Beyond Worst-Case Analysis with aspects in Mechanism Design and Computational Social Choice

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Worst-case analysis has long been the most prominent and well-established framework for studying the performance of algorithms and the tractability of computational problems. While worst-case analysis offers strong guarantees that algorithms will meet expectations, it is widely accepted that it is often unnecessarily pessimistic and uninformative about the tractability of problems in 'real-world' or 'natural' scenarios. For this reason, the trend to study problems beyond worst-case analysis emerged. Recently, this focus has also extended to the analysis of Mechanism Design and Computational Social Choice.

This course will begin with an introduction to various prominent beyond worst-case analysis notions and techniques related to the computational complexity of algorithms, including an in-depth analysis of some motivating algorithmic problems. After that, a brief introduction to Mechanism Design and Computational Social Choice (with an emphasis on distortion in voting) will be provided. Finally, we will present cutting-edge results from beyond worst-case analysis perspectives on these domains, with an emphasis on developing learning-augmented algorithms through prediction techniques.

Pre-requisites Basic familiarity with notions of algorithm analysis and complexity is recommended. Some previous familiarity with aspects from Algorithmic Game Theory will be appreciated but not required.

Detailed (tentative) syllabus:

- **Part 1:** Introduction to beyond worst-case analysis of algorithms: instance optimality, perturbation stability, smoothed analysis and more. Study cases such as Clustering, Max/Min Cuts, Linear Programming, etc.
- **Part 2:** Introduction to basic aspects and notions of Mechanism Mesing and Computational Social Choice, such as incentive compatibility, mechanisms without money, distortion in voting.
- **Part 3:** Present beyond worst case analysis results in Mechanism Design and Distortion in voting, such as perturbation stable analysis and learning augmented through predictions.

Some References

[1] Alexander Lindermayr, Nicole Megow, Bertrand Simon, Adam Polak, and Niklas Hahn. Algorithms with predictions site (ALPS). https:// algorithms-with-predictions.github.io/.

[2] Anshelevich, E., Filos-Ratsikas, A., Shah, N., & Voudouris, A. A. (2021). Distortion in Social Choice Problems: The First 15 Years and Beyond. https://arxiv.org/abs/2103.00911

[3] T. Roughgarden, Ed., Beyond the Worst-Case Analysis of Algorithms. Cambridge: Cambridge University Press, 2021.

[4] T. Roughgarden, Twenty Lectures on Algorithmic Game Theory. Cambridge: Cambridge University Press, 2016.