MSc internship/PhD in mathematical optimization Tractable quasi-Newton non-smooth optimization methods for large scale data science

Announcement

Applications are invited for a 6-month MSc internship in mathematical data science and optimization. The successful candidate, if she/he gives entire satisfaction upon completion of the internship, would be offered a 3 year PhD. We have two PhD grants that are already secured thanks to an international collaborative funding. The preferred starting period of the internship is spring 2021, and the PhD is autumn 2021.

Scientific program

Context and motivations The context of this project is within the international funded project TRINOM-DS [1] between France (Caen) and Germany (Tuebingen). It is concerned with bringing novel systems in the field of light scattering, with applications to optical surface characterization.

Structured composite non-smooth optimization has proved to be extremely useful in data science, where a common trend is the deluge of large-scale multidimensional data, which drives the need for more efficient optimization schemes. While, so far, primarily, first-order schemes have been widely used to solve such optimization problems, they are quickly approaching their natural (and provable) limitations. In contrast, higher-order methods, in particular quasi-Newton ones, are hardly used due to their lack of scalability, the complexity in their mathematical analysis and the deployment in the non-smooth case. TRINOM-DS project will unlock these bottlenecks and develop theoretical, numerical and algorithmic advances to exploit the great potential of quasi-Newton-type schemes for non-smooth large-scale optimization problems, which are ubiquitous in data science. These algorithms will be developed in a variety of challenging settings, and are expected to have far reaching applications in data science, e.g., machine learning (optimal transport, deep learning, etc), imaging and computer vision. They will be implemented as fast optimization codes, possibly on dedicated architectures, that will be made publicly available following the philosophy of reproducible research.

Goals The goal of TRINOM-DS is to develop theoretical, numerical and algorithmic advances to enable tractable and provably guaranteed non-smooth and splitting-type quasi-Newton algorithms for large-scale optimization problems that are ubiquitous in data science. **Depending on her/his interest and proficiency in the field, the recruited candidate will work on one or several of the following projects** :

1. `https://mop.math.uni-tuebingen.de/research/trinomDS/index.shtml`.

WP. I New problem classes and algorithms. Modern data science applications lead to diverse types of optimization problems. Therefore, we plan to develop tractable quasi-Newton-type algorithms for various settings, each of which requires a special design of metric and solution of subproblems (variational inclusion problems, stochastic optimization, distributed optimization, non-convex optimization).

WP. II The dynamical system perspective. Viewing an iterative algorithm as a discrete version of a continuous dynamical system sheds new light on the properties of this algorithm, the geometry of its dynamics, offers Lyapunov functions that are useful for the study of its asymptotic behavior, and suggests new neighboring classes of algorithms. Our goal in this project is to systematically exploit the synergy between the two worlds for quasi-Newton methods which has never been done before. This is expected to help us to design new metrics, establish relation/equivalence to inertial methods, and obtain novel provably convergent quasi-Newton algorithms for non-smooth optimization.

WP. III Flagship applications. This project will target flagship applications in data science which are more ambitious and far larger scale than typical settings where quasi-Newton methods are currently used. Examples are machine learning problems, inverse problems and optimal transport.

Required background and skills

We are looking for a MSc student with a strong background in applied mathematics and optimization. Background in data science is a plus but not mandatory. The candidate should also have good programming skills, and good communication skills in English, both written and oral.

Host institution and place of work

The successful candidate will be hosted by the GREYC laboratory, in Caen, Normandy, France, with visits to the group or Prof ; Peter Ochs at the department of mathematics at the University of Tuebingen, Germany. The work will be carried out in a unique international environment involving collaboration and interaction with recognized experts in optimization and data science.

Supervisor

Applicants are requested to send a CV and a brief statement of research interests.

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MSc internship/PhD in mathematical data science and optimization
Data-driven and Model-driven Approaches for Inverse Problems in Imaging: Optimization and Learning Challenges

Announcement

Applications are invited for a 6-month MSc internship in mathematical data science and optimization. The successful candidate, if she/he gives entire satisfaction upon completion of the internship, would be offered a 3 year PhD. The funding is already secured thanks to an Artificial Intelligence chair funding. The preferred starting period of the internship is spring 2021, and the PhD is autumn 2021.

Scientific program

Inverse problems (e.g., 3D-reconstruction, shape-from-X, optical flow) have historically been solved by formulating them as an optimization problem, where the objective functional to be minimized has a composite structure, and involving a cost function derived from a physics-based forward model. Such model-based methods provide explainable results in a computationally-efficient way, yet their application remains limited by the physical model they rely on. On the other hand, in the last decade, the rise of deep learning has demonstrated that these limits may eventually be overpassed, as such methods replace the forward model by the redundancy of data. Still, the outcome of data-driven methods remains most of the times unexplainable ("black box"), and it happens very often that results do not respect very basic physical constraints. The objective of this research is thus to explore the possible combination of data-driven and model-driven techniques for designing state-of-the-art algorithms for solving inverse problems. The goals are :

- Design appropriate network architectures able to incorporate physical and mathematical constraints derived from model-based methods.
- Design efficient and scalable algorithms to solve the underlying optimization problems.
- Equip the developed approaches with grounded mathematical guarantees.

Required background and skills

We are looking for a MSc student with a strong background in applied mathematics, in particular in optimization and data science. Background in imaging and computer vision would be a plus but not mandatory. The candidate should also have good programming skills, and good communication skills in English, both written and oral.

Host institution and place of work

The successful candidate will be hosted by the GREYC laboratory, in Caen, Normandy, France. The work will be carried out in a unique multidisciplinary and international environment involving collaboration and interaction with recognized experts in optimization, machine learning and computer vision.

Supervisor

Applicants are requested to send a CV and a brief statement of research interests.

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