DesCartes program: PhD (WP3)

DesCartes Program is looking for one PhD 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 [1] 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 $\mathcal{R}$ and the discrepancy $\mathcal{D}$ were defined from a model-based perspective, provided the prior knowledge we have on the solution and the knowledge we have on the various degradations affecting the acquired data y (e.g., noise, quantification, background signal).

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 Inspired by the P&P and unrolled approaches principles, the PhD will aim at designing hybrid AI architectures enabling the process of various inverse problems in image and signal processing.

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

The common thread will be to take advantage of the neural network architectures to learn important characteristics while exploiting the physics knowledge we have on the object of interest and/or the related parameters.
Attention will be paid to the convergence theoretical guaranties, ensuring explainability and interpretability of the proposed architecture.
Finally, the developments will be adapted and applied to real image and signal processing problem we face in Descartes program such as image restoration (mainly deblurring/denoising), compressed sensing (sparse signal processing) and (informed) source-separation, all these applications occuring in the context of the smart city.

3 Experience & Qualifications

Minimum:

- Master's degree in Mathematics, Computer Science, Computer Engineering or related fields.
- Background in Signal and Image processing, Optimization and Machine Learning.
- Familiarity with Python.

Desirable:

- Research experience in machine learning.

Salary Range: SGD 3200 to SGD 3700
Workplace Address: 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.