Learning Enhanced Optimization



1 Sep 2025 BOOTCAMP

INTERPLAY OF MACHINE LEARNING AND OPTIMIZATION

2 - 4 Sep 2025 INTERNATIONAL PHD SCHOOL

MACHINE LEARNING AND OPTIMIZATION

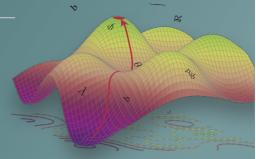
7 - 10 Oct 2025 SATELLITE WORKSHOP 1

LEARNING AUGMENTED ALGORITHMS

3 - 6 Nov 2025 SATELLITE WORKSHOP 2

LEARNED METHODS FOR OPERATIONS RESEARCH







Welcome

On behalf of the organizers, we are delighted to welcome you to the Workshop on Learning Augmented Algorithms, held at Centrum Wiskunde & Informatica (CWI) in Amsterdam, October 7–10, 2025. This workshop is part of the broader CWI Research Semester Programme on *Learning Enhanced Optimization*.

The programme features four keynote lectures, contributed and lightning talks, and provides ample time for open problem sessions and research discussions. We are grateful that the following four speakers accepted our invitation to give keynote lectures at the workshop: Eric Balkanski (Columbia University, USA), Marek Eliáš (Bocconi University, Italy), Nicole Megow (University of Bremen, Germany) and Sergei Vassilvitskii (Google Research, USA).

We very much hope that you will enjoy the workshop and your stay in Amsterdam.

Antonios Antoniadis, Guido Schäfer and Leen Stougie

(on behalf of the organizers Antonios Antoniadis, Daniel Dadush, Ruben Hoeksma, Debankur Mukherjee, Guido Schäfer, Leen Stougie, Marc Uetz, Bert Zwart)

Reaching CWI

The workshop takes place at Centrum Wiskunde & Informatica (CWI), Science Park 123, 1098 XG Amsterdam. CWI is situated in the Amsterdam Science Park area (see last page for a map).

All sessions of the conference are held in the **Turing room** (congress hall next to CWI).

CWI can be reached conveniently by public transport. Google Maps or http://9292.nl/en can be used to plan your journey.

The nearest train station is Amsterdam Science Park (about 6–10 minutes walk). There are several trains per hour from/to Amsterdam Central Station. The train ride takes 8–10 minutes (2 stops).

The other nearby train stations are Amsterdam Amstel and Amsterdam Muiderpoort. From Amsterdam Amstel (close to Hotel Casa) you can take bus 40 (towards Muiderpoort Station) and get off at Science Park Aer. From Amsterdam Muiderpoort you can take bus 40 (towards Amstel Station) and get off at Science Park Amsterdam.

In all public transportation including the train, you can check in and out with a Mastercard or Visa contactless credit card and also with Apple Pay and Google Wallet. At the website of Dutch Railways (NS) under FAQ "Travel with your debit card" you can read how it works. Please note that you have to **check out** when you leave the bus, tram or the station!

Registration Desk and WiFi Access

The registration desk is located next to the Turing room. If you need help for any specific issues during the workshop, please approach the staff at the registration desk, or get in

touch with Silke Kleinen.

CWI provides the *eduroam* wireless network that should be accessible by all workshop participants. But please be aware that it is not available in the Turing room.

Speaker Presentations

Speakers are kindly requested to be in the Turing room at least 10 minutes before their session begins to check their presentations. We strongly encourage you to upload your presentation in advance using the following link: http://www.cwi.nl/upload. Even if you plan to use your own laptop for the presentation, having a backup on our system is always a good idea. Please use the following naming convention when uploading:

 ${\tt LAA2025-presentation-[lastname].\{pdf|ppt|pptx\}}$

If you are using your own laptop, kindly ensure that all equipment is properly set up and functioning beforehand to allow for a smooth transition between talks.

Lunches, Reception and Workshop Dinner

All lunches will be served onsite. We will have a casual reception at the end of the first day (Tuesday) at 17:00 at CWI. Some light bites and beverages will be served.

The workshop dinner takes place at restaurant IJ Kantine. The address of the restaurant is NSDM-Kade 5, 1033 PG Amsterdam. We start at 19:00. Please be there on time.

Getting to the restaurant IJ-Kantine

- 1. Go to Amsterdam Central Station.
- 2. From Amsterdam Central Station, you have to take the ferry to the destination NDSM-Werf. The ferry departs from the **backside** of Amsterdam Central Station. The trip on the ferry is for free and takes about 13 minutes. From the destination NDSM-Werf it is less than one minute walking to the Restaurant IJ-Kantine. See here for directions via Google maps (use Ferry F4 NDSM-Werf).

Sponsors

The organization of this workshop would have been impossible without the financial support of our sponsors CWI, Networks, and VVSOR Operations Research.







Program, Tuesday, October 7, 2025

9:50-10:20	Registration & Coffee/Tea
10:20-10:30	Welcome (Guido Schäfer)
10:30-11:20	Introduction Round 1
11:20-11:40	Coffee/Tea
11:40-12:30	Introduction Round 2
12:30	Group photo
12:30-13:30	Lunch
	Chair: Leen Stougie
13:30–14:30	Invited Talk: Sergei Vasilvitski (online)
	New Directions in Algorithms with Predictions
14:30-15:00	Discussion
	Chair: Leen Stougie
15:00-15:20	Lightning Talks 1
	Christoph Dürr: Decision-Theoretic Approaches in Learning- Augmented Algorithms
	Bertrand Simon: Contract Scheduling with Distributional and Multiple Advice
15:30–16:00	Coffee/Tea
	Chair: Antonios Antoniadis
16:00-16:40	Contributed Talks 1
	Debmalya Panigrahi: Algorithms with Predictions via Convex Programming
	Christian Coester: Online Parking Permit via Learned Duals
17:00–18:30	Reception (Dutch appetizers and drinks)

Program, Wednesday, October 8, 2025

9:50-10:00	Coffee/Tea
10:00-11:00	Chair: Guido Schäfer Invited Talk: Eric Balkanski
10.00 11.00	Mechanism Design with Predictions
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11:00-11:30	Coffee/Tea
	Chair: Marc Uetz
11:30–12:30	Contributed Talks 2
	Jens Schlöter: Non-Clairvoyant Scheduling with Progress Bars
	Spyros Angelopoulos: Learning-Augmented Online Bidding in Stochastic Settings
	Xizhi Tan: Procurement Auctions with Predictions: Improved Frugality for Facility Location
12:30–13:30	Lunch
12.30-13.30	
13:30-14:30	Chair: Ruben Hoeksma Lightning Talks 2 & Open Problems
	Lene Favrholdt: Complexity Classes for Online Problems with (and)
	without) Predictions
	Pieter Kleer: Distributionally Robust Mechanism Design: How to
	Augment it?
14:30–15:30	Discussion & Collaboration
15:30-16:00	Coffee/Tea
	Chair: Guido Schäfer
16:00-16:40	Contributed Talks 3
	Vasilis Gkatzelis: Clock Auctions Augmented with Unreliable Advice
	Ioannis Caragiannis: Randomized Learning-Augmented Auctions with Revenue Guarantees
19:00–22:30	Dinner at IJ Kantine

Program, Thursday, October 9, 2025

9:50-10:00	Coffee/Tea
9.50-10.00	Chair: Ruben Hoeksma
10:00-11:00	Invited Talk: Nicole Megow
	The Power of Two Oracles: Minimum Spanning Tree and Matroid Optimization
11:00–11:30	Coffee/Tea Chair: Guido Schäfer
11:30-12:30	Contributed Talks 4
	Alkmini Sgouritsa: Mechanism Design Augmented with Incom- plete Prediction
	Giorgos Christodoulou: Learning-Augmented Coordination Mechanisms
	Yossi Azar: Load Balancing with Duration Predictions
12:30-13:30	Lunch
13:30–14:30	Chair: Marc Uetz Lightning Talks 3 & Open Problems
13.30-14.30	Annamaria Kovacs: The Communication Complexity of Combina-
	torial Auctions in Graphs
	Yasamin Nazari: Dynamic algorithms with prediction
14:30-15:30	Discussion & Collaboration
15:30–16:00	Coffee/Tea
	Chair: Antonios Antoniadis
16:00-16:40	Contributed Talks 5
	Joan Boyar: Distributed Graph Algorithms with Predictions
	Artem Tsikiridis: Mechanism Design with Outliers and Predictions

Program, Friday, October 10, 2025

9:50-10:00	Coffee/Tea
	Chair: Antonios Antoniadis
10:00-11:00	Invited Talk: Marek Eliáš
	Learning Challenges in Algorithms with Predictions
11:00–11:30	Coffee/Tea
	Chair: Ruben Hoeksma
11:30–12:10	Contributed Talks 6
	Georgios Kalantzis: Utilitarian Distortion with Predictions
	• Panagiotis Tsamopoulos: Online Budget-Feasible Mechanism Design with Predictions
12:10–12:30	Evaluation and Wrap-Up
12:30-13:30	Lunch

Invited Talks

Invited Talk, Tuesday, October 7, 2025, 13:30–14:30 (online)

Sergei Vassilvitskii (Google Research, USA)

New Directions in Algorithms with Predictions

Abstract:

The Algorithms with Predictions area has emerged as a vibrant research area that allows researchers to go beyond worst-case to analyze performance of algorithms and heuristics. In this talk we will review some of the recent work in the area with a specific focus on new directions, including distributional predictions, prediction portfolios, and applications to learning.

Homepage: https://theory.stanford.edu/~sergei/

Invited Talk, Wednesday, October 8, 2025, 10:00-11:00

Eric Balkanski (Columbia University, USA)

Mechanism Design with Predictions

Abstract:

This talk presents recent advancements in the design of strategyproof mechanisms in the learning-augmented framework. To exhibit the potential benefits of this approach, I will mostly focus on the problem of facility location with strategic agents. In this problem, a set of agents reports their locations in a metric space and the goal is to use these reports to open a new facility, minimizing an aggregate distance measure from the agents to the facility. However, agents are strategic and may misreport their locations to influence the facility's placement in their favor. The aim is to design truthful mechanisms, ensuring agents cannot gain by misreporting. We study both the egalitarian and utilitarian social cost functions, and propose new strategyproof mechanisms that leverage predictions to guarantee an optimal trade-off between consistency and robustness guarantees.

Homepage: https://ericbalkanski.com

Invited Talk, Thursday, October 9, 2025, 10:00-11:00

Nicole Megow (University of Bremen, Germany)

The Power of Two Oracles: Minimum Spanning Tree and Matroid Optimization

Abstract:

The performance of learning-based algorithms benefits from high-quality predictions, while remaining robust under unreliable predictions. Querying large models such as neural networks can provide highly accurate predictions, but often at significant computational cost. At the same time, lightweight heuristics or smaller models can return approximate information much faster, albeit with reduced reliability. In this talk, we introduce a two-oracle model that formalizes this setting by giving algorithms access to both a fast but noisy oracle and a slow but accurate one, enabling them to balance efficiency and solution quality. We discuss this model in the context of matroid optimization problems, which generalize many classical problems in combinatorial optimization. Our focus is on the maximum-weight basis problem and its special case, the minimum spanning tree. We analyze scenarios involving two different kinds of information: a structural oracle (the independence oracle) and a numerical oracle (weights of elements). We design algorithms that make provably few calls to the clean oracle while remaining robust against arbitrarily poor dirty oracles, thereby approaching the performance of classic algorithms.

Homepage: https://www.uni-bremen.de/en/cslog/nmegow

Invited Talk, Friday, October 10, 2025, 10:00-11:00

Marek Eliáš (Bocconi University, Italy)

Learning Challenges in Algorithms with Predictions

Abstract:

Learning-augmented algorithms use predictions generated by machine learning models to improve their performance beyond the classical worst-case lower bounds. In this talk, I will discuss various facets of the design of such algorithms which can be framed as learning problems. While the most apparent challenge lies in generating accurate predictions, additional considerations? such as the online estimation of prediction quality and the identification of distinct types of input instances? play an important role in enabling the algorithm to adapt its strategy in the usual setting with unknown prediction error and in scenarios where inputs are drawn from several distinct underlying distributions.

Homepage: https://elias.id

Contributed Talks

Speaker Spyros Angelopoulos

Title Learning-Augmented Online Bidding in Stochastic Settings

Abstract:

Online bidding is a classic optimization problem, with several applications in online decision-making, the design of interruptible systems, and the analysis of approximation algorithms. In this work, we study online bidding under learning-augmented settings that incorporate stochasticity, in either the prediction oracle or the algorithm itself. In the first part, we study bidding under distributional predictions, and find Pareto-optimal algorithms that offer the best-possible tradeoff between the consistency and the robustness of the algorithm. In the second part, we study the power and limitations of randomized bidding algorithms, by presenting upper and lower bounds on the consistency/robustness tradeoffs. Previous works focused predominantly on oracles that do not leverage stochastic information on the quality of the prediction, and deterministic algorithms.

Speaker Yossi Azar

Title Load Balancing with Duration Predictions

Abstract:

We study the classic fully dynamic load balancing problem on unrelated machines where jobs arrive and depart over time and the goal is minimizing the maximum load, or more generally the ℓ_p -norm of the load vector. Previous work studied either the *clairvoyant setting* in which exact durations are known to the algorithm, or the *unknown duration* setting in which no information on the duration is given to the algorithm. For the clairvoyant setting algorithms with polylogarithmic competitive ratios were designed, while for the unknown duration setting strong lower bounds exist and only polynomial competitive factors are possible. We bridge this gap by studying a more realistic model in which some estimate/prediction of the duration is available to the algorithm. We observe that directly incorporating predictions into classical load balancing algorithms designed for the clairvoyant setting can lead to a notable decline in performance. We design better algorithms whose performance depends smoothly on the accuracy of the available prediction. We also prove lower bounds on the competitiveness of algorithms that use such inaccurate predictions. Joint work with Niv Buchbinder and Tomer Epshtein

Speaker Joan Boyar

Title Distributed Graph Algorithms with Predictions

Abstract:

Algorithms with predictions have not previously been studied for distributed graph algorithms; we initiate such a study in synchronous message passing systems. Each node in the graph is given a prediction, which is some extra, possibly incorrect, information about the problem instance. We present a framework for evaluating distributed graph algorithms with predictions and transforming existing algorithms without predictions to effectively use predictions.

Speaker Ioannis Caragiannis

Title Randomized Learning-Augmented Auctions with Revenue Guarantees

Abstract:

We consider the fundamental problem of designing a truthful single-item auction with the challenging objective of extracting a large fraction of the highest agent valuation as revenue. Following a recent trend in algorithm design, we assume that the agent valuations belong to a known interval, and a (possibly erroneous) prediction for the highest valuation is available. Then, auction design aims for high consistency and robustness, meaning that, for appropriate pairs of values γ and ρ , the extracted revenue should be at least a γ - or ρ -fraction of the highest valuation when the prediction is correct for the input instance or not. We characterize all pairs of parameters γ and ρ so that a randomized γ -consistent and ρ -robust auction exists. Furthermore, for the setting in which robustness can be a function of the prediction error, we give sufficient and necessary conditions for the existence of robust auctions and present randomized auctions that extract a revenue that is only a polylogarithmic (in terms of the prediction error) factor away from the highest agent valuation.

Speaker Giorgos Christodoulou

Title Learning-Augmented Coordination Mechanisms

Abstract:

We study the fundamental problem of reducing the inefficiency of equilibria in congestion games via coordination mechanisms. We adopt the learning-augmented framework, and design a coordination mechanism that modifies the latency functions based on a predicted demand vector. Our main results are learning-augmented coordination mechanisms for both non-atomic and atomic congestion games that exploit the prediction to provide an equilibrium with much stronger performance guarantees whenever the advice is correct (consistency), while preserving worst-case guarantees even if the advice is arbitrarily far off (robustness).

Speaker Christian Coester

Title Online Parking Permit via Learned Duals

Abstract:

We present a learning-augmented online algorithm for the parking permit problem based on machine-learned predictions for the corresponding dual linear program. Unlike optimal primal solutions, which can change drastically under tiny instance perturbations, dual solutions are much more stable—and thus efficiently learnable. While previous work has used dual predictions in offline settings and for online maximization problems, our algorithm is, to the best of our knowledge, the first demonstration that dual predictions can be effective for online minimization. Based on joint work with Alex Turoczy.

Speaker Vasilis Gkatzelis

Title Clock Auctions Augmented with Unreliable Advice

Abstract:

We provide the first analysis of (deferred acceptance) clock auctions in the learning-augmented framework. These auctions satisfy a unique list of appealing properties that make them particularly well-suited for real-world applications. However, no deterministic clock auction with n bidders can achieve much better than a O(log n) approximation of the optimal social welfare, even in very simple settings. This overly pessimistic impossibility result heavily depends on the assumption that the designer has no information regarding the bidders' values. Leveraging the learning-augmented framework, we instead consider a designer equipped with some (machine-learned) advice regarding the optimal solution. Our main results are learning-augmented clock auctions that use this advice to achieve optimal trade-offs between robustness and consistency. We also consider a much stronger notion of consistency, which we refer to as consistency[∞], and we show that it implies lower bounds on the "cost of smoothness," i.e., on the achievable robustness if we also require that the performance of the auction degrades smoothly as a function of the prediction error.

Speaker Georgios Kalantzis

Title Utilitarian Distortion with Predictions

Abstract:

We study the utilitarian distortion of social choice mechanisms under the recently proposed learning-augmented framework where some (possibly unreliable) predicted information about the preferences of the agents is given as input. In particular, we consider two fundamental social choice problems: single-winner voting and one-sided matching. In these settings, the ordinal preferences of the agents over the alternatives (either candidates or items) is known, and some prediction about their underlying cardinal values is also provided. The goal is to leverage the prediction to achieve improved distortion guarantees when it is accurate, while simultaneously still achieving reasonable worst-case bounds when it is not. This leads to the notions of consistency and robustness, and the quest to achieve the best possible tradeoffs between the two. We show tight tradeoffs between the consistency and robustness of ordinal mechanisms for single-winner voting and one-sided matching, for different levels of information provided by as prediction.

Speaker Debmalya Panigrahi

Title Algorithms with Predictions via Convex Programming

Abstract:

I will talk about a new framework that uses convex programming duality to obtain online algorithms with predictions for a broad class of covering and allocation problems including load balancing, routing, and fair allocation. This is joint work with Ilan Cohen. Speaker Jens Schlöter

Title Non-Clairvoyant Scheduling with Progress Bars

Abstract:

In non-clairvoyant scheduling, the goal is to minimize the total job completion time without prior knowledge of individual job processing times. This classical online optimization problem has recently gained attention through the framework of learning-augmented algorithms. We introduce a natural setting in which the scheduler receives continuous feedback in the form of progress bars?estimates of the fraction of each job completed over time. We design new algorithms for both adversarial and stochastic progress bars and prove strong competitive bounds. Our results in the adversarial case surprisingly induce improved guarantees for learning-augmented scheduling with job size predictions. We also introduce a general method for combining scheduling algorithms, yielding further insights in scheduling with predictions. Finally, we propose a stochastic model of progress bars as a more optimistic alternative to conventional worst-case models, and present an asymptotically optimal scheduling algorithm in this setting. Based on joint work with Ziyad Benomar, Romain Cosson and Alexander Lindermayr.

Speaker Alkmini Sgouritsa

Title Mechanism Design Augmented with Incomplete Prediction

Abstract:

Our work revisits the design of mechanisms via the learning-augmented framework. In this model, the algorithm is enhanced with imperfect (machine-learned) information usually referred to as prediction. The goal is to use the prediction to design mechanisms with low approximation guarantees whenever the prediction is accurate (consistency), but at the same time to provide worst-case guarantees whenever the prediction is arbitrarily off (robustness). In algorithm design with predictions, various types of prediction models are considered, each providing different levels of information. Input predictions are generally more informative than output predictions/recommendations, as the latter can typically be derived from the former, but not vice versa. In this talk, we first discuss the consistency-robustness tradeoff for truthful mechanisms for the scheduling problem on unrelated machines under those two extreme types of predictions. We then explore a hybrid advice model combining a recommendation about the output allocation with a partial prediction of the input types. Investigating intermediate forms of prediction offers insight into the amount of information required to achieve performance guarantees comparable to those obtained with full input predictions. This is a joint work with Giorgos Christodoulou and Ioannis Vlachos.

Speaker Xizhi Tan

Title Procurement Auctions with Predictions: Improved Frugality for Facility Lo-

cation

Abstract:

We study the problem of designing procurement auctions for the strategic uncapacitated facility location problem: an agency needs to procure a set of facility locations

in order to open new facilities for its customers. The owner of each location has a private cost for providing access to that facility (e.g., renting it or selling it) and needs to be compensated accordingly. The goal is to design auctions that decide where to open the facilities and how much to pay the corresponding owners, aiming to minimize the total cost, i.e., the opening cost paid to the owners and the total distance between the customers and the opened facilities. We evaluate the performance of these auctions using the frugality ratio. We first analyze the performance of the classic VCG auction in this context and prove that its frugality ratio is exactly 3. We then leverage the learning-augmented framework and design auctions that are augmented with predictions regarding the owner's true opening costs. Specifically, we propose a family of learning-augmented auctions that achieve significant payment reductions, leading to much better frugality ratios, when the predictions are accurate. At the same time, we demonstrate that these auctions remain robust even if the predictions are arbitrarily inaccurate, and maintain reasonable frugality ratios even under adversarially inaccurate predictions. We then extend this result to provide a family of "error-tolerant" auctions that perform well even if the prediction is approximately accurate, and we provide bounds regarding their frugality ratio as a function of the prediction error.

Speaker Panagiotis Tsamopoulos

Title Online Budget-Feasible Mechanism Design with Predictions

Abstract:

Augmenting the input of algorithms with predictions is an algorithm design paradigm that suggests leveraging a (possibly erroneous) prediction to improve worst-case performance guarantees when the prediction is perfect (consistency), while also providing a performance guarantee when the prediction fails (robustness). Recently, Xu and Lu [2022] and Agrawal et al. [2024] proposed to consider settings with strategic agents under this framework. In this paper, we initiate the study of budget-feasible mechanism design with predictions. These mechanisms model a procurement auction scenario in which an auctioneer (buyer) with a strict budget constraint seeks to purchase goods or services from a set of strategic agents, so as to maximize her own valuation function. We focus on the online version of the problem where the arrival order of agents is random. We design mechanisms that are truthful, budget-feasible, and achieve a significantly improved competitive ratio for both monotone and non-monotone submodular valuation functions compared to their state-of-the-art counterparts without predictions. Our results assume access to a prediction for the value of the optimal solution to the offline problem. We complement our positive results by showing that for the offline version of the problem, access to predictions is mostly ineffective in improving approximation guarantees.

Speaker Artem Tsikiridis

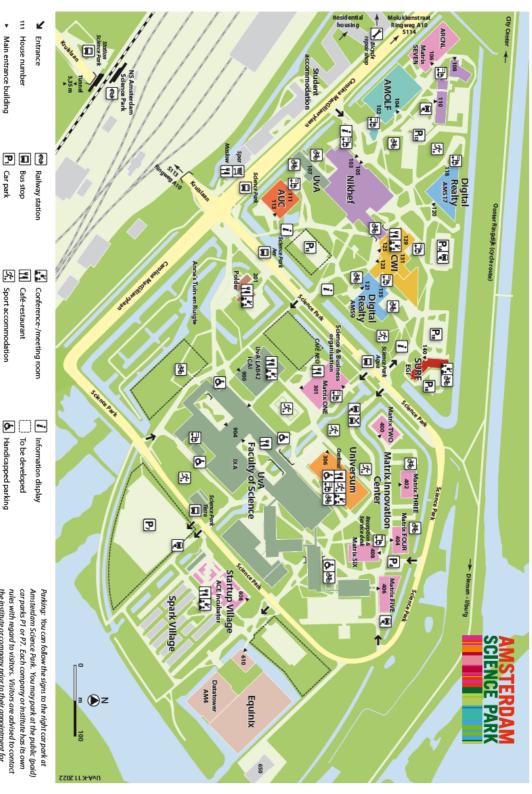
Title Mechanism Design with Outliers and Predictions

Abstract:

We initiate the study of mechanism design with outliers, where the designer can discard z agents from the social cost objective. This setting is particularly relevant when some agents exhibit extreme or atypical preferences. As a natural case study, we con-

sider facility location on the line: n strategic agents report their preferred locations, and a mechanism places a facility to minimize a social cost function. In our setting, the z agents farthest from the chosen facility are excluded from the social cost. While it may seem intuitive that discarding outliers improves efficiency, our results reveal that the opposite can hold. We derive tight bounds for deterministic strategyproof mechanisms under the two most-studied objectives: utilitarian and egalitarian social cost. Our results offer a comprehensive view of the impact of outliers. We first show that when z > n/2, no strategyproof mechanism can achieve a bounded approximation for either objective. For egalitarian cost, selecting the (z+1)-th order statistic is strategyproof and 2-approximate. In fact, we show that this is best possible by providing a matching lower bound. Notably, this lower bound of 2 persists even when the mechanism has access to a prediction of the optimal location, in stark contrast to the setting without outliers. For utilitarian cost, we show that strategyproof mechanisms cannot effectively exploit outliers, leading to the counterintuitive outcome that approximation guarantees worsen as the number of outliers increases. However, in this case, access to a prediction allows us to design a strategyproof mechanism achieving the best possible trade-off between consistency and robustness. Finally, we also establish lower bounds for randomized mechanisms that are truthful in expectation.

Joint work with Argyrios Deligkas, Eduard Eiben, Sophie Klumper and Guido Schäfer. ArXiv Preprint: https://arxiv.org/abs/2509.09561.



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