# Distributed Optimization and Applications

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**Timetable:** 20 hrs (see Class Schedule on https://phd.dei.unipd.it/course-catalogues/)

**Course requirements:** Advanced calculus, and probability theory and random processes.

**Examination and grading:** A project assignment for students in groups of 2 requiring about 20 hours of work.

**SSD:**

**Aim:** The aim of this course is to introduce postgraduate students to the topical area of Distributed Optimization. As we enter the era of Big Data, engineers and computer scientists face the unenviable task of dealing with massive amounts of data to analyse and run their algorithms on. Often such data reside in many different computing nodes which communicate over a network, and the availability and processing of the entire data set at one central place is simply infeasible. One needs to thus implement distributed optimization techniques with message passing amongst the computing nodes. The objective remains to achieve a solution that can be as close as possible to the solution to the centralized optimization problem. In this course, we will start with some history on the origins of distributed optimization algorithms such as the Alternating Direction Method of Multipliers (ADMM), discuss its properties, and applications to both convex and non-convex problems, and explore distributed statistical machine learning methods, and finish with discussions on very recent and largely open areas such as networked optimization. This course will provide a glimpse into this fascinating subject, and will be of relevance to graduate students in Electrical, Mechanical and Computer Engineering, Computer Science students, as well as graduate students in Applied Mathematics and Statistics, along with students dealing with large data sets and machine learning applications to Bioinformatics.

**Course contents:**

- Lectures 1-3: Precursors to distributed optimization algorithms: parallelization and decomposition of optimization algorithms (dual de- composition, proximal minimization algorithms, augmented Lagrangian and method of multipliers), The Alternating Direction Method of Multipliers (ADMM): (Algorithm, convergence, optimality conditions, stopping criteria, constrained convex optimization)
- Lectures 4-5: Applications of ADMM to machine learning problems: l1 norm problems, ADMM based methods for solving consensus and sharing problems, ADMM for non-convex problems and examples
- Lectures 6-8: Applications of distributed optimization to distributed machine learning, Federated Learning, distributed Newton methods
- Lectures 9-10: Networked Optimization (e.g. over a graph) and fully distributed optimization under communication constraints

**References:**

1. S. Boyd, N. Parikh, E. Chu, B. Peleato, and J. Eckstein, Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers, Foundations and Trends in Machine Learning, 3(1):1122, 2011.
2. Dimitri Bertsekas and John N. Tsitsiklis, Parallel and Distributed Computation: Numerical Methods, Athena Scientific, 1997.
3. S. Boyd and L. Vandenverghe, Convex Optimization, Cambridge University Press.
4. M. Zhu and S. Martinez, Distributed Optimization-Based Control of Multi-Agent Networks in Complex Environments, Springer, 2015.

Relevant recent papers will be referred to and distributed during the lectures.