Optimization for sparse learning at scale

Mathieu Besançon **Jérôme Malick**

Université Grenoble Alpes, Inria, CNRS

mathieu.besancon@inria.fr, jerome.malick@univ-grenoble-alpes.fr

Context

In machine learning, sparsity drastically improves explainability, robustness, and efficiency of models. Training with sparsity constraints is much harder than pruning heuristics but comes with stronger guarantees on the quality of the trained models. We seek to improve the optimization algorithms used to train sparse models.

Exact and heuristic methods have been developed for these problems [1]. When the loss corresponds to a least square in particular, several approaches have been designed to explore the combinatorial space of possible supports, including conic relaxations [2], branch-and-bound [3], cutting planes [4], and proximal methods [5].

Internship Project

We will tackle sparse regression problems by building convex constrained relaxations tackled with gradient-based methods. These models can typically be trained by solving optimization problems of the form:

$$\min_{\theta} \sum_{i=1}^{N} f_i(\theta) + \lambda \|\theta\|_2^2$$

$$\text{s.t. } \|\theta\|_0 \leq k$$

where f_i are the losses associated with the data, and k and λ are hyperparameters.

During the internship, we will review different formulations for sparsity-constrained training and propose new algorithms to solve them. We will study their convergence guarantees and evaluate their effectiveness computationally.

The project will be a first-hand opportunity to dive into research and prepare for the start of a Ph.D. thesis in the group.

Environment

The intern will integrate the newly created research chair on Structured Optimization for Learning of the Grenoble MIAI Cluster for Artificial Intelligence, at the interface of the GHOST and DAO teams at the Université Grenoble Alpes. They will be supervised by Mathieu Besançon and Jérôme Malick, both researchers working on multiple facets of optimization and its application to learning problems.

The internship will be based on the campus of Université Grenoble Alpes, surrounded by great research and stunning mountains. The intern will benefit from the thriving Grenoble AI environment and will have opportunities to exchange with the international collaborators of the supervisors, in particular at the Zuse Institute Berlin.

Profile

We are looking for a candidate in their final Master's year, in applied mathematics, computer science, or operations research, for an internship planned for six months. Basics of optimization and of scientific computing (in Julia or Python) are mandatory.

How to apply

Applicants can reach out per email with a CV, an explanation of potential relevant experience, and references whom we can contact.

Bibliography

[1] A. M. Tillmann, D. Bienstock, A. Lodi, and A. Schwartz, "Cardinality minimization, constraints, and regularization: a survey," *SIAM Review*, 2024.

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[3] D. Hendrych, M. Besançon, and S. Pokutta, "Solving the Optimal Experiment Design Problem with Mixed-integer Convex Methods," in *Proceedings of the Symposium on Experimental Algorithms*, 2024.

[4] D. Bertsimas, R. Cory-Wright, and J. Pauphilet, "A unified approach to mixed-integer optimization problems with logical constraints," *SIAM Journal on Optimization*, 2021.

[5] J. Liu, S. Shafiee, and A. Lodi, "Scalable First-order Method for Certifying Optimal k-Sparse GLMs," *arXiv preprint arXiv:2502.09502*, 2025.