1 DS 607: Course Logistics

This course focuses on designing optimization algorithms over non-Euclidean geometries. In particular, we will primarily study optimization over smooth manifolds in the first half of the course. A large part of the second half will focus on computational optimal transport including optimization under Wasserstein geometry.

Course slot

Slot 11: Tuesday and Friday 3:30 - 5:00pm

Pre-requisites

The students are expected to refresh their basics of linear algebra and (to some extent) optimization for this course. These include

- Linear algebra: vectors, vector spaces, inner products, norms, matrices, rank, eigenvalues, eigenvectors, matrix calculus, and related concepts. These can be refreshed using lectures by Gilbert Strang or Chandra Murthy.
- Optimization: Basics of convexity, gradient, Hessian, chain rule, gradient descent, line-search, Lipschitz continuous gradient, Newton direction, and related concepts. These can be refreshed using lectures by Ryan Tibshirani or Constantine Caramanis.
- Basics of probability and statistics (required primarily for the second half).
- Basics of machine learning (required for any ML-application specific project, if any).

Reference books

- Nicolas Boumal's online lectures on An introduction to optimization on smooth manifolds is an excellent reference. We will be using his book (Boumal, 2023) as the main reference book in the first half of the course.
- Other reference books in Riemannian optimization include Absil et al. (2008) and Sato (2021).
- Reference books on optimal transport: Computational optimal transport (Peyré & Cuturi, 2019) and Statistical optimal transport (Chewi et al., 2024).

Attendance

Attendance is compulsory. A maximum of 3 unapproved absences will be allowed. Additional absences must be pre-approved by the instructor. Missing more than 4 lectures without proper justification means you need to drop or fail the course.

Grading policy (tentative)

The final scores will be a weighted combination of the following:

- **Quizes:** In-person quiz in class.
- **Assignments:** Must be formally typeset in latex and submitted on moodle. You may discuss with your classmates while solving the assignments but (a) you must write it yourself, (b) their names should be mentioned on the top. We have zero tolerance towards plagiarism and it would lead to disciplinary action. Homework deadlines will be announced in the homework. No late submissions will be entertained.
- **Exams:** In-person midsem and endsen exams.
- **Course Project:** TBD.

References

Absil, P.-A., Mahony, R., and Sepulchre, R. *Optimization Algorithms on Matrix Manifolds*. Princeton University Press, Princeton, NJ, 2008. ISBN 978-0-691-13298-3. (Cited on page 2.)

Boumal, N. *An Introduction to Optimization on Smooth Manifolds*. Cambridge University Press, 2023. ISBN 9781009166164. doi: 10.1017/9781009166164. URL https://www.cambridge.org/core/books/an-introduction-to-optimization-on-smooth-manifolds/EAF2B35457B7034AC747188DC2FFC058. (Cited on page 2.)

Chewi, S., Niles-Weed, J., and Rigollet, P. Statistical optimal transport. *arXiv preprint arXiv:2407.18163*, 2024. doi: 10.48550/arXiv.2407.18163. URL https://arxiv.org/abs/2407.18163. (Cited on page 2.)

Peyré, G. and Cuturi, M. *Computational Optimal Transport: With Applications to Data Science*, volume 11 of *Foundations and Trends in Machine Learning*. Now Publishers, 2019. ISBN 9781680835502. doi: 10.1561/2200000073. URL https://ieeexplore.ieee.org/book/8641476. (Cited on page 2.)

Sato, H. *Riemannian Optimization and Its Applications*. SpringerBriefs in Electrical and Computer Engineering. Springer, 2021. doi: 10.1007/978-3-030-62391-3. URL https://link.springer.com/book/10.1007/978-3-030-62391-3. (Cited on page 2.)