also be designed carefully for successful reconstruction. Ideally, it should be precisely adapted to the various degradations affecting the acquired data y [1] (e.g., noise, quantification, background signal). From a Bayesian point of view, given a specific noise, a natural choice for $\mathcal{D}$ is the associated negative log-likelihood. Yet, in practice these degradations are usually complex (e.g., mixture of

[1] https://descartes.cnrsatcreate.cnrs.fr/

noise, distortions, spurious signals) and unknown. As such, standard log-likelihoods are not the choice that best complies with the nature of the data.

Building upon the idea of unrolled algorithms, the RF will develop new reconstruction approaches that learn the measure of fit from data. Both supervised and unsupervised approaches will be explored.

Expected outcomes The developed solutions will be first tested on synthetic data. In a second time, they will be adapted to process real data obtained within the Descartes project. Various inverse problems will be considered as image restoration, sparse image processing, matrix factorization.
The produced codes will be shared under a GIT repository.

3 Experience & Qualifications

Profile We are looking for a highly motivated research fellow with a background in optimization, machine learning, signal and image processing. Strong abilities in computer sciences are required. Experience with Python is a plus.

Keywords Artificial Intelligence, Signal processing, Image processing, Optimization (convex, non convex), Machine learning, Deep learning, Programming (python).

Salary range 109K to 120K SGD (depending on suitability and experience)

Workplace address CREATE Campus, CREATE Tower, 1 Create Way #08-01 Singapore 138602

4 Further information & Contact

- Interested applicants please send your resume to Caroline Chaux (Prof) caroline.chaux@cnrs.fr, Emmanuel Soubies (Prof) emmanuel.soubies@irit.fr and Vincent Tan (Prof) vtan@nus.edu.sg.
- Please attach your full CV, with the names and contacts (including email addresses) of two character referees.

References

[1] C. Chaux, P. L. Combettes, J.-C. Pesquet, and V. R. Wajs. A variational formulation for frame based inverse problems. *Inverse Problems*, 23(4):1495–1518, Aug. 2007.

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[4] V. Monga, Y. Li, and Y. Eldar. Algorithm unrolling: Interpretable, efficient deep learning for signal and image processing. *IEEE Signal Process. Mag.*, 38(2):18–44, 3 2021.

[5] P. Nguyen, E. Soubies, and C. Chaux. MAP-informed unrolled algorithms for hyper-parameter estimation. In *Proc. Int. Conf. Image Process.*, pages 2160–2164, Kuala Lumpur, Malaysia, Oct. 2023.

[6] E. Z. C. Tan, C. Chaux, E. Soubies, and V. Y. F. Tan. Deep unrolling for nonconvex robust principal component analysis. In *IEEE Int. Workshop Mach. Learn. Signal Process.*, Roma, Italy, Sep. 2023.