CSC one-pager round 2023

Project title: Variance reduced zero-order methods for hyperparameter tuning in deep neural networks and mathematical imaging.

Project leader: Dr. Mathias Staudigl

Function: Associate Professor

Collaborators (including promotor, if that is not the project leader): Prof. Dr. Ralf Peters (promoter), Dr. Joel Karel, Dr. Pietro Bonizzi

Proposal (250 words):

Introduction: Most algorithms, be it in optimization or any other field, depend on critical parameters that need to be tuned to achieve a satisfactory degree of computational accuracy and reliability. Specific application domains of interest where this is the case are the tuning or regularization hyperparameters in deep neural networks and variable projection methods in inverse problems, and variational regularization in mathematical imaging. The optimization method in action in all these different application domains is the general mathematical programming technique called bilevel optimization. Bilevel optimization can be seen as a leader-follower game, in which the leader solves an upper-level problem, fixing the hyperparameters, and a follower optimizes a lower-level problem, usually corresponding to a data fidelity function, for a given choice of parameters dictated by the leader. To solve such a two-stage optimization problem, a common assumption is that the lower-level problem can be solved exactly for each possible parameter configuration designed by the leader. This assumption is, however, practically infeasible.
Objectives: The aim of this project is to revisit optimal parameter tuning in variational regularization problems arising in computational imaging and deep learning. Our aim is to couple variance reduction algorithms in the lower-level problem, with derivative-free methods in the upper-level.This algorithm will be tested in medical imaging applications.
Methods: This project will improve upon the state-of-the-art by introducing variance reduction strategies, that are already prominent in machine learning, into a bilevel optimization framework.
Impact: This project is going to have significant impact on computational imaging and signal processing. The combination of variance reduction, optimal parameter tuning and bilevel optimization is new to the field, and will become a significant contribution to the community.

Requirements candidate: Highly motivated student with good English communication skills and proactive and resolute attitude. Excellent analytic and programming skills are also needed.

Keywords: Imaging, Variational Regularization, Stochastic Optimization, Variance Reduction

Top 5 relevant selected publications (of proposed research team, citations after 2017):

1. Bot, R., Mertikopoulos, P., Staudigl, M., & Vuong, P. T. (2021). Mini-batch forward-backward-forward methods for solving stochastic variational inequalities. Stochastic Systems, 11(2), 112-139.
2. Franci, Barbara, and Mathias Staudigl. "Mini-batch stochastic three-operator splitting for distributed optimization." IEEE Control Systems Letters (2022).
3. Cluitmans, Matthijs, et al. "Wavelet-promoted sparsity for non-invasive reconstruction of electrical activity of the heart." Medical & biological engineering & computing (2018): 2039-2050.
4. Ehrhardt, M.J., Roberts, L. Inexact Derivative-Free Optimization for Bilevel Learning. J Math Imaging Vis 63, 580–600 (2021)
5. M. Cluitmans, P. Bonizzi, J. Karel, M. Das, B. Kietselaer, M. de Jong, F. Prinzen, R. Peeters, R. Westra, and P. Volders. In vivo validation of electrocardiographic imaging. JACC: Clinical Electrophysiology, 2017, 3 (3), 232-242.