MATCH-UP 2022

6th Interdisciplinary, International Workshop on Matching Under Preferences

August 24–26, 2022, TU Vienna, Austria

www.ac.tuwien.ac.at/matchup2022

TECHNISCHE UNIVERSITÄT WIEN

Vienna Center for Logic and Algorithms

Vienna Science and Technology Fund

Organization

Workshop Venue

TU Vienna, Vienna, Austria
Address: Freihaus building of TU Vienna, 2nd floor, Lecture hall 8
Wiedner Hauptstraße 8-10
1040 Wien

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Preface

This is the 6th international, interdisciplinary workshop on Matching Under Preferences, MATCH-UP 2022, which takes place on August 24–26, 2022, at TU Vienna, Austria and is co-located with the 47th International Symposium on Mathematical Foundations of Computer Science (MFCS) conference.

The remit of the MATCH-UP series of workshops is to explore matching problems with preferences from the perspective of algorithms and complexity, discrete mathematics, combinatorial optimization, game theory, mechanism design, and economics. Thus, a key objective is to bring together the research communities of the related areas. Another important aim is to convey the excitement of recent research and new application areas, exposing participants to new ideas, new techniques, and new problems.

As in previous editions, we invited two types of submissions. Format A papers were required to be original, not previously published in (or accepted by) another conference proceedings or journal, and not under review for a conference or journal elsewhere. Format B papers had no such restrictions. Both types of papers were restricted to at most twelve pages, not counting appendices. Format A papers got higher priority in the decision making. In a positive response to our call for papers, we received a record number of 91 submissions (36 Format A and 55 Format B), which were quite well-balanced between the economics and computer science communities.

Due to time constraints and our desire to give every speaker enough time to discuss their results, we accepted 30 submissions (16 Format A and 14 Format B), and extended our workshop from two full days to two and a half days. To give more authors an opportunity to present their work, we additionally accepted twelve papers for poster presentation at an evening session on August 24th. We feel that the accepted papers and posters represent an excellent snapshot of the current state of the art regarding research in the area of matching problems with preferences; topics include school choice, many-to-many matchings, combinatorics of stable matchings, fairness in mechanism design, paper assignment, house and resource allocations, experiments, machine learning, and computational aspects of popular matchings, matching manipulations, and envy-free matchings.

We would like to thank the Program Committee (and additional reviewers), our invited speakers Sophie Bade and Vijay Vazirani, and the authors of all submitted papers for their important contributions to the scientific aspects of this workshop. Moreover, we would like to thank the members of the Organizing Committee, for all of their efforts. Additionally we thank several colleagues and students at the TU Vienna for their assistance, namely Doris Brazda, Andreas Müller, Michael Huber, and the organizers of the MFCS 2022 conference for welcoming our workshop to be co-located with their conference, and the wonderful suggestions to share an invited speaker, namely Vijay Vazirani.

Last but not least, we gratefully acknowledge the sponsorship that we received from TU Vienna and VCLA (Vienna Center for Logic and Computation) to cover the expenses of the invited speakers, and WWTF (Vienna Science and Technology Fund) to cover the venue rental fees and overhead (grant number VRG18-012).

MATCH-UP 2022 organizing and program committee co-chairs:
Jiehua Chen, David Manlove, and Alexander Teytelboym

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MATCH-UP 2022 Program

Talks and posters.

- Keynote by Vazirani takes places in lecture hall 1 (1st floor).
- Keynote by Bade and all oral presentations take place in lecture hall 8 (2nd floor).
- The poster session and all coffee breaks take place in front of lecture hall 8.

Lunches and group photo.

- All lunches take place in the mensa (1st floor). Lunch service only available until **13:30**!
- Group photo in front of the main building of TU Vienna (Karlsplatz).

Workshop dinner at a *Heuriger*.

- Heuriger: Fuhrgassl-Huber.
- Date: Thursday, August 25, 19:30
- Location: Neustift am Walde 68, 1190, Wien
- Transport: A shuttle bus will depart at 18:30 from Wiedner Hauptstrasse/Resselgasse. The shuttle bus for the way back leaves at 22:00.

Wednesday, August 24	
13:30–14:15 Registration	
14:15–14:30 Opening Remarks	
14:30–14:55	Cantillon, **Chen**, Pereyra: *Respecting priorities versus respecting preferences in school choice: When is there a trade-off?*
14:55–15:20	**Ehlers**: *Student-Optimal Interdistrict School Choice: District-Based versus School-Based Admissions*
15:20–15:45	**Dreyfuss**, Glicksohn, Heffetz, Romm: *Deferred Acceptance with News Utility*
15:45–16:30 Coffee Break	
16:30–16:55	Faenza, **Zhang**: *Affinely representable lattices, stable matchings, and choice functions*
16:55–17:20	Alkan, **Yıldız**: *Modular stable matching mechanisms*
17:20–17:45	Aziz, Baychkov, **Biró**: *Cutoff stability under distributional constraints with an application to summer internship matching*
17:45–19:30 Poster Session	

Thursday, August 25		Friday, August 26	
9:00–9:25	**Heeger**, Cseh: *Popular matchings with weighted voters*	9:00–10:00	Keynote: **Sophie Bade** *A procession of Royals: Incentives, Efficiency and Fairness in Two-sided Matching*
9:25–9:50	Biró, **Csáji**: *Strong core and Pareto-optimal solutions for the multiple partners matching problem under lexicographic preferences*		
9:50–10:15	**Rozenzweig**, Meir, Mattei: *Mitigating Skewed Bidding for Conference Paper Matching*		
10:15–10:40	**Ravindranath**, Feng, Li, Ma, Kominers, Parkes: *Deep Learning for Two-Sided Matching*	10:00–10:25	Arnosti, **Bonet**, Sethuraman: *A Systematic Approach to Selection Problems*
10:40–11:10 Coffee Break		10:25–10:50	**Feng**, Klaus, Klijn: *Characterizing the Coordinatewise Top-Trading-Cycles Mechanism for Multiple-Type Housing Markets*
11:10–11:35	Gonczarowski, Heffetz, **Thomas**: *Strategy-proofness-Exposing Mechanism Descriptions*	10:50–11:20 Coffee Break	
11:35–12:00	Romm, Roth, **Shorrer**: *Stability vs. No Justified Envy*	11:20–11:45	**Aziz**, Sun: *Multi-Rank Smart Reserves*
12:00–12:25	**Shorrer**, Sóvágó: *Dominated Choices in a Strategically Simple College*	11:45–12:10	**Herings**, Zhou: *Equilibria in Matching Markets with Soft and Hard Liquidity Constraints*
12:25–14:00 Lunch Break		12:10–13:45 Lunch Break	
14:00–15:00	Keynote: **Vijay Vazirani** (in lecture hall 1) *Online Bipartite Matching and Adwords*	13:45–14:10	**Vocke**: *Anonymity and stability*
		14:10–14:35	**Bérczi**, Bérczi-Kovács, Szögi: *A dual approach for dynamic pricing in multi-demand markets*
		14:35–15:00	**Artemov**, Che, He: *Stable Matching with Mistaken Agents*
15:10–15:35	**Blom**, Smeulders, Spieksma: *Rejection-proof Kidney Exchange Mechanisms*	15:00–15:25	**Bobbio**, Carvalho, Lodi, Rios, Torrico: *Capacity Planning in Stable Matching: An Application to School Choice*
15:35–16:00	**Biró**, Klijn, Klimentova, Viana: *Shapley-Scarf Housing Markets: Respecting Improvement, Integer Programming, and Kidney Exchange*	15:25–16:00 Coffee Break	
16:00–16:30 Coffee Break		16:00–16:25	Boehmer, **Heeger**, Szufa: *A Map of Diverse Synthetic Stable Roommates Instances*
16:30–16:55	**Ortega**, Klein: *Improving Efficiency and Equality in School Choice*	16:25–16:50	**Imamura**, Kawase: *Efficient matching under general constraints*
16:55–17:20	Freeman, Pritchard, **Wilson**: *Order Symmetry: A New Fairness Criterion for Assignment Mechanisms*	16:50–17:15	Chen, **Li**, Li, Zhang: *Fair Graphical Resource Allocation with Matching-Induced Utilities*
17:20–17:45	Kornbluth, **Kushnir**: *Undergraduate Course Allocation through Pseudo-Markets*	17:15–17:40	Li, Wang, **Zhou**: *Fair Allocation of Indivisible Chores: Beyond Additive Valuations*
18:00–22:00 Dinner		17:40 Closing Remarks	

Keynote Talk Vijay Vazirani

Online Bipartite Matching and Adwords

Vijay Vazirani (University of California, Irvine)
Thursday, August 25, 14:00–15:00

Abstract. Over the last three decades, the online bipartite matching (OBM) problem has emerged as a central problem in the area of Online Algorithms. Perhaps even more important is its role in the area of Matching-Based Market Design. The resurgence of this area, with the revolutions of the Internet and mobile computing, has opened up novel, path-breaking applications, and OBM has emerged as its paradigmatic algorithmic problem. In a 1990 joint paper with Richard Karp and Umesh Vazirani, we gave an optimal algorithm, called RANKING, for OBM, achieving a competitive ratio of $(1–1/e)$; however, its analysis was difficult to comprehend. Over the years, several researchers simplified the analysis.

We will start by presenting a "textbook quality" proof of RANKING. Its simplicity raises the possibility of extending RANKING all the way to a generalization of OBM called the adwords problem. This problem is both notoriously difficult and very significant, the latter because of its role in the AdWords marketplace of Google. We will show how far this endeavor has gone and what remains. We will also provide a broad overview of the area of Matching-Based Market Design and pinpoint the role of OBM.

Keynote Talk Sophie Bade

A procession of Royals: Incentives, Efficiency and Fairness in Two-sided Matching

Sophie Bade (Royal Holloway College, University of London)
Friday, August 26, 9:00–10:00

Abstract. We study the set of incentive compatible and efficient two-sided matching mechanisms. We classify all such mechanisms under an additional assumption – "gender-neutrality" – which guarantees that the two sides be treated symmetrically. All group strategy-proof, efficient, and gender-neutral mechanisms are defined recursively in a sequence of rounds. In each round two agents are selected, one from each side. These agents are either "matched-by-default" or "unmatched-by-default". In the former case either of the selected agents can unilaterally force the other to match with them while in the latter case, they may only match together if both agree. In either case, if this pair of agents is not matched together, each gets their top choices among the set of remaining agents. As an important step in the characterization, we first show that in one-sided matching all group strategy-proof and efficient mechanisms are sequential dictatorships. An immediate corollary is that there are no individually rational, group strategy-proof and efficient one-sided matching mechanisms.

Oral Presentation Paper Abstracts – August 24, Afternoon

Respecting priorities versus respecting preferences in school choice: When is there a trade-off?

Estelle Cantillon, **Li Chen**, and Juan Pereyra
Wednesday, August 24, 14:30–14:55

Abstract. A classic trade-off that school districts face when deciding which algorithm to use to match students to schools is that it is not possible to always respect both priorities and preferences. The student-proposing Deferred Acceptance algorithm respects priorities but can lead to inefficient allocations. The Top Trading Cycle algorithm respects preferences (efficiency) but may violate priorities. We identify new conditions on school choice markets under which DA is efficient and TTC respects priorities. Our conditions capture the common congruence, in applications, between priorities and preferences and they apply to the relevant choice sets for students. We show in simulations that our conditions significantly expand the known range of environments for which there is no tradeoff between efficiency and respect for priorities and we argue that they arise naturally in many school environments.

Student-Optimal Interdistrict School Choice: District-Based versus School-Based Admissions

Lars Ehlers
Wednesday, August 24, 14:55–15:20

Abstract. Hafalir, Kojima and Yenmez (2022) introduce a model of interdistrict school choice: each district consists of a set of schools and the district's admission rule places applicants to the schools in the district. We show that any district's admission rule satisfying their assumptions is uniquely rationalized by a collection of schools' choice functions satisfying substitutability and acceptance. We then establish that all students weakly prefer the outcome of the cumulative offer process (COP) under the school-based admissions to the outcome under the district-based admissions. This has the implication that if students prefer the interdistrict outcome for the district-based admissions to the intradistrict outcome, then all students are weakly better off under the school-based admissions compared to either of these outcomes. Therefore, for student-optimal interdistrict school choice the introduction of district admission rules hurts students and it suffices to endow schools with usual choice priorities (if students' welfare is more important than districts' policy goals) and to decentralize district admissions by letting schools choose.

Deferred Acceptance with News Utility

Bnaya Dreyfuss, Ofer Glicksohn, Ori Heffetz, and Assaf Romm
Wednesday, August 24, 15:20–15:45

Abstract. Can incorporating expectations-based-reference-dependence (EBRD) considerations reduce seemingly dominated choices in the Deferred Acceptance (DA) mechanism? We run two experiments (total $N = 500$) where participants are randomly assigned into one of four DA variants—{static, dynamic} × {student proposing, student receiving}—and play ten simulated large-market school-assignment problems. While a standard, reference-independent model predicts the same straightforward behavior across all problems and variants, a news-utility EBRD model predicts stark differences across variants and problems. As the EBRD model predicts, we find that (i) across problems, deviations from straightforward behavior increase with competitiveness, and (ii) across variants, *dynamic student receiving* leads to significantly fewer deviations.

Affinely representable lattices, stable matchings, and choice functions

Yuri Faenza and **Xuan Zhang**
Wednesday, August 24, 16:30–16:55

Abstract. Birkhoff's representation theorem defines a bijection between elements of a distributive lattice and the family of upper sets of an associated poset. When elements of the distributive lattice are the stable matchings in an instance of Gale and Shapley's marriage model, Irving et al. (1987) showed how to use the associated poset to devise a combinatorial algorithm for maximizing a linear function over the set of stable matchings. In this paper, we introduce a general property of distributive lattices, which we term as affine representability, and show its role in efficiently solving linear optimization problems over the elements of a distributive lattice, as well as describing the convex hull of the characteristic vectors of lattice elements. We apply this concept to the stable matching model with path-independent quota-filling choice functions, thus giving efficient algorithms and a compact polyhedral description for this model. To the best of our knowledge, this model generalizes all models from the literature for which similar results were known, and our paper is the first that proposes efficient algorithms for stable matchings with choice functions, beyond extension of the Deferred Acceptance algorithm.

Modular stable matching mechanisms

Ahmet Alkan and **Kemal Yıldız**
Wednesday, August 24, 16:55–17:20

Abstract. We propose and analyze modular stable matching mechanisms as a candidate for a foundational framework to address issues of social welfare and equity in the stable matching model. We present two characterizations for modular stable matching mechanisms that reveal the ordinal content of optimizing a modular function under the constraints of stability and invariance under stability and present several examples. Then, we propose a new equity notion and characterize the class of modular stable matching mechanisms that comply with this notion. Our analysis indicates that modular matching mechanisms are both structured and rich enough to implement a wide range of objectives.

Cutoff stability under distributional constraints with an application to summer internship matching

Haris Aziz, Anton Baychkov, and **Péter Biró**
Wednesday, August 24, 17:20–17:45

Abstract. We introduce a new two-sided stable matching problem that describes the summer internship matching practice of an Australian university. The model is a case between two models of Kamada and Kojima on matchings with distributional constraints. We study three solution concepts, the strong and weak stability concepts proposed by Kamada and Kojima, and a new one in between the two, called cutoff stability. Kamada and Kojima showed that a strongly stable matching may not exist in their most restricted model with disjoint regional quotas. Our first result is that checking its existence is NP-hard. We then show that a cutoff stable matching exists not just for the summer internship problem but also for the general matching model with arbitrary heredity constraints. We present an algorithm to compute a cutoff stable matching and show that it runs in polynomial time in our special case of summer internship model. However, we also show that finding a maximum size cutoff stable matching is NP-hard, but we provide a Mixed Integer Linear Program formulation for this optimisation problem.

Popular matchings with weighted voters

Klaus Heeger and Ágnes Cseh
Thursday, August 25, 9:00–9:25

Abstract. In the Popular Matching problem, we are given a bipartite graph $G = (A \cup B, E)$ and for each vertex $v \in A \cup B$, strict preferences over the neighbors of v. Given two matchings M and M', matching M is more popular than M' if the number of vertices preferring M to M' is larger than the number of vertices preferring M' to M. A matching M is called *popular* if there is no matching M' that is more popular than M.

We consider a natural generalization of Popular Matching where every vertex has a weight. Then, we call a matching M more popular than matching M' if the weight of vertices preferring M to M' is larger than the weight of vertices preferring M' to M. For this case, we show that it is NP-hard to find a popular matching. Our main result is a polynomial-time algorithm that delivers a popular matching or a proof for it non-existence in instances where all vertices on one side have weight c for some $c > 3$ and all vertices on the other side have weight 1.

Strong core and Pareto-optimal solutions for the multiple partners matching problem under lexicographic preferences

Péter Biró and **Gergely Csáji**
Thursday, August 25, 9:25–9:50

Abstract. In a multiple partners matching problem the agents can have multiple partners up to their capacities. We consider the two-sided many-to-many stable matching problem and the one-sided stable fixtures problem under lexicographic preferences. We study strong core and Pareto-optimal solutions from a computational point of view. First we provide an example to show that the strong core can be empty for many-to-many problems, and that deciding the non-emptiness of the strong core is NP-hard. We also show that for a given matching checking Pareto-optimality and the strong core properties are co-NP-complete problems for the many-to-many problem, and deciding the existence of a complete Pareto-optimal matching is also NP-hard for the fixtures problem. On the positive side, we give efficient algorithms for finding a near feasible strong core solution, where the capacities are only violated by at most one unit for each agent, and also for finding a half-matching in the strong core of fractional matchings. These polynomial time algorithms are based on the Top Trading Cycle algorithm. Finally, we also show that finding a maximum size matching that is Pareto-optimal can be done efficiently for many-to-many problems, which is in contrast with the hardness result for the fixtures problem.

Mitigating Skewed Bidding for Conference Paper Matching

Inbal Rozenzweig, Reshef Meir, and Nicholas Mattei
Thursday, August 25, 9:50–10:15

Abstract. The explosion of conference paper submissions in AI and related fields, has underscored the need to improve many aspects of the peer review process, especially the matching of papers and reviewers. Recent work argues that the key to improve this matching, is to modify aspects of the *bidding phase* itself, to ensure that the set of bids over papers is balanced, and in particular to avoid 'orphan papers' with no bids. We have developed a flexible bidding platform to test adaptations to the bidding process. Using this platform, we performed a field experiment during the bidding phase of a medium-size international workshop that compared two bidding methods. We further examined via controlled experiments on Amazon Mechanical Turk various factors that affect bidding, and in particular the order in which papers are presented [Cabanac&Preuss 2013, Fiez et al. 2020]; and information on paper demand [Meir et al. 2021]. Our results suggest that several simple adaptations, that can be added to any existing platform, may significantly reduce the skew in bids, thereby improving the allocation for both reviewers and conference organizers.

Deep Learning for Two-Sided Matching

Sai Srivatsa Ravindranath, Zhe Feng, Shira Li, Jonathan Ma, Scott D. Kominers, and David C. Parkes
Thursday, August 25, 10:15–10:40

Abstract. We initiate the use of a multi-layer neural network to model two-sided matching and to explore the design space between strategy-proofness and stability. It is well known that both properties cannot be achieved simultaneously, but the efficient frontier in this design space is not understood. We show empirically that it is possible to achieve a good compromise between stability and strategy-proofness—substantially better than that achievable through a convex combination of deferred acceptance (stable and strategy-proof for only one side of the market) and randomized serial dictatorship (strategy-proof but not stable).

Strategyproofness-Exposing Mechanism Descriptions

Yannai Gonczarowski, Ori Heffetz, and **Clayton Thomas**
Thursday, August 25, 11:10–11:35

Abstract. A "menu description" defines a mechanism to player i in two steps. Step (i) uses the reports of other players to describe i's menu: the set of i's potential outcomes. Step (ii) uses i's report to select i's favorite outcome from her menu. Can menu descriptions better expose strategyproofness, without sacrificing simplicity? We propose a new, simple menu description of Deferred Acceptance (DA). We prove that—in contrast with other common matching mechanisms—this menu description must differ substantially from traditional descriptions of DA. We demonstrate, with a lab experiment on two simple mechanisms, the promise and challenges of menu descriptions.

Stability vs. No Justified Envy

Assaf Romm, Alvin Roth, and **Ran Shorrer**
Thursday, August 25, 11:35–12:00

Abstract. Stability and "no justified envy" are used almost synonymously in the matching theory literature. However, they are conceptually different and have logically separate properties. We generalize the definition of justified envy to environments with arbitrary school preferences, feasibility constraints, and contracts, and show that stable allocations may admit justified envy. When choice functions are substitutable, the outcome of the deferred acceptance algorithm is both stable and admits no justified envy.

Dominated Choices in a Strategically Simple College

Ran Shorrer and Sándor Sóvágó
Thursday, August 25, 12:00–12:25

Abstract. Although many centralized school assignment systems use the strategically simple Deferred Acceptance mechanism, applicants often make dominated choices. Using administrative data from Hungary, we show that many college applicants forgo the free opportunity to receive a tuition waiver. Using two empirical strategies, we provide causal evidence that applicants make more such dominated choices when applying to programs where tuition waivers are more selective. Our results suggest that dominated choices are more common when their expected utility cost is lower. But, a non-negligible share of these dominated choices are consequential and when they are, the cost is significant, averaging more than 3,000 dollars.

Rejection-proof Kidney Exchange Mechanisms

Danny Blom, Bart Smeulders, and Frits Spieksma
Thursday, August 25, 15:10–15:35

Abstract. Kidney exchange programs (KEPs) form an innovative approach to increasing the donor pool by allowing the participation of renal patients together with a willing but incompatible donor. The aim of a KEP is to identify groups of incompatible donor-recipient pairs that could exchange donors leading to feasible transplants. As a kidney exchange program grows, a larger proportion of participants can be transplanted. Collaboration between multiple transplant centers, by merging their separate kidney exchange pools, is thus desirable. As each transplant center has its own interest in providing the best care to its own patients, collaboration requires balancing individual and common objectives. We consider a class of algorithmic mechanisms for multi-center kidney exchange programs we call *rejection-proof mechanisms*. Such mechanisms propose solutions with the property that no player wishes to unilaterally deviate. We provide a mechanism optimizing social value under this restriction, although the underlying optimization problem is Σ_2^P-hard. We also describe a computationally easier but suboptimal alternative. Experiments show that rejection-proofness can be achieved at a limited cost compared to optimal solutions for regular kidney exchange. Computationally, we provide algorithms to compute optimal rejection-proof solutions for small and medium instance sizes.

Shapley-Scarf Housing Markets: Respecting Improvement, Integer Programming, and Kidney Exchange

Péter Biró, Flip Klijn, Xenia Klimentova, and Ana Viana
Thursday, August 25, 15:35–16:00

Abstract. In a housing market of Shapley and Scarf (1974), each agent is endowed with one indivisible object and has preferences over all objects. We show that for strict preferences the unique strong core allocation "respects improvement": if an agent's object becomes more desirable for some other agents, then the agent's allotment in the unique strong core allocation weakly improves. We obtain similar results for the domain of weak preferences. Respecting improvements is an important property for applications of the housing markets model such as kidney exchange: it incentivises each patient to bring the best possible set of donors to the market. We conduct computer simulations using markets that resemble the pools of kidney exchange programmes. We compare the game-theoretical solutions with current techniques (maximum size and maximum weight allocations) in terms of price of fairness, number of blocking cycles, and number of violations of the respecting improvement property. We find that game-theoretical solutions fare much better at respecting improvements and they do so at a low efficiency cost. As a stepping-stone for our simulations, we provide novel integer programming formulations for computing core, strong core, and competitive allocations.

Improving Efficiency and Equality in School Choice

Josué Ortega and Thilo Klein
Thursday, August 25, 16:30–16:55

Abstract. How should students be assigned to schools? Two mechanisms have been suggested and implemented around the world: deferred acceptance (DA) and top trading cycles (TTC). These two mechanisms are widely considered excellent choices owing to their outstanding stability and incentive properties. We show theoretically and empirically that both mechanisms perform poorly with regard to two key desiderata such as efficiency and equality, even in large markets. In contrast, the rank-minimizing mechanism (RM) is significantly more efficient and egalitarian. It is also Pareto optimal for the students, unlike DA, and generates less justified envy than TTC.

Order Symmetry: A New Fairness Criterion for Assignment Mechanisms

Rupert Freeman, Geoffrey Pritchard, and **Mark Wilson**
Thursday, August 25, 16:55–17:20

Abstract. We introduce a new fairness criterion, order symmetry, for assignment mechanisms that match n objects to n agents with ordinal preferences over the objects. An assignment mechanism is order symmetric with respect to some probability measure over preference profiles if every agent is equally likely to receive their favorite object, every agent is equally likely to receive their second favorite, and so on. When associated with a sufficiently symmetric probability measure, order symmetry is a relaxation of anonymity that, crucially, can be satisfied by discrete assignment mechanisms. Furthermore, it can be achieved without sacrificing other desirable axiomatic properties satisfied by existing mechanisms. In particular, we show that it can be achieved in conjunction with strategyproofness and ex post efficiency via the Top Trading Cycles mechanism (but not Serial Dictatorship). We additionally design a novel mechanism that is both order symmetric and ordinally efficient. The practical utility of order symmetry is substantiated by simulations on Impartial Culture and Mallows-distributed preferences for four common assignment mechanisms.

Undergraduate Course Allocation through Pseudo-Markets

Daniel Kornbluth and **Alexey Kushnir**
Thursday, August 25, 17:20–17:45

Abstract. We consider a many-to-many matching problem with a priority structure such as the one in undergraduate course allocation. We develop a deterministic market mechanism based on the approximate competitive equilibrium from equal incomes that allocates courses to students based on student preferences and respects course priorities. The novel mechanism has desirable theoretical properties in terms of stability, efficiency, fairness, and strategy-proofness. In simulated environments, its outcomes increase student mean utility and allocation fairness as compared to the outcomes of the celebrated deferred acceptance mechanisms with single and multiple tie-breakings and the widely used random serial dictatorship with set-asides.

A Systematic Approach to Selection Problems

Nick Arnosti, **Carlos Bonet**, and Jay Sethuraman
Friday, August 26, 10:00–10:25

Abstract. We discuss a systematic approach to Prioritized Selection Problems, in which an organization is presented with a set of individuals, and must choose which subset to accept. We assume that the organization has a complete priority ranking of the individuals. In addition, the selection rule may be constrained to select from a pre-defined set of feasible subsets, which may be specified explicitly or implicitly (through quotas or reserves). We identify a natural family or rules—sequential dictator rules—and characterize it using some natural axiomatic properties. In cases where the feasible subsets are implicitly specified through quotas or reserves, we identify important special cases for which there exists a selection that unambiguously selects higher priority individuals than any other feasible selection.

Our general approach is motivated by the observation that it is easier for the general public and policymakers to reason about outcomes rather than algorithms. Our sequential dictator rules do not require policymakers to reason about the effect of tweaking some step of the algorithm. Rather, they rely only on a description of which final selections are acceptable. We believe that this feature makes these rules more "designer friendly," promotes transparency, making them less likely to produce unintended consequences.

Characterizing the Coordinatewise Top-Trading-Cycles Mechanism for Multiple-Type Housing Markets

Di Feng, Bettina Klaus, and Flip Klijn
Friday, August 26, 10:25–10:50

Abstract. We consider the generalization of the classical Shapley and Scarf housing market model of trading indivisible objects (houses) (Shapley and Scarf, 1974) to so-called multiple-type housing markets (Moulin, 1995). When preferences are separable, the prominent solution for these markets is the coordinatewise top-trading-cycles (cTTC) mechanism. We first show that on the subdomain of lexicographic preferences, a mechanism is unanimous (or onto), individually rational, strategy-proof, and non-bossy if and only if it is the cTTC mechanism (Theorem 1). Second, using Theorem 1, we obtain a corresponding characterization on the domain of separable preferences (Theorem 2). We obtain corresponding results when replacing [strategy-proofness and non-bossiness] with effective group (or pairwise) strategy-proofness (Corollaries 1 and 2). Finally, we show that on the domain of strict preferences, there is no mechanism satisfying unanimity, individual rationality, and strategy-proofness (Theorem 3). Our characterizations of the cTTC mechanism constitute the first characterizations of an extension of the prominent top-trading-cycles (TTC) mechanism to multiple-type housing markets.

Multi-Rank Smart Reserves

Haris Aziz and Zhaohong Sun
Friday, August 26, 11:20–11:45

Abstract. We study the school choice problem where each school has flexible multi-ranked diversity goals, and each student may belong to multiple overlapping types, and consumes only one of the positions reserved for their types. We propose a novel choice function and show that it is the unique rule that satisfies three fundamental properties: maximal diversity, non-wastefulness, and justified envy-freeness. We provide a fast polynomial-time algorithm for our choice function that is based on the Dulmage Mendelsohn Decomposition Theorem as well as new insights into the combinatorial structure of constrained rank maximal matchings. Even for the case of minimum and maximum quotas for types (that capture two ranks), ours is the first known polynomial-time approach to compute an optimally diverse choice outcome. Finally, we prove that the choice function we design for schools, satisfies substitutability and hence can be directly embedded in the generalized deferred acceptance algorithm to achieve strategyproofness and stability. Our algorithms and results have immediate policy implications and directly apply to a variety of scenarios, such as where hiring positions or scarce medical resources need to be allocated while taking into account diversity concerns or ethical principles.

Equilibria in Matching Markets with Soft and Hard Liquidity Constraints

Jean-Jacques Herings and Yu Zhou
Friday, August 26, 11:45–12:10

Abstract. We consider a matching with contracts model in the presence of liquidity constraints on the buyers side. Liquidity constraints can be either soft or hard. A convergent sequence of economies with increasingly stringent soft liquidity constraints is an economy with hard liquidity constraints at the limit. The limit of a corresponding convergent sequence of competitive equilibria may fail to be a competitive equilibrium in the limit economy. We instead establish limit results for two alternative notions of competitive equilibrium, quantity-constrained competitive equilibrium and expectational equilibrium. The limit results of stable outcomes and core outcomes follow as corollaries.

Anonymity and stability

Karolina Vocke
Friday, August 26, 13:45–14:10

Abstract. In many-to-many matching markets, various stability concepts have been introduced. Not all of these stability concepts offer a clear interpretation. This paper argues that the differences between stability concepts reflect different implicit anonymity assumptions. Such anonymity assumptions can best be modeled in large markets, described in this paper with a continuum of agents. In such large markets, it is shown that various differences between stability concepts disappear. In particular, stability and weak setwise stability coincide. Stability is a better-behaved solution concept; stability blocks do indeed lead to an improvement for all members of a blocking coalition, unlike in finite markets. Moreover, the relationship between anonymity and largeness of the market can be made explicit in natural non-cooperative foundations of stability concepts.

A dual approach for dynamic pricing in multi-demand markets

Kristóf Bérczi, Erika R. Bérczi-Kovács, and Evelin Szögi
Friday, August 26, 14:10–14:35

Abstract. Dynamic pricing schemes were introduced as an alternative to posted-price mechanisms. In contrast to static models, the dynamic setting allows to update the prices between buyer-arrivals based on the remaining sets of items and buyers, and so it is capable of maximizing social welfare without the need for a central coordinator.

In this talk, we study the existence of optimal dynamic pricing schemes in combinatorial markets. In particular, we concentrate on multi-demand valuations, a natural extension of unit-demand valuations. The proposed approach is based on computing an optimal dual solution of the maximum social welfare problem with distinguished structural properties. Our contribution is twofold. By relying on an optimal dual solution, we show the existence of optimal dynamic prices in unit-demand markets and in multi-demand markets up to three buyers, thus giving new interpretations of results of Cohen-Addad et al. and Berger et al., respectively. Furthermore, we provide an optimal dynamic pricing scheme for bi-demand valuations with an arbitrary number of buyers. In all cases, our proofs also provide efficient algorithms for determining the optimal dynamic prices.

Stable Matching with Mistaken Agents

Georgy Artemov, Yeon-Koo Che, and Yinghua He
Friday, August 26, 14:35–15:00

Abstract. Motivated by growing evidence of agents' mistakes in strategically simple environments, we propose a solution concept—robust equilibrium—that requires only an asymptotically optimal behavior. We use it to study large random matching markets operated by the applicant-proposing Deferred Acceptance (DA). Although truth-telling is a dominant strategy, almost all applicants may be non-truthful in robust equilibrium; however, the outcome must be arbitrarily close to the stable matching. Our results imply that one can assume truthful agents to study DA outcomes, theoretically or counterfactually. However, to estimate the preferences of mistaken agents, one should assume stable matching but not truth-telling.

Capacity Planning in Stable Matching: An Application to School Choice

Federico Bobbio, Margarida Carvalho, Andrea Lodi, Ignacio Rios, and Alfredo Torrico
Friday, August 26, 15:00–15:25

Abstract. In this work, we introduce the problem of jointly allocating a school capacity expansion (given a fixed budget) and finding the best allocation for the students in the expanded market.

Given the computational complexity of the problem, we provide an integer quadratically-constrained programming formulation and study its linear reformulations. We also propose two heuristics: A greedy algorithm and an LP-based method. We empirically evaluate the performance of our approaches in a detailed computational study. We observe the practical superiority of the linearized model in comparison with its quadratic counterpart and we outline their computational limits. Finally, we use the Chilean school choice system data to empirically demonstrate the impact of capacity planning under stability conditions.

Our results show that each additional school seat can benefit multiple students. In addition, depending on the decision-maker, our methodology can prioritize the assignment of previously unassigned students or improve the assignment of several students through improvement chains.

A Map of Diverse Synthetic Stable Roommates Instances

Niclas Boehmer, **Klaus Heeger**, and Stanisław Szufa
Friday, August 26, 16:00–16:25

Abstract. Focusing on Stable Roommates (SR) instances, we contribute to the toolbox for conducting experiments for stable matching problems. We introduce a polynomial-time computable pseudometric to measure the similarity of SR instances, analyze its properties, and use it to create a map of SR instances. This map visualizes 460 synthetic SR instances (each sampled from one of ten different statistical cultures) as follows: Each instance is a point in the plane, and two points are close on the map if the corresponding SR instances are similar to each other. Subsequently, we conduct several exemplary experiments and depict their results on the map, illustrating the map's usefulness as a non-aggregate visualization tool, the diversity of our generated dataset, and the need to use instances sampled from different statistical cultures. Lastly, to demonstrate that our framework can also be used for other matching problems under preference, we create and analyze a map of Stable Marriage instances.

A full version of the paper is available at: https://arxiv.org/abs/2208.04041

Efficient matching under general constraints

Kenzo Imamura and Yasushi Kawase
Friday, August 26, 16:25–16:50

Abstract. We study indivisible goods allocation problems under constraints and provide algorithms to check whether a given matching is Pareto efficient. We first show that the serial dictatorship algorithm can be used to check Pareto efficiency by assuming a constraint to be a matroid. To prove this, we develop a generalized top trading cycles algorithm. Moreover, we show that the matroid structure is necessary for obtaining all Pareto efficient matchings by the serial dictatorship algorithm. Second, we provide an extension of the serial dictatorship algorithm to check Pareto efficiency under general constraints. Subsequently, we propose an efficiency-adjusted deferred acceptance algorithm for path-independent choice functions.

Fair Graphical Resource Allocation with Matching-Induced Utilities

Zheng Chen, **Bo Li**, Minming Li, and Guochuan Zhang
Friday, August 26, 16:50–17:15

Abstract. Motivated by real-world applications, we study the fair allocation of graphical resources, where the resources are the vertices in a graph. Upon receiving a set of resources, an agent's utility equals the weight of the maximum matching in the induced subgraph. We care about both maximin share (MMS) fairness and envy-freeness up to one item (EF1). Regarding MMS, the problem does not admit a finite approximation ratio for heterogeneous agents. For homogeneous agents, we design constant-approximation polynomial-time algorithms, and also note that a significant amount of social welfare is sacrificed inevitably in order to ensure (approximate) MMS fairness. We then consider EF1 allocations whose existence is guaranteed. We show that for homogeneous agents, there is an EF1 allocation that ensures at least a constant fraction of the maximum possible social welfare. However, the social welfare guarantee of EF1 allocations degrades to 1/n for heterogeneous agents, where n is the number of agents. Fortunately, for two special yet typical cases, namely binary-weight and two-agent, we are able to design polynomial-time algorithms ensuring constant fractions of the maximum social welfare.

Fair Allocation of Indivisible Chores: Beyond Additive Valuations

Bo Li, Fangxiao Wang, and **Yu Zhou**
Friday, August 26, 17:15–17:40

Abstract. We study the maximin share (MMS) fair allocation of m indivisible tasks to n agents who have costs for completing assigned tasks. For additive cost functions, there are various constant-approximation algorithms, but beyond additivity, very little is known. In this work, we first prove that for subadditive costs, the tight approximation ratio is n or $\tilde{\Theta}(\log m)$. This result shows a sharp contrast with the allocation of goods where constant approximations exist as shown by Barman and Krishnamurthy [TEAC, 2020] and Ghodsi et al [AIJ, 2022]. We then focus on two practical settings where the cost functions are subadditive but they admit constant approximations. In the first setting, agents need to use bins to pack items and want to use as few bins as possible to pack the items assigned to them. In the second setting, each agent has a set of machines that can be used to process the items, and her objective is to minimize the makespan of processing the items assigned to her. Finally, we show that if the fairness notion is changed to proportionality up to one/any item, the tight approximation ratio is n even in the two specific settings.

Poster Presentation Paper Abstracts

Maximum-utility popular matchings with bounded instability

Ildikó Schlotter and Ágnes Cseh

Abstract. In a graph where vertices have preferences over their neighbors, a matching is called popular if it does not lose a head-to-head election against any other matching when the vertices vote between the matchings. Popular matchings can be seen as an intermediate category between stable matchings and maximum-size matchings. In this paper, we aim to maximize the utility of a matching that is popular but admits only a few blocking edges.

We observe that for general graphs finding a popular matching with at most one blocking edge is already NP-complete. For bipartite instances, we study the problem of finding a maximum-utility popular matching with a bound on the number (or more generally, the cost) of blocking edges applying a multivariate approach. We show classical and parameterized hardness results for severely restricted instances. By contrast, we design an algorithm for instances where preferences on one side admit a master list, and show that this algorithm is optimal.

On the Price of Fairness of Allocating Contiguous Blocks

Ankang Sun and Bo Li

Abstract. In this work, we revisit the problem of fairly allocating a number of indivisible items that are located on a line to multiple agents. A feasible allocation requires that the allocated items to each agent are connected on the line. The items can be goods on which agents have non-negative utilities, or chores on which the utilities are non-positive. Our objective is to understand the extent to which welfare is inevitably sacrificed by enforcing the allocations to be fair, i.e., price of fairness (PoF). We study both egalitarian and utilitarian welfare. Previous works by Suksompong [Discret. Appl. Math., 2019] and Höhne and van Stee [Inf. Comput., 2021] have studied PoF regarding the notions of envy-freeness and proportionality. However, these fair allocations barely exist for indivisible items, and thus in this work, we focus on the relaxations of maximin share fairness and proportionality up to one item, which are guaranteed to be satisfiable. For most settings, we give (almost) tight ratios of PoF and all the upper bounds are proved by designing polynomial time algorithms.

Manipulating the outcome of stable matching and roommates problems

Kristóf Bérczi, **Gergely Csáji**, and Tamás Király

Abstract. In the stable marriage and stable roommates problems, it might happen that no stable solution exists, or stable solutions do not meet certain requirements. In such cases, one might be interested in modifying the instance so that the existence of a stable outcome with the desired properties is ensured.

We focus on three different modifications. In the stable roommates problem, removing an agent from each odd cycle of a stable partition achieves stability optimally. We show that the problem becomes NP-complete when the capacities are greater than one, or when only a subset of agents is removable.

We also investigate how to modify the preferences of the agents as little as possible so that a given matching becomes stable. We show that, assuming the Unique Games Conjecture, the problem does not admit a better than 2 approximation. We further give a polynomial-time algorithm for the bipartite case and a 2-approximation for general graphs.

Last, we consider problems where the preferences of agents are not fully prescribed, and the goal is to decide whether the preference lists can be extended so that a stable matching exists. We settle the complexity of several variants.

Envy-free matchings with cost-controlled quotas

Girija Limaye and Meghana Nasre

Abstract. We consider the problem of assigning agents to programs under two-sided preferences. In the standard setting, each program has a rigid upper-quota which cannot be violated. Motivated by applications where quotas are governed by resource availability, we propose and study the problem of computing optimal matchings with cost-controlled quotas – denoted as the CCQ setting.

In the CCQ setting every program has an associated cost which denotes the cost of matching a single agent to the program. Our goal is to compute a matching that matches *all* agents, respects the preferences and is optimal with respect to the cost criteria. We consider *envy-freeness* as a notion of optimality and study two optimization problems with respect to the costs – minimize the total cost (MINSUM) and minimize the maximum cost at a program (MINMAX). We show that the MINMAX problem is polynomial time solvable whereas MINSUM is hard to approximate below $\frac{7}{6}$ unless P=NP even under severe restrictions. On the positive side, we present approximation algorithms for the general case and a special hard case of the MINSUM problem. We achieve the approximation guarantee for the special case via a technically involved linear programming (LP) based algorithm.

Core-Stability in Assignment Markets with Financially Constrained Buyers

Eleni Batziou, Martin Bichler, and **Maximilian Fichtl**

Abstract. We study markets where a set of indivisible items is sold to bidders with unit-demand valuations, subject to hard budget limits. Without financial constraints and quasilinear bidders, this assignment model allows for a simple ascending auction format that maximizes welfare and is incentive-compatible and core-stable. Introducing budget constraints, the ascending auction requires strong additional conditions on the unit-demand preferences to maintain its properties. We show that, without these conditions, we cannot hope for an incentive-compatible and core-stable mechanism. We design an iterative algorithm that depends solely on a trivially verifiable ex-post condition and demand queries, and with appropriate decisions made by an auctioneer, always yields a welfare-maximizing and core-stable outcome. If these conditions do not hold, we cannot hope for incentive-compatibility and computing core-stable welfare-maximizing outcomes is hard: Even in the presence of value queries, where bidders reveal their valuations and budgets, we prove that the problem becomes NP-complete. The analysis complements complexity results for markets with more complex valuations and shows that even with simple unit-demand bidders the problem becomes intractable. This raises doubts on the efficiency of simple auction designs as they are used in high-stakes markets, where budget constraints typically play a role.

Matching with Transfers under Distributional Constraints

Devansh Jalota, Michael Ostrovsky, and Marco Pavone

Abstract. We study two-sided many-to-one matching markets with transferable utilities, e.g., labor and rental housing markets, in which money can exchange hands between agents, subject to distributional constraints on the set of feasible allocations. In such markets, we establish the efficiency of equilibrium arrangements, specified by an assignment and transfers between agents on the two sides of the market, and study the conditions on the distributional constraints and agent preferences under which equilibria exist and can be computed efficiently. To this end, we first consider the setting when the number of institutions (e.g., firms in a labor market) is one and show that equilibrium arrangements exist irrespective of the constraint structure or the agents' preferences. However, equilibrium arrangements may not exist in markets with multiple institutions even when agents on each side have linear preferences over agents on the other side. Thus, for markets with linear preferences, we study sufficient conditions on the constraint structure that guarantee the existence of equilibria using linear programming duality. Our linear programming approach not only generalizes that of Shapley and Shubik (1971) in the one-to-one matching setting to the many-to-one matching setting under distributional constraints but also provides a method to compute market equilibria efficiently.

The core of housing markets from an agent's perspective: Is it worth sprucing up your home?

Ildikó Schlotter, Péter Biró, and Tamás Fleiner

Abstract. We study housing markets as introduced by Shapley and Scarf (1974). We investigate the computational complexity of various questions regarding the situation of an agent a in a housing market H: we show that it is NP-hard to find an allocation in the core of H where (i) a receives a certain house, (ii) a does not receive a certain house, or (iii) a receives a house other than her own. We prove that the core of housing markets *respects improvement* in the following sense: given an allocation in the core of H where agent a receives a house h, if the value of the house owned by a increases, then the resulting housing market admits an allocation where a receives either h, or a house that she prefers to h; moreover, such an allocation can be found efficiently. We further show an analogous result in the Stable Roommates setting by proving that stable matchings in a one-sided market also respect improvement.

Envy-Free Coalitions of Fixed Size

Ágnes Cseh, **Michael McKay**, and David Manlove

Abstract. We study the problem of partitioning a set of agents into coalitions based on the agents' additively separable preferences, which can also be viewed as a hedonic game. We apply three successively weaker solution concepts, namely envy-freeness, weakly justified envy-freeness, and justified envy-freeness. In a model in which coalitions may be any size, trivial solutions exist for these concepts, which provides a strong motivation for considering restrictions on coalition size. In this paper, we require feasible coalitions to have size three. We study the existence of partitions that are envy-free, weakly justified envy-free, and justified envy-free, and the computational complexity of finding such partitions, if they exist. We show that for successively weaker solution concepts, existence and polynomial-time solvability hold for successively larger sets of problem instances.

Strategy-Proof and Envy-free Random Assignment

Christian Basteck and Lars Ehlers

Abstract. We study the random assignment of indivisible objects among a set of agents with strict preferences. We show that there exists no mechanism which is unanimous, strategy-proof and envy-free. Weakening the first requirement to q-unanimity – i.e., when every agent ranks a different object at the top, then each agent shall receive his most-preferred object with probability of at least q – we show that a mechanism satisfying strategy-proofness, envy-freeness and ex-post weak non-wastefulness can be q-unanimous only for $q \leq \frac{2}{n}$ (where n is the number of agents). To demonstrate that this bound is tight, we introduce a new mechanism, Random-Priority-cum-Equal-Division (RPcED), and show that it achieves this maximal bound when all objects are acceptable. In addition, for three agents, RPcED is characterized by the first three properties and ex-post weak efficiency. If objects may be unacceptable, strategy-proofness and envy-freeness are jointly incompatible even with ex-post weak non-wastefulness.

Multidimensional Stable Roommates with Master List

Robert Bredereck, Klaus Heeger, **Dušan Knop**, and Rolf Niedermeier

Abstract. Since the early days of research in algorithms and complexity, the computation of stable matchings is a core topic. While in the classic setting the goal is to match up two agents (either from different "gender" (this is Stable Marriage) or "unrestricted" (this is Stable Roommates)), Knuth [1976] triggered the study of three- or multidimensional cases. Here, we focus on the study of Multidimensional Stable Roommates, known to be NP-hard since the early 1990's. Many NP-hardness results, however, rely on very general input instances that do not occur in at least some of the specific application scenarios. With the quest for identifying islands of tractability, we look at the case of master lists. Here, as natural in applications where agents express their preferences based on "objective" scores, one roughly speaking assumes that all agent preferences are "derived from" a central master list, implying that the individual agent preferences shall be similar. Master lists have been frequently studied in the two-dimensional (classic) stable matching case, but seemingly almost never for the multidimensional case. This work, also relying on methods from parameterized algorithm design and complexity analysis, performs a first systematic study of Multidimensional Stable Roommates under the assumption of master lists.

Generalized Rental Harmony

Erel Segal-Halevi

Abstract. *Rental harmony* is the problem of assigning rooms in a rented house to tenants with different preferences, and simultaneously splitting the rent among them, such that no tenant envies the bundle (room and price) given to another tenant. Various researchers have studied this problem mainly under two incompatible assumptions: the *miserly tenants* assumption — each tenant prefers a free room to a room with a positive price; and the *quasilinear tenants* assumption — each tenant attributes a monetary value to each room, and prefers a room of which the difference between value and price is maximum. This article shows that the main technique used for rental harmony with miserly tenants, using Sperner's lemma, can be adapted to a much more general class of preferences, one that contains both miserly tenants and quasilinear tenants as special cases. As a corollary, some recent results derived for miserly tenants are found to be applicable to this more general class, too.

Published at American Mathematical Monthly, 2022.
https://www.tandfonline.com/doi/abs/10.1080/00029890.2022.2037988

Rawlsian Assignments

Tom Demeulemeester and Juan S. Pereyra

Abstract. We study the assignment of indivisible objects to individuals when transfers are not allowed. Previous literature has mainly focused on efficiency (from ex-ante and ex-post perspectives), and *individually* fair assignments. Consequently, egalitarian concerns have been overlooked. We are inspired by the assignment of apartments in housing cooperatives where families regard the egalitarianism of the assignments as a first-order requirement. In particular, they want to avoid assignments where some families get their most preferred apartment, while others get options ranked very low in their preferences. Based on Rawls' idea of fairness, we introduce the notion of Rawlsian assignments. We prove that there always exists a unique Rawlsian assignment, which is ordinally efficient, and satisfies equal treatment of equals. We illustrate our analysis with preference data from housing cooperatives. Our results show that the Rawlsian assignment substantially improves, from an egalitarian perspective, both the probabilistic serial mechanism, and the mechanism currently in use.