Post-doc offer in optimization

20 months – CentraleSupélec (Paris-Saclay University)

Relaxation methods for large-scale optimization and the management of electrical systems

Francis Bach · Nadia Oudjane · Laurent Pfeiffer · Adrien Séguret

Framework Our post-doc offer deals with the development and the analysis of new numerical methods for the resolution of non-convex and large-scale optimization problems. The targeted class of problems is motivated by applications in energy management, in particular for the management of fleets of small production or consumption units. The methods to be developed will rely on relaxation techniques with probability distributions.

The duration of the post-doc is 2 years. The hired person will be supervized by Francis Bach (Inria Paris), Nadia Oudjane (EDF R&D), Laurent Pfeiffer (Inria Saclay et CentraleSupélec), and Adrien Séguret (EDF R&D). He/she will be employed by the Inria Saclay research center and will mainly work at CentraleSupélec within the DISCO team. The post-doc is funded by the Inria-EDF Défi on the "management of tomorrow's electrical systems", a project gathering an active network of about 40 permanent researchers of Inria and EDF (Electricity of France).

Industrial context A major challenge in the management of the electrical system consists in maintaining at every time the balance between producted and consumed electrical power. This requires to leverage all available and controllable technologies: thermal and hydrolic power plants, batteries of electrical cars, thermal uses of electricity... While the massive integration of non-dispatchable energy sources may disturb the balance of the electrical system, consumption and storage flexibilities open up new possibilities to mitigate or to cancel those fluctuations.

The exploitation of the multiplicity of the flexibilities yields large-scale optimization problems, for which new algorithmic tools are needed.

Scientific context This research project is a continuation of the work [2], in which a distributed algorithm (named Stochastic Frank-Wolfe algorithm) is propozed for finding an approximate solution to an optimization problem involving many flexible agents. In its simplest form, the problem writes:

$$\min_{x_i \in X_i} f\Big(\frac{1}{N}\sum_{i=1}^{N} g_i(x_i)\Big), \tag{1}$$

where

- X_i denotes the (possibly nonconvex) decision set corresponding to the flexible agent i
- $g_i(x_i)$ denotes the production or consumption profil on a given time horizon (for example one day) of agent i
- f models the minimal production cost, supposed convex, used to satisfy the residual demand $D - \sum_{i=1}^{N} g_i(x_i)$, where D is the fixed non-dispatchable energy profile.

The article [2] proposes the following convex relaxation in which the optimization variables x_i are replaced by probability measures:

$$\min_{\mu_i \in \mathcal{P}(X_i)} f\Big(\frac{1}{N}\sum_{i=1}^{N}\int_{X_i} g_i \,\mathrm{d}\mu_i\Big). \tag{2}$$

It is shown, under regularity assumptions on f, that the relaxed problem is a good approximation of the original problem when the number of flexibilities N is large. The relaxed problem forms the basis of our numerical approach for finding an approximate global solution to the problem, despite its non-convexity.

Research axes The post-doc project aims at developing new approaches for the global resolution of large-scale optimization problems, that go beyond the abstract framework described in (1). The post-doc work will rely on the two extensions listed below, both motivated by concrete situations related to energy management.

1. **Non-convex coupling function.** The method developed in [2] relies in a crucial fashion on the convexity of f. This assumption is however restrictive and does not cover the case where the cost f for satisfying the residual demand involves conventional energy sources subject to non-convex constraints.

   We propose to develop a new method, combining the cutting-plane approach proposed in [1] with the Stochastic Frank-Wolfe introduced in [2], in order to handle the case where f is not convex.

2. **When the number of agents is not that large.** In view of capacity constraints in the electrical network, aggregative models involving only a moderate number of agents are of special interest. In this case the quality of the approximation (2) is deteriorated. We propose to develop numerical approaches based on the following problem:

$$\min_{\mu_i \in \mathcal{P}(X_i)} f\Big(\frac{1}{N}\sum_{i=1}^{N}\int_{X_i} g_i \,\mathrm{d}\mu_i\Big) + \frac{1}{N\varepsilon}\sum_{i=1}^{N} V_i(\mu_i), \tag{3}$$

   where $\varepsilon > 0$ and where $V_i(\mu_i)$ is a variance term. This non-convex problem may be seen as an interpolation between the two problems (1) and (2), corresponding to the limit cases when ε goes to 0 or to $+\infty$, respectively. It may be addressed with techniques for minimizing differences of convex functions [3].

Desired profile and material conditions The hired person will hold a PhD. He/she will be specialized in optimization theory and will have a good programming experience. PhD students about to defend their thesis are strongly encouraged to apply. Applications must include

- a curriculum vitae
- a concise research statement
- a cover letter, specifying a possible starting date
- the name of one or two personalities ready to support you.

The applications should be sent to the post-doc supervizors at the following e-mail addresses:

francis.bach@inria.fr nadia.oudjane@edf.fr laurent.pfeiffer@inria.fr adrien.seguret@edf.fr.

Applications will be processed on a rolling basis. Do not hesitate to contact Laurent Pfeiffer if you have any questions.

References

[1] O. Beaude, P. Benchimol, S. Gaubert, P. Jacquot, and N. Oudjane. A privacy-preserving method to optimize distributed resource allocation. *SIAM Journal on Optimization*, 30(3):2303–2336, 2020.

[2] J.F. Bonnans, K. Liu, N. Oudjane, L. Pfeiffer, and Cheng Wan. Large-scale nonconvex optimization: randomization, gap estimation, and numerical resolution. *SIAM Journal on Optimization*, 33(4):3083–3113, 2023.

[3] T. Lipp and S. Boyd. Variations and extension of the convex–concave procedure. *Optimization and Engineering*, 17:263–287, 2016.