Report from Dagstuhl Seminar 21301

Matching Under Preferences: Theory and Practice

Edited by

Haris Aziz[1], Péter Biró[2], Tamás Fleiner[3], and Bettina Klaus[4]

1 **UNSW – Sydney, AU,** haris.aziz@unsw.edu.au
2 **Hungarian Academy of Sciences – Budapest, HU,** biro.peter@krtk.mta.hu
3 **Budapest University of Technology & Economics, HU,** fleiner@cs.elte.hu
4 **University of Lausanne, CH,** bettina.klaus@unil.ch

Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 21301 "Matching Under Preferences: Theory and Practice". The seminar featured a mixture of technical scientific talks, survey talks, open problem presentations, working group sessions, five-minute contributions ("rump session"), and a panel discussion. This was the first Dagstuhl seminar that was dedicated to matching under preferences.

Seminar July 25–30, 2021 – http://www.dagstuhl.de/21301
2012 ACM Subject Classification Theory of computation → Algorithmic game theory and mechanism design; Applied computing → Economics; Mathematics of computing → Graph theory
Keywords and phrases market design, matching under preferences, matching with distributional constraints, organ exchange, stable matching
Digital Object Identifier 10.4230/DagRep.11.7.124
Edited in cooperation with Özbilen, Seçkin

1 Executive Summary

Haris Aziz
Péter Biró
Tamás Fleiner
Bettina Klaus

Matching under preferences is a general field spanning computer science, economics, and mathematics. The seminal paper in the field is one by Gale and Shapley (1962) that launched an algorithmic approach to matching agents with preferences. The central problems in the field involve matching agents to each other and to resources in a stable and efficient manner. Matching market algorithms based on the preferences of the agents have several applications such as in school admissions, placement of hospital residents, and centralized kidney markets. Topics in the field include two-sided matchings involving agents on both sides (e.g., job markets, school choice, etc.); two-sided matchings involving agents and items (e.g. course allocation, project allocation, assigning papers to reviewers etc.); one-sided matchings (roommates problem, kidney exchanges, etc.); and matching with payments (assignment game, auctions, etc.).

Matching Under Preferences: Theory and Practice, *Dagstuhl Reports*, Vol. 11, Issue 06, pp. 124–146
Editors: Haris Aziz, Péter Biró, Tamás Fleiner, and Bettina Klaus

Dagstuhl Reports
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

The topic of matching under preferences not only has tremendous applications but is based on a deep mathematical theory that has been developed by multiple research communities including theoretical computer science, artificial intelligence, discrete mathematics, game theory, and microeconomics. One of the main purposes of the seminar was to bring together leading researchers from various communities working on the topic and facilitate collaboration. The participant list was a mixture of researchers from computer science, mathematics, and economics. The seminar provided a platform to discuss state of the art in matching under preferences; identify new and exciting applications of developing research; and understand the mathematical and algorithmic requirements of new and upcoming problems in the field.

The seminar was conducted in a hybrid manner, with 15 participants attending the seminar physically from the Dagstuhl center and 34 participants attending online. The hybrid nature of the work required the need for careful planning to keep participants engaged and to facilitate collaboration between off-site and on-site participants. The online participation was managed via zoom and gather-town softwares.

The four main focus topics of the workshop were the following ones.

1. Matching markets with distributional constraints,
2. Probabilistic and Fractional Matching,
3. Matching in online and dynamic settings, and
4. Matching Markets and machine learning.

All of the four focus areas are important directions for the field. As new applications arise, it is clear that many real-life matching markets have additional feasibility and distributional constraints. Secondly, most of the theoretical developments in the field concern deterministic outcomes, so one of the goals was to make further progress on probabilistic mechanisms. During the seminar, current and new research on probabilistic approaches was discussed. Thirdly, many practical matching markets have online and dynamic aspects. There were several discussions on how to model and solve online matching problems. Fourthly, with the increased importance of machine learning in building computer systems, the seminar provided an opportunity to discuss how learning approaches help solve market design problems.

On each of the first four days, there was a one-hour survey talk given by an expert on the above topics. On the first day, Yash Kanoria presented a survey on “online matching markets”. On the second day, John Dickerson gave a survey talk on machine learning and matching markets. On day three, Makoto Yokoo presented an overview of “matching under constraints.” On day four, Jay Sethuraman surveyed “probabilistic matchings.”

On each of the days there were several shorter scientific presentations. During the workshop, two rump sessions were organized to facilitate different time zones. The rump sessions gave an opportunity to the participants to give brief updates or share open problems.

During the week, there were several time slots dedicated to flexible discussion and collaboration as well as dedicated working groups working on particular research topics. Apart from collaborations in smaller groups, the workshop witnessed major collaboration or discussion around several topics. Robert Bredereck brought up the issue of unifying and streamlining terminology and discussed the issue of using gender-neutral terms. There was a large working group led by Sushmita Gupta and Pallavi Jain that examined computational problems that combine the goals of stability and popularity. There was a group led by Bettina Klaus on lexicographic preferences in matching and market design. Finally, Florian Brandl led a group on the intersection between matching and fair division.

On the last day, there was a panel discussion that was moderated by Haris Aziz and Bettina Klaus. The discussants in the panel were Péter Biró, Ágnes Cseh, Lars Ehlers, Alex Teytelboym, and Utku Ünver. The main topics discussed included ways to build synergies between research communities and having an impact on the practice of matching markets.

The organisers thank all the Dagstuhl staff members for their professional support, the participants for enriching the seminar, Somouaoga Bonkoungou and Alex Lam for providing video conferencing support, and Seçkin Özbilen for his support in putting together the abstracts that compose this report.

2 Table of Contents

3 Overview of Talks

3.1 Decentralized Matching in a Probabilistic Environment

Irene Lo (Stanford University, US)

Joint work of Amin Saberi, Irene Lo, Mobin Y. Jeloudar, Tristan Pollner
Main reference Mobin Y. Jeloudar, Irene Lo, Tristan Pollner, Amin Saberi: "Decentralized Matching in a Probabilistic Environment", CoRR, Vol. abs/2106.06706, 2021.
URL https://arxiv.org/abs/2106.06706

We consider a model for repeated stochastic matching where compatibility is probabilistic, is realized the first time agents are matched, and persists in the future. Such a model has applications in the gig economy, kidney exchange, and mentorship matching.

We ask whether a *decentralized* matching process can approximate the optimal online algorithm. In particular, we consider a decentralized *stable matching* process where agents match with the most compatible partner who does not prefer matching with someone else, and known compatible pairs continue matching in all future rounds. We demonstrate that the above process provides a 0.316-approximation to the optimal online algorithm for matching on general graphs. We also provide a $1/7$-approximation for many-to-one bipartite matching, a $1/11$-approximation for capacitated matching on general graphs, and a $1/2k$-approximation for forming teams of up to k agents. Our results rely on a novel coupling argument that decomposes the successful edges of the optimal online algorithm in terms of their round-by-round comparison with stable matching.

3.2 The Vigilant Eating Rule: A General Approach for Probabilistic Economic Design with Constraints

Haris Aziz (UNSW – Sydney, AU) and Florian Brandl (Universität Bonn, DE)

Main reference Haris Aziz, Florian Brandl: "The Vigilant Eating Rule: A General Approach for Probabilistic Economic Design with Constraints", CoRR, Vol. abs/2008.08991, 2020.
URL https://arxiv.org/abs/2008.08991

We consider the problem of probabilistic allocation of objects under ordinal preferences. We devise an allocation mechanism, called the vigilant eating rule (VER), that applies to nearly arbitrary feasibility constraints. It is constrained ordinally efficient, can be computed efficiently for a large class of constraints, and treats agents equally if they have the same preferences and are subject to the same constraints. When the set of feasible allocations is convex, we also present a characterization of our rule based on ordinal egalitarianism. Our results about VER do not just apply to allocation problems but to all collective choice problems in which agents have ordinal preferences over discrete outcomes. As a case study, we assume objects have priorities for agents and apply VER to sets of probabilistic allocations that are constrained by stability. VER coincides with the (extended) probabilistic serial rule when priorities are flat and the agent proposing deterministic deferred acceptance algorithm when preferences and priorities are strict. While VER always returns a stable and constrained efficient allocation, it fails to be strategyproof, unconstrained efficient, and envy-free. We show, however, that each of these three properties is incompatible with stability and constrained efficiency.

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

Péter Biró (Hungarian Academy of Sciences – Budapest, HU), Anton Baychkov, Haris Aziz (UNSW – Sydney, AU)

Main reference Haris Aziz, Anton Baychkov, Péter Biró: "Cutoff stability under distributional constraints with an application to summer internship matching", CoRR, Vol. abs/2102.02931, 2021.
URL https://arxiv.org/abs/2102.02931

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.

3.4 Stable roommates with narcissistic, single-peaked, and single-crossing preferences

Robert Bredereck (HU Berlin, DE), Jiehua Chen (TU Wien, AT)

Joint work of Robert Bredereck, Jiehua Chen, Ugo Paavo Finnendahl, Rolf Niedermeier
Main reference Robert Bredereck, Jiehua Chen, Ugo Paavo Finnendahl, Rolf Niedermeier: "Stable roommates with narcissistic, single-peaked, and single-crossing preferences", Auton. Agents Multi Agent Syst., Vol. 34(2), p. 53, 2020.
URL https://doi.org/10.1007/s10458-020-09470-x

The classical Stable Roommates problem is to decide whether there exists a matching of an even number of agents such that no two agents which are not matched to each other would prefer to be with each other rather than with their respectively assigned partners. We investigate Stable Roommates with complete (i.e., every agent can be matched with any other agent) or incomplete preferences, with ties (i.e., two agents are considered of equal value to some agent) or without ties. It is known that in general allowing ties makes the problem NP-complete. We provide algorithms for Stable Roommates that are, compared to those in the literature, more efficient when the input preferences are complete and have some structural property, such as being narcissistic, single-peaked, and single-crossing. However, when the preferences are incomplete and have ties, we show that being single-peaked and single-crossing does not reduce the computational complexity – Stable Roommates remains NP-complete.

References

1 Bredereck, Robert; Chen, Jiehua; Finnendahl, Ugo Paavo; and Niedermeier, Rolf. Stable roommate with narcissistic, single-peaked, and single-crossing preferences. In *Proc. of ADT '17*, volume 10576 of *LNCS*, pages 315–330. Springer, 2017.

2 Bredereck, Robert; Chen, Jiehua; Finnendahl, Ugo Paavo; and Niedermeier, Rolf. Stable roommates with narcissistic, single-peaked, and single-crossing preferences. *Auton. Agents Multi Agent Syst.*, 34(2):53, 2020.

3.5 Fractional Matchings under Preferences: Stability and Optimality

Jiehua Chen (TU Wien, AT)

Joint work of Jieua Chen, Sanjukta Roy, Manuel Sorge

We study generalizations of stable matching in which agents may be matched fractionally; this models time-sharing assignments. We focus on the so-called ordinal stability and cardinal stability, and investigate the computational complexity of finding an ordinally stable or cardinally stable fractional matching which either maximizes the social welfare (i.e., the overall utilities of the agents) or the number of fully matched agents (i.e., agents whose matching values sum up to one). We complete the complexity classification of both optimization problems for both ordinal stability and cardinal stability, distinguishing between the marriage (bipartite) and roommates (non-bipartite) cases and the presence or absence of ties in the preferences. In particular, we prove a surprising result that finding a cardinally stable fractional matching with maximum social welfare is NP-hard even for the marriage case without ties. This answers an open question and exemplifies a rare variant of stable marriage that remains hard for preferences without ties. We also complete the picture of the relations of the stability notions and derive structural properties.

3.6 Group Fairness in Social Service Allocation

Sanmay Das (George Mason University – Fairfax, US)

Joint work of Sanmay Das, Tasfia Mashiat, Xavier Gitiaux, Patrick J. Fowler, Huzefa Rangwala

Motivated by allocation of different types of housing resources to those experiencing homelessness, we consider how to measure the fairness of different allocation rules for different subpopulations. We note how distributional differences in utilities/costs across subpopulations as well as different ways of measuring fairness may affect perceptions of allocation fairness.

3.7 Machine Learning for Mechanism Design:A Short Intro to Differentiable Economics

John Dickerson (University of Maryland – College Park, US)

Joint work of John Dickerson, Michael Curry, Samuel Dooley, Ping-yeh Chiang, Uro Lyi, Neehar Peri, Anthony Ostuni, Elizabeth Horishny, Tom Goldstein
Main reference Neehar Peri, Michael J. Curry, Samuel Dooley, John P. Dickerson: "PreferenceNet: Encoding Human Preferences in Auction Design with Deep Learning", CoRR, Vol. abs/2106.03215, 2021.
URL https://arxiv.org/abs/2106.03215

The design of revenue-maximizing auctions with strong incentive guarantees is a core concern of economic theory. Computational auctions enable online advertising, sourcing, spectrum allocation, and myriad financial markets. Analytic progress in this space is notoriously difficult; since Myerson's 1981 work characterizing single-item optimal auctions, there has been limited progress outside of restricted settings. A recent paper by Dütting et al. circumvents analytic difficulties by applying deep learning techniques to, instead, approximate optimal auctions. Their RegretNet architecture can represent auctions with arbitrary numbers of items and participants; it is trained to be empirically strategyproof, but the property is never exactly verified leaving potential loopholes for market participants to exploit. In parallel, new research from Ilvento et al. and other groups has developed notions of fairness in the context of auction design. Inspired by these advances, in this talk, we discuss extensions of these techniques for approximating auctions using deep learning to address concerns of

- fairness while maintaining high revenue and strong incentive guarantees;
- certified robustness, that is, verification of claimed strategyproofness of deep learned auctions; and
- expressiveness via different demand functions and other constraints.

To enable that last point, we propose a new architecture to learn incentive compatible, revenue-maximizing auctions from sampled valuations, which uses the Sinkhorn algorithm to perform a differentiable bipartite matching. Our new framework allows the network to learn strategyproof revenue-maximizing mechanisms in settings not learnable by the previous RegretNet architecture. This talk connects work in the deep learning for auction design space into the deep learning for **matching market** design space, and provides concrete steps forward regarding differentiable economics and matching market design.

This talk covers hot-off-the-presses work led by: PhD students Michael Curry, Ping-yeh Chiang, and Samuel Dooley; and undergraduate students Elizabeth Horishny, Kevin Kuo, Uro Lyi, Anthony Ostuni, Neehar Peri; and Tom Goldstein at UMD. Papers have appeared at AI/ML conferences or are currently under review; please check arXiv or get in touch for drafts.

3.8 Robust Minimal Instability of the Top Trading Cycles Mechanism

Lars Ehlers (University of Montreal, CA) and Battal Dogan

URL www.battaldogan.com

In the context of priority-based allocation of objects, we formulate methods to compare assignments in terms of their stability. We introduce three basic properties that a reasonable stability comparison should satisfy. We show that, for any stability comparison satisfying the

three properties, the top trading cycles mechanism is minimally unstable among efficient and strategy-proof mechanisms when objects have unit capacities. Our unifying approach covers basically all natural stability comparisons and establishes the robustness of a recent result by Abdulkadiroglu et al. (2020). When objects have non-unit capacities, we characterize the capacity-priority structures for which our result is preserved.

3.9 A Parameterized Complexity Analysis of Incremental Stable Matching

Klaus Heeger (TU Berlin, DE)

Joint work of Niclas Boehmer, Klaus Heeger, Rolf Niedermeier

When computing stable matchings, it is usually assumed that the set of participants in the matching market as well as their preferences is fixed. However, in reality, these may change over time (e.g. when considering the assignment of children to schools, children may leave the market because their family moves to another city). Consequently, an initially stable matching may become unstable over time. Then, a natural goal is to find a stable matching which is as close as possible to the initial one. This problem was introduced as Incremental Stable Matching by Bredereck, Chen, Knop, Luo, and Niedermeier [1]. As they showed that this problem is NP-complete in the roommates setting, we consider its parameterized complexity in ongoing work. Among our results we answer two open questions from Bredereck et al. [1], showing that Incremental Stable Roommates is W[1]-hard parameterized by the number of changes in the preferences (but admits an XP-algorithm with respect to this parameter) and that Incremental Weakly Stable Marriage with Ties is W[1]-hard parameterized by the number of ties. Furthermore, we give FPT-algorithms for two parameters measuring the similarity of the agent's preferences to each other.

References

1 Robert Bredereck, Jiehua Chen, Dušan Knop, Junjie Luo, and Rolf Niedermeier. *Adapting Stable Matchings to Evolving Preferences*. In: Proceedings of the Thirty-Fourth AAAI Conference on Artificial Intelligence, AAAI 2020, pp. 1830–1837, 2020.

3.10 Accomplice Manipulation of the Deferred Acceptance Algorithm

Hadi Hosseini (Pennsylvania State University, US)

Joint work of Hadi Hosseini, Fatima Umar, Rohit Vaish
Main reference Hadi Hosseini, Fatima Umar, Rohit Vaish: "Accomplice Manipulation of the Deferred Acceptance Algorithm", in Proc. of the Thirtieth International Joint Conference on Artificial Intelligence, IJCAI 2021, Virtual Event / Montreal, Canada, 19-27 August 2021, pp. 231–237, ijcai.org, 2021.
URL https://doi.org/10.24963/ijcai.2021/33

The deferred acceptance algorithm is an elegant solution to the stable matching problem that guarantees optimality and truthfulness for one side of the market. Despite these desirable guarantees, it is susceptible to strategic misreporting of preferences by the agents on the other side. We study a novel model of strategic behavior under the deferred acceptance algorithm:

manipulation through an accomplice. Here, an agent on the proposed-to side (say, a woman) partners with an agent on the proposing side – an accomplice – to manipulate on her behalf (possibly at the expense of worsening his match). We show that the optimal manipulation strategy for an accomplice comprises of promoting exactly one woman in his true list (i.e., an inconspicuous manipulation). This structural result immediately gives a polynomial-time algorithm for computing an optimal accomplice manipulation. We also study the conditions under which the manipulated matching is stable with respect to the true preferences. Our experimental results show that accomplice manipulation outperforms self manipulation both in terms of the frequency of occurrence as well as the quality of matched partners.

3.11 Stable partitions for proportional generalized claims problems

Bettina Klaus (University of Lausanne, CH)

Joint work of Bettina Klaus, Oihane Gall

We consider a set of agents, e.g., a group of researchers, who have claims on an endowment, e.g., a research budget from a national science foundation. The research budget is not large enough to cover all claims. Agents can form coalitions and coalitional funding is proportional to the sum of the claims of its members, except for singleton coalitions which do not receive any funding. We analyze the structure of stable partitions when coalition members use well-behaved rules to allocate coalitional endowments, e.g., the well-known constrained equal awards rule (CEA) or the constrained equal losses rule (CEL).

For continuous, (strictly) resource monotonic, and consistent rules, stable partitions with (mostly) pairwise coalitions emerge. For CEA and CEL we provide algorithms to construct such a stable pairwise partition. While for CEL the resulting stable pairwise partition is assortative and sequentially matches lowest claims pairs, for CEA the resulting stable pairwise partition is obtained sequentially by matching in each step either a highest claims pair or a highest-lowest claims pair.

More generally, we can also assume that the minimal coalition size to have a positive endowment is larger or equal to two. We then show how all results described above are extended to this general case.

3.12 Strict Core and Strategy-Proofness for Hedonic Games with Friend-Oriented Preferences

Bettina Klaus (University of Lausanne, CH), Flip Klijn (CSIC – Barcelona, ES), and Seçkin Özbilen (University of Lausanne, CH)

We consider hedonic coalition formation problems with friend-oriented preferences; that is, each agent has preferences over coalitions she is part of based on a partition of the set of other agents into friends and enemies. We assume that for each of her coalitions, (1) adding an enemy makes her strictly worse off, (2) adding a friend together with a set of enemies makes her strictly better off, and (3) adding a friend makes her strictly better off than

losing a set of enemies. We show that the partition associated with the strongly connected components (SCC) of the so-called friend-oriented preference graph is in the strict core. The SCC mechanism, which assigns the SCC partition to each hedonic coalition formation problem with friend-oriented preferences, is group strategy-proof. Furthermore, the SCC mechanism is the only mechanism that satisfies strategy-proofness and strict core stability.

3.13 Minimal-Access Rights in School Choice and the Deferred Acceptance Mechanism

Flip Klijn (CSIC – Barcelona, ES) and Bettina Klaus (University of Lausanne, CH)

Main reference Bettina Klaus, Flip Klijn: "Minimal-Access Rights in School Choice and the Deferred Acceptance Mechanism" BSE Working Paper: 1264, June 2021
URL https://www.barcelonagse.eu/research/working-papers/minimal-access-rights-school-choice-and-deferred-acceptance-mechanism

A classical school choice problem consists of a set of schools with priorities over students and a set of students with preferences over schools. Schools' priorities are often based on multiple criteria, e.g., merit-based test scores as well as minimal-access rights (siblings attending the school, students' proximity to the school, etc.). Traditionally, minimal-access rights are incorporated into priorities by always giving minimal-access students higher priority over non-minimal-access students. However, stability based on such adjusted priorities can be considered unfair because a minimal-access student may be admitted to a popular school while another student with higher merit-score but without minimal-access right is rejected, even though the former minimal-access student could easily attend another of her minimal-access schools.

We therefore weaken stability to minimal-access stability: minimal-access rights only promote access to at most one minimal-access school. Apart from minimal-access stability, we also would want a school choice mechanism to satisfy strategy-proofness and minimal-access monotonicity, i.e., additional minimal-access rights for a student do not harm her. Our main result is that the student-proposing deferred acceptance mechanism is the only mechanism that satisfies minimal-access stability, strategy-proofness, and minimal-access monotonicity. Since this mechanism is in fact stable, our result can be interpreted as an impossibility result: fairer outcomes that are made possible by the weaker property of minimal-access stability are incompatible with strategy-proofness and minimal-access monotonicity.

3.14 Core-Stability in Assignment Markets with Financially Constrained Buyers

Martin Bichler (TU München, DE)

Joint work of Eleni Batziou, Martin Bichler, Maximilian Fichtl

We consider auctions of indivisible items to unit-demand bidders with budgets. Without financial constraints and pure 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, there does not exist an incentive-compatible and core-stable mechanism. Even if bidders reveal their valuations and budgets truthfully, the allocation and pricing problem becomes an NP-hard optimization problem. The analysis complements complexity results for more complex valuations and raises doubts on the efficiency of simple auction designs in the presence of financially constrained buyers.

3.15 Behavioral Stable Marriage Problems

Nicholas Mattei (Tulane University – New Orleans, US)

Joint work of Nicholas Mattei, Andrea Martin, Brent Venable
Main reference Andrea Martin, Nicholas Mattei, Brent Venable: "Behavioral Stable Marriage Problems", Presented at the 3rd Games, Agents, and Incentives Workshop @ AAMAS 2021.
URL https://preflib.github.io/gaiw2021/papers/GAIW_2021_paper_33.pdf

The stable marriage problem (SMP) is a mathematical abstraction of two-sided matching markets with many practical applications. Several preference models have been considered in the context of SMPs including orders with ties, incompleteness, and uncertainty, but none have yet captured behavioral aspects of human decision making such as contextual effects. We introduce Behavioral Stable Marriage Problems (BSMPs), bringing together the formalism of matching with cognitive models of decision making to account for multi-attribute, non-deterministic preferences and to study the impact of well known behavioral deviations from rationality on two core notions of SMPs: stability and fairness. We analyze the computational complexity of several related problems, show that proposal-based approaches are affected by contextual effects and propose and evaluate novel ILP and local-search-based methods to efficiently find optimally stable and fair matchings.

3.16 Quick presentation of the French college admission procedure

Simon Mauras (University Paris Diderot, FR)

Each year in France, around 800 000 high-school students apply to the centralized college admission procedure. In 2018, the new platform, called Parcoursup, was launched. The main novelty of procedure is that students do not have to order their applications. Instead, the platform run the school proposing deferred acceptance mechanism, where students answer queries online and have a few days to chose which application they keep each time they receive multiple offers.

The goal of this informal talk was to present the upsides and downsides of this new mechanism. On the positive side, seats vacated by students leaving the market can be filled quickly by the online procedure; and the fact that students do not have to order applications can decrease self-censorship. On the negative side, the speed of convergence of the procedure becomes of paramount importance, and can be the cause of strategic and non-truthful behaviors from colleges and students.

3.17 Almost Stable Marriage

Sushmita Gupta (The Institute of Mathematical Sciences – Chennai, IN), Pallavi Jain (Indian Institute of Techology, IN)

Joint work of Meirav Zehavi, Pallavi Jain, Saket Saurabh, Sanjukta Roy, and Sushmita Gupta
Main reference Sushmita Gupta, Pallavi Jain, Sanjukta Roy, Saket Saurabh, Meirav Zehavi: "On the (Parameterized) Complexity of Almost Stable Marriage", in Proc. of the 40th IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science, FSTTCS 2020, December 14-18, 2020, BITS Pilani, K K Birla Goa Campus, Goa, India (Virtual Conference), LIPIcs, Vol. 182, pp. 24:1–24:17, Schloss Dagstuhl – Leibniz-Zentrum für Informatik, 2020.
URL https://doi.org/10.4230/LIPIcs.FSTTCS.2020.24

In the Stable Marriage problem, when the preference lists are complete, all agents of the smaller side can be matched. However, this need not be true when preference lists are incomplete. In most real-life situations, where agents participate in the matching market voluntarily and submit their preferences, it is natural to assume that each agent wants to be matched to someone in his/her preference list as opposed to being unmatched. In light of the Rural Hospital Theorem, we have to relax the "no blocking pair" condition for stable matchings in order to match more agents. In this paper, we study the question of matching more agents with fewest possible blocking edges. In particular, the goal is to find a matching whose size exceeds that of a stable matching in the graph by at least t and has at most k blocking edges. We study this question in the realm of parameterized complexity with respect to several natural parameters, k, t, d, where d is the maximum length of a preference list. Unfortunately, the problem remains intractable even for the combined parameter k + t + d. Thus, we extend our study to the local search variant of this problem, in which we search for a matching that not only fulfills each of the above conditions but is "closest", in terms of its symmetric difference to the given stable matching, and obtain an FPT algorithm.

3.18 Allocation with Weak Priorities and General Constraints

Thanh Nguyen (Purdue University – West Lafayette, US)

Joint work of Thanh Nguyen, Young-san Lin, Hai Nguyen, Kemal Altinkemer
Main reference Young-San Lin, Hai Nguyen, Thành Nguyen, Kemal Altinkemer: "Allocation with Weak Priorities and General Constraints", in Proc. of the EC '21: The 22nd ACM Conference on Economics and Computation, Budapest, Hungary, July 18-23, 2021, pp. 690–691, ACM, 2021.
URL https://doi.org/10.1145/3465456.3467581

We consider a resource allocation problem that combines three general features: complex resource constraints, weak priority rankings over the agents, and ordinal preferences over bundles of resources. We develop a mechanism based on a new concept called *Competitive Stable Equilibrium*. It has several attractive properties, unifies two different frameworks of one-sided and two-sided markets, and extends existing methods to richer environments. Our framework also allows for an alternative and more flexible tie-breaking rule by giving agents different budgets. We empirically apply our mechanism to reassign season tickets to families in the presence of social distancing. Our simulation results show that our method outperforms existing ones in both efficiency and fairness measures.

3.19 Survey on online matching markets

Peng Shi

Main reference Peng Shi: "Optimal Matchmaking Strategy in Two-sided Marketplaces" (June 4, 2021). USC Marshall School of Business Research Paper
URL https://doi.org/10.2139/ssrn.3536086

I provided an idiosyncratic survey of modern online matching markets, such as those for dating, lodging, labor, school and college admissions, transportation, etc., and research inspired by such marketplaces. A key issue in many of these markets is congestion, i.e., difficulty clearing the market. An interdisciplinary perspective combining operations research, economics, engineering and computer science has been fruitful in understanding congestion and identifying ways to mitigate it. We discussed some recent research in the area and open directions.

3.20 Reallocation with Priorities

Jan Christoph Schlegel (City – University of London, GB)

Joint work of Jan Christoph Schlegel, Julien Combe
URL https://crest.science/wp-content/uploads/2021/06/2021-09.pdf

We consider a reallocation problem with priorities where each agent is initially endowed with a house and is willing to exchange it, but where each house has a priority ordering over the agents of the market. In this setting, it is well known that there is no individually rational and stable mechanism so that the literature has introduced a modified stability notion called μ_0-stability. Contrary to college admission problems, where priorities are present but there is no initial endowment, we show that the modified Deferred Acceptance mechanism identified in the literature is not the only Individually Rational, Strategy-Proof and μ_0-stable mechanism. Introducing a new axiom called Independence of Irrelevant Agents and using the standard axiom of unanimity, we show that modified Deferred Acceptance mechanism is the unique mechanism that is individually rational, strategy-proof, μ_0-stable, unanimous and independent of irrelevant agents.

3.21 Is it worth sprucing up your home?

Ildikó Schlotter (Hungarian Academy of Sciences – Budapest, HU), Péter Biró (Hungarian Academy of Sciences – Budapest, HU), and Tamás Fleiner (Budapest University of Technology & Economics, HU)

We study housing markets as introduced by Shapley and Scarf in 1974. We investigate the computational complexity of various questions regarding the situation of an agent p in a housing market H: we show that it is NP-hard to find an allocation in the core of p where (i) p receives a certain house, (ii) p does not receive a certain house, or (iii) p 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 p receives a house h, if the value of the house owned by p increases, then the resulting housing market admits an allocation where p 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.

3.22 Fractional and Probabilistic Matching: a brief overview

Jay Sethuraman (Columbia University – New York, US)

I will review selected results on probabilistic and fractional matchings, focusing on classical results and highlighting some recent developments.

3.23 Matching and Prices

Alexander Teytelboym (University of Oxford, GB)

Joint work of Alexander Teytelboym, Ravi Jagadeesan
Main reference Ravi Jagadeesan, Alexander Teytelboym: "Matching and Money", in Proc. of the EC '21: The 22nd ACM Conference on Economics and Computation, Budapest, Hungary, July 18-23, 2021, p. 634, ACM, 2021.
URL https://doi.org/10.1145/3465456.3467587

Indivisibilities and budget constraints are pervasive features of many matching markets. But gross substitutability – a standard condition on preferences in matching models – typically fails in such markets. To accommodate budget constraints and other income effects, we instead assume that agents' preferences satisfy net substitutability. Although competitive equilibria do not generally exist in our setting, we show that stable outcomes always exist and are efficient. We illustrate how the flexibility of prices is critical for our results. We also discuss how budget constraints and other income effects affect the properties of standard auction and matching procedures, as well as of the set of stable outcomes.

3.24 Blood Allocation with Replacement Donors: A Theory of Multi-unit Exchange with Compatibility-based Preferences

Utku Ünver (Boston College, US)

Joint work of Utku Ünver. (Boston College, US), Xiang Han, and Onur Kesten
Main reference Xiang Han, Onur Kesten, M. Utku Ünver: "Blood Allocation with Replacement Donors: A Theory of Multi-unit Exchange with Compatibility-based Preferences", in Proc. of the EC '21: The 22nd ACM Conference on Economics and Computation, Budapest, Hungary, July 18-23, 2021, pp. 585–586, ACM, 2021.
URL https://doi.org/10.1145/3465456.3467565

In 56 developing and developed countries, blood component donations by volun-teer non-remunerated donors can only meet less than 50% of the demand. In these countries, blood banks rely on replacement donor programs that provide blood to patients in return for donations made by their relatives or friends. These programs appear to be disorganized, non-transparent, and inefficient. We introduce the design of replacement donor programs and blood allocation schemes as a new application of market design. We introduce optimal blood allocation mechanisms that accommodate fairness, efficiency, and other allocation objectives, together with endogenous exchange rates between received and donated blood units beyond the classical one-for-one exchange. Additionally, the mechanisms provide correct incentives for the patients to bring forward as many replacement donors as possi- ble. This framework and the mechanism class also apply to general applications of multi-unit exchange of indivisible goods with compatibility-based preferences beyond blood allocation with different information problems.

3.25 Stability in Large Markets

Karolina Lena Johanna Vocke (Universität Innsbruck, AT)

Joint work of Karolina Lena Johanna Vocke, Ravi Jagadeesan

In matching models, pairwise stable outcomes do not generally existwithout substantial restrictions on both preferences and the topology of the networkof contracts. We address the foundations of matching markets by developing amatching model with a continuum of agents that allows for complex preferencesand network structures. We argue thattree stability—a refinement of pairwisestability introduced by Ostrovsky (2008)—is the natural solution concept for thissetting. Our main results show that tree-stable outcomes are guaranteed to existin large markets for arbitrary preferences and network topologies (unlike for otherstability concepts), and provide a noncooperative microfoundation for tree stability.Our framework can flexibly capture the degree to which agents can coordinate byallowing subnetworks of contracts to be made contingent on each other by beingbundled together.

3.26 Mechanisms for Facility Location with Capacity Limits

Toby Walsh (UNSW – Sydney, AU)

Joint work of Toby Walsh, Haris Aziz, Hau Chan, Barton E. Lee, Bo Li
Main reference Haris Aziz, Hau Chan, Barton Lee, Bo Li, Toby Walsh: "Facility Location Problem with Capacity Constraints: Algorithmic and Mechanism Design Perspectives", Proceedings of the AAAI Conference on Artificial Intelligence, Vol. 34(02), pp. 1806–1813, 2020.
URL https://doi.org/10.1609/aaai.v34i02.5547

I consider the facility location problem in the one dimensional setting where each facility can serve a limited number of agents from the algorithmic and mechanism design perspectives. From the algorithmic perspective, the optimization problem, where the goal is to locate facilities to minimize either the total cost to all agents or the maximum cost of any agent is NP-hard. However, the problem is fixed-parameter tractable, and the optimal solution can be computed in polynomial time whenever the number of facilities is bounded, or when all facilities have identical capacities. I then consider the problem from a mechanism design perspective where the agents are strategic and need not reveal their true locations. Several natural mechanisms studied in the uncapacitated setting either lose strategy-proofness or a bound on the solution quality for the total or maximum cost objective.

3.27 Approximability vs. Strategy-proofness in Stable Matching Problems with Ties

Yu Yokoi (National Institute of Informatics – Tokyo, JP) and Shuichi Miyazaki (Kyoto University, JP)

Joint work of Hiromichi Goko, Kazuhisa Makino, Shuichi Miyazaki, Yu Yokoi
Main reference Hiromichi Goko, Kazuhisa Makino, Shuichi Miyazaki, Yu Yokoi: "Maximally Satisfying Lower Quotas in the Hospitals/Residents Problem with Ties", CoRR, Vol. abs/2105.03093, 2021.
URL https://arxiv.org/abs/2105.03093

We consider a two-sided stable matching model. When ties are introduced, the rural hospitals theorem fails to hold, which makes some optimization problems nontrivial, such as maximizing the matching size or satisfaction ratio of lower quotas. For these problems, strategy-proof algorithms fail to find an optimal solution, irrespective of the computational complexity. This talk reviews recent three papers on strategy-proof approximation algorithms for those problems. The first two deal with cardinality-maximization of a stable matching and show the best approximation ratios attained by deterministic strategy-proof algorithms. The third one, which is the main part of this talk, investigates the problem of finding a stable matching that maximally satisfies lower quotas. For this new problem, we provide a strategy-proof approximation algorithm and several inapproximability results.

3.28 Survey on Constrained Matching

Makoto Yokoo (Kyushu University – Fukuoka, JP)

Two-sided matching deals with finding a desirable combination of two parties, e.g., students and colleges, workers and companies, and medical residents to hospitals. Beautiful theoretical results on two-sided matching have been obtained, i.e., the celebrated Deferred Acceptance mechanism is strategyproof for students, and obtains the student optimal matching among all stable matchings. However, these results are applicable only for the standard model, where only distributional constraints are the maximum quota (capacity limit) of each college. In many real application domains, various distributional constraints are imposed due to social requirements. For example, a college needs a certain number of students to operate, or some medical residents must be assigned to a rural hospital.

In this talk, I represent a simple and general abstract model, and introduce a few representative constraints that can be formalized using this model. In this model, distributional constraints are defined over a set of allocation vectors, each of which describes the number of students allocated to each college. Then, I present two general mechanisms. One is the generalized DA, which works when distributional constraints satisfy two conditions: hereditary and an M-natural-convex set [1]. More specifically, the generalized DA is strategyproof, and finds the student optimal matching among all matchings that satisfy some stability requirement. The other is the adaptive DA [2], which works when distributional constraints satisfy hereditary condition. It is strategyproof and nonwasteful.

References

1 Kojima, F., Tamura, A., Yokoo, M.: Designing matching mechanisms under constraints: An approach from discrete convex analysis, Journal of Economic Theory, 176 (2018)
2 Goto, M., Kurata, R., Kojima, F., Kurata, R., Tamura, A, Yokoo, M.: Designing Matching Mechanisms under General Distributional Constraints, American Economic Journal: Microeconomics, 9 (2):226-62, (2017).

3.29 Absolutely and simply popular rankings

Ágnes Cseh (Hasso-Plattner-Institut, Universität Potsdam, DE)

Joint work of Ágnes Cseh, Sonja Kraiczy, David Manlove
Main reference Sonja Kraiczy, Ágnes Cseh, David F. Manlove: "On absolutely and simply popular rankings", CoRR, Vol. abs/2102.01361, 2021.
URL https://arxiv.org/abs/2102.01361

Van Zuylen et al. introduced the notion of a popular ranking in a voting context, where each voter submits a strictly-ordered list of all candidates. A popular ranking π of the candidates is at least as good as any other ranking σ in the following sense: if we compare π to σ, at least half of all voters will always weakly prefer π. Whether a voter prefers one ranking to another is calculated based on the Kendall distance.

A more traditional definition of popularity – as applied to popular matchings, a well-established topic in computational social choice – is stricter, because it requires at least half of the voters *who are not indifferent between π and σ* to prefer π. In this paper, we derive

structural and algorithmic results in both settings, also improving upon the results by van Zuylen et al. We also point out strong connections to the famous open problem of finding a Kemeny consensus with 3 voters.

3.30 Kidney Exchange progress in Germany

Ágnes Cseh

URL https://crossover-nierenspenderliste.de/

A short report on the current status quo of kidney exchange in Germany.

4 Working groups

4.1 Gender Terminology in Bipartite Stable Matching

Robert Bredereck (HU Berlin, DE)

Bipartite Stable Matching is classically presented as "Stable Marriage" with one site being men and the other site being women. Meant as illustration and not as proposal for real marriage, the many successful applications of the model are all in completely different domains. The classical terminology, however, can be easily misunderstood and becomes questionable at latest when

- one site behaves always passive while the other behaves always active,
- one site manipulates while the other is honest,
- there is external manipulation, or
- some couples are forced or forbidden.

Participants of the seminar discussed the seriousness of these issues in particular in situations where people from outside the community are involved (teaching, grant proposals, etc.). To avoid misunderstanding many participants are using alternative terminologies:

- sportsmen ↔ sportswomen (mixed teams such as tennis)
- leaders ↔ followers (dancing)
- doctors ↔ hospitals
- student ↔ colleges
- workers ↔ companies
- workers ↔ apprentices
- mentors ↔ mentees

While some of the alternatives even allow to keep using different grammatical gender for the two sites (and so allow to write easily comprehensible texts), other alternatives fit better with the manipulation setting. Some of these alternative terminologies are already established in more specialized or generalized settings of Stable Matching, but may still qualify for the illustration of Bipartite Stable Matching. Another possibility in use is to keep the marriage market terminology while clearly putting it into a historical context.

4.2 Popular Matching with few blocking pairs

Sushmita Gupta (The Institute of Mathematical Sciences – Chennai, IN), Ágnes Cseh (Hasso-Plattner-Institut, Universität Potsdam, DE), Pallavi Jain (Indian Institute of Techology, IN), Baharak Rastegari (University of Southampton, GB), Ildikó Schlotter (Hungarian Academy of Sciences – Budapest, HU), and Kavitha Telikepalli (TIFR Mumbai, IN)

We work in the classic 2-sided matching market model with strict preferences on both sides. In the context of popular matchings, we study two scenarios.

1. We aim to find a popular matching that is blocked by a given edge set. We have a fixed set of edges along which agents won't deviate from the matching. This is very much like free edges / socially stable matchings, with a different optimality principle. We look for a stable matching M with free edges that indeed block M, plus we want M to be popular on the top of it.
2. We aim to find a popular matching that is blocked by exactly / at most k edges. We have limited resources to compensate agents who could be better off by switching to their blocking partner. The regret of a blocking agent is calculated by counting the number of her blocking edges.

Our goal is to find out whether a popular matching in the above two scenarios exist. Preliminary results indicate hardness even in restricted cases.

4.3 Lexicographic preferences in matching and market design

Bettina Klaus (University of Lausanne, CH)

In some recent research projects (own and other's research), lexicographic preference domains have nice interpretations and allow for new positive results. One example are Shapley-Scarf housing markets

- with limited externalities or
- with multiple types.

Another example is the joint coalition formation paper Seçkin Özbilen presented in this workshop.

The working group studied other matching and related models for which lexicographic preferences can be defined in a meaningful way and with the potential for new positive results. In particular, many-to-many two-sided matching markets were considered. The main outcome was an update to all working group participants on the current literature and a better understanding of specific open questions in relation to lexicographic preferences in many-to-many two-sided matching markets.

Participants

- Péter Biró
Hungarian Academy of Sciences – Budapest, HU
- Somouaoga Bonkoungou
University of Lausanne, CH
- Florian Brandl
Universität Bonn, DE
- Jiehua Chen
TU Wien, AT
- Ágnes Cseh
Hasso-Plattner-Institut, Universität Potsdam, DE
- Lars Ehlers
University of Montreal, CA
- Tamás Fleiner
Budapest University of Technology & Economics, HU
- Martin Hoefer
Goethe-Universität – Frankfurt am Main, DE
- Zsuzsanna Jankó
Corvinus University – Budapest, HU
- Bettina Klaus
University of Lausanne, CH
- Simon Mauras
University Paris Diderot, FR
- Seckin Özbilen
University of Lausanne, CH
- Katarzyna Paluch
University of Wroclaw, PL
- Jan Christoph Schlegel
City – University of London, GB
- Karolina Lena Johanna Vocke
Universität Innsbruck, AT

Remote Participants

- Haris Aziz
UNSW – Sydney, AU
- Martin Bichler
TU München, DE
- Felix Brandt
TU München, DE
- Robert Bredereck
HU Berlin, DE
- Christine Cheng
University of Wisconsin – Milwaukee, US
- Sanmay Das
George Mason University – Fairfax, US
- John Dickerson
University of Maryland – College Park, US
- Di Feng
University of Lausanne, CH
- Sushmita Gupta
The Institute of Mathematical Sciences – Chennai, IN
- Klaus Heeger
TU Berlin, DE
- Hadi Hosseini
Pennsylvania State University – University Park, US
- Pallavi Jain
Indian Institute of Techology – Jodhpur, IN
- Yash Kanoria
Columbia University – New York, US
- Flip Klijn
CSIC – Barcelona, ES
- Fuhito Kojima
University of Tokyo, JP
- Alexander Lam
UNSW – Sydney, AU
- Irene Y. Lo
Stanford University, US
- Nicholas Mattei
Tulane University – New Orleans, US
- Michael McKay
University of Glasgow, GB
- Shuichi Miyazaki
Kyoto University, JP
- Thayer Morrill
North Carolina State University – Raleigh, US
- Thanh Nguyen
Purdue University – West Lafayette, US
- Sofiat Olaosebikan
University of Glasgow, GB
- Daniel Paulusma
Durham University, GB
- Baharak Rastegari
University of Southampton, GB
- Ildikó Schlotter
Hungarian Academy of Sciences – Budapest, HU
- Jay Sethuraman
Columbia University – New York, US
- Kavitha Telikepalli
TIFR Mumbai, IN
- Alexander Teytelboym
University of Oxford, GB
- Utku Unver
Boston College, US
- Toby Walsh
UNSW – Sydney, AU
- Mobin YahyazadehJeloudar
Stanford University, US
- Yu Yokoi
National Institute of Informatics – Tokyo, JP
- Makoto Yokoo
Kyushu University – Fukuoka, JP