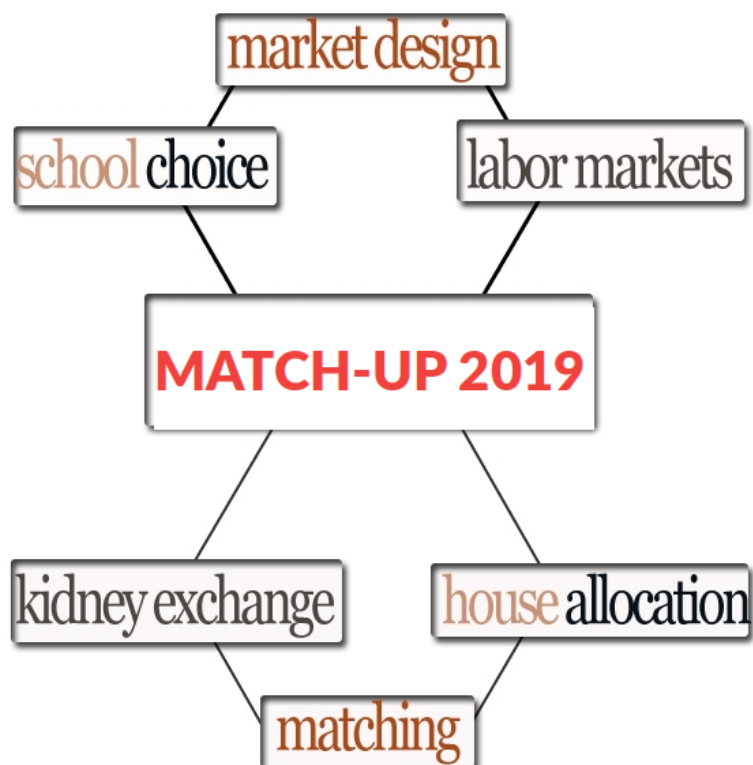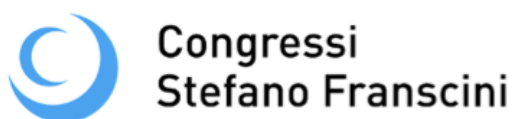# MATCH-UP 2019:
Program and Abstract Booklet

5th International Workshop on Matching Under Preferences
Congressi Stefano Franscini, Monte Verità, Ascona, Switzerland
`http://www.optimalmatching.com/MATCHUP2019/`

May 26th - 29th, 2019

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Preface

This is the fifth International Workshop on Matching Under Preferences, MATCH-UP 2019. Matching problems with preferences occur in applications such as the matching of school-leavers and universities, junior doctors and hospitals, refugees and resources dedicated to them, students and campus housing, children and schools, kidney transplant patients and donors and so on. The workshop focus is on matchings that are in some sense optimal with respect to participants preferences over possible outcomes. This problem is explored from the perspective of algorithms and complexity, discrete mathematics, combinatorial optimization, game theory, mechanism design and economics.

A key objective of the MATCH-UP series of interdisciplinary workshops is to bring together the research communities of these related areas. The series began at the University of Reykjavik, Iceland, in 2008; with the second workshop at Corvinus University of Budapest, Hungary, in 2012, the third workshop at the University of Glasgow, UK, in 2015, and the fourth workshop at Microsoft Research, Cambridge, USA, in 2017.

For the current fifth workshop we received 57 presentation submissions and 7 poster submissions, which were reasonably well-balanced in terms of representing the economics and computer science communities. Due to time constraints and the workshop tradition of not running parallel sessions, we accepted 29 presentation submissions; we also accepted all poster submissions. In addition, we invited five keynote talks from leading matching scholars. The abstracts of the presentations and poster submissions are published in this program booklet. We think that these represent well the current frontier of research on matching problems with preferences.

We thank the Program Committee and additional reviewers, the invited speakers, and the authors of all submitted papers and posters for their important contributions to the scientific aspects of this workshop. We thank the members of the Organizing Committee and the Steering Committee for their key role in creating the program and in planning phase of the conference. Additionally, we are grateful to Andrea Hofer and Manuela Steinauer for their help with this program booklet, Sofiat Olaosebikan for her help with the conference webpage, as well as Liliana Cantoreggi (Fondazione Monte Verità), Therese Egli (Congressi Stefano Franscini, ETH), and Irene Schmidli (ETH) for their help with the local organization and navigating all administrative processes.

Finally, we thank the conference sponsors. We received generous financial support from Congressi Stefano Franscini at whose premises the workshop is held as well as from the ETH Zürich, University of Zürich, and the Swiss National Science Foundation. Additionally, Congressi Stefano Franscini and the journal Algorithms financed the two best paper prizes of MATCH-UP 2019.

Tamás Fleiner, Bettina Klaus, and Marek Pycia

MATCH-UP 2019 Conference Chair and Program Committee Co-Chairs

MATCH-UP 2019 Program

Presenters are marked in **boldface**.

Sunday, May 26th

14:00 - 14:15 **Conference Opening (Bettina Klaus)**

14:15 - 14:40 "Stability Against Robust Deviations in the Roommate Problem" Daisuke Hirata, Yusuke Kasuya, and **Kentaro Tomoeda**

14:40 - 15:05 "Robust Group Strategy-Proofness" **Steven Kivinen** and Norovsambuu Tumennasan

15:05 - 15:30 "Robust Design in Monotonic Matching Markets: A Case for Firm-Proposing Deferred-Acceptance" **Lars Ehlers** and Jordi Massó

15:30-16:00 **Coffee Break**

16:00 - 17:20 **Poster Presentation Session 1**

"Preprocessing in Matching Problems" Maxence Delorme, Sergio Garcìa, Jacek Gondzio, Joerg Kalcsics, David Manlove, and **William Pettersson**

"Legal Assignments, the EADAM (Efficiency Adjusted Deferred Acceptance Mechanism) Algorithm" Yuri Faenza and **Xuan Zhang**

"A General Framework for Stable Roommate Problems: A Preliminary Report" **Müge Fidan** and Esra Erdem

"Preference Manipulation in Two-Sided Matching - Strategic Behavior and Robustness of Solution Algorithms" **Christian Haas**

"Practical Issues in Matching - A Case Study on Genetic Counseling Admissions in North America" **Jonah Peranson**

"Unpopularity Factor in the Marriage and Roommates Problems" **Suthee Ruangwises** and Toshiya Itoh

"School choice with priority levels: Constrained Efficient and Fair Assignment" **Thomas Wouters**

18:30 **Welcome Drink**

19:00 **Dinner**

Monday, May 27th

09:10	**CSF Welcome Address**
09:25 - 10:10	**Invited Talk** "Parameterizing Stable Matching Problems" **Ildi Schlotter**
10:10 - 10:35	"Stable Noncrossing Matchings" **Suthee Ruangwises** and Toshiya Itoh
10:35 - 11:05	**Coffee Break**
11:05 - 11:30	"Refugee Resettlement" **David Delacrétaz**, Scott Duke Kominers, and Alexander Teytelboym
11:30 - 11:55	"Matching Problem of Civil Service" **Ashutosh Thakur**
11:55 - 12:20	"Trading Networks with General Preferences" **Jan Christoph Schlegel**
12:20 - 13:45	**Lunch**
13:45 - 14:30	**Invited Talk** "International Kidney Exchange Programmes: Optimisation and Games" **Péter Biró**
14:30 - 14:55	"Pareto Optimal Coalitions of Fixed Size" **Ágnes Cseh**, Tamás Fleiner, and Petra Harján
14:55 - 15:20	"Balanced Stable Marriage: How Close is Close Enough?" **Sushmita Gupta**, Sanjukta Roy, Saket Saurabh, and Meirav Zehavi
15:20 - 15:50	**Coffee Break**
15:50 - 16:15	"Flexibility in House Allocation and Housing Markets" **Madhav Raghavan**
16:15 - 16:40	"Endowment Manipulations in Probabilistic Assignment Problem" **Yuki Tamura**
16:40 - 17:05	"Equivalent Choice Functions and Stable Mechanisms" **Jan Christoph Schlegel**
17:05 - 17:15	**Short Break (no coffee)**
17:15 - 17:40	"Centralized Matching with Incomplete Information" **Marcelo Ariel Fernandez** and Leeat Yariv
17:40 - 18:05	"Simultaneous Search: Beyond Independent Successes" **Ran I. Shorrer**
18:05 - 18:30	"Deferred Acceptance and Regret-free Truth-telling: A Characterization Result" **Marcelo Ariel Fernandez**
19:00	**Dinner**

Tuesday, May 28th

09:00 - 09:45   **Invited Talk** "Balanced Exchange in a Multi-Object Shapley-Scarf Market" Péter Biró, **Flip Klijn**, and Szilvia Pápai

09:45 - 10:10   "Competing for Priorities in School Choice" Greg Leo and **Martin Van der Linden**

10:10 - 10:35   "Information Acquisition Costs in Matching Markets" Nicole S. Immorlica, Jacob D. Leshno, and **Irene Y. Lo**

10:35 - 11:05   **Coffee Break**

11:05 - 11:30   "Efficient and (Pretty) Fair Course Assignment with Quotas" Martin Bichler, Alexander Hammerl, Thayer Morrill, and **Stefan Waldherr**

11:30 - 11:55   "An Algorithm for Strong Stability in the Student-Project Allocation Problem with Ties" **Sofiat Olaosebikan** and David Manlove

11:55 - 12:20   "Strategy-Proof Approximation Algorithms for the Stable Marriage Problem with Ties and Incomplete Lists", Koki Hamada, **Shuichi Miyazaki**, and Hiroki Yanagisawa

12:20 - 13:45   **Lunch**

Afternoon   **Excursion** (Castles of Bellinzona)

19:30   **Social Dinner**

Wednesday, May 29th

09:00 - 09:45 **Invited Talk** "Efficient and Incentive-Compatible Liver Exchange" Haluk Ergin, Tayfun Sönmez, and **M. Utku Ünver**

09:45 - 10:10 "Matching for the Israeli "Mechinot" Gap-Year Programs: Handling Rich Diversity Requirements" **Yannai A. Gonczarowski**, Lior Kovalio, Noam Nisan, and Assaf Romm

10:10 - 10:35 "Recourse in Kidney Exchange Programs" Valentin Bartier, Yves Crama, **Bart Smeulders**, and Frits C.R. Spieksma

10:35 - 11:05 **Coffee Break**

11:05 - 11:30 "Obvious Dominance and Random Priority" Marek Pycia and **Peter Troyan**

11:30 - 11:55 "Subgame Perfect Equilibria under the Deferred Acceptance Algorithm" Keisuke Bando and **Yasushi Kawase**

11:55 - 12:20 "Optimizing Reserves in School Choice: A Dynamic Programming Approach" **Franklyn Wang**, Ravi Jagadeesan, and Scott Duke Kominers

12:20 - 13:45 **Lunch**

13:45 - 14:10 "Strategy-proof, Envy-free and Pareto Efficient Online Mechanisms for Fair Division with Additive Valuations" **Martin Aleksandrov** and Toby Walsh

14:10 - 14:35 "An Alternative Approach to Asylum Assignment" **Gian Caspari**

14:35 - 15:00 "Matching with Myopic and Farsighted Players" **Jean-Jacques Herings**, Ana Mauleon, and Vincent Vannetelbosch

15:00 - 15:30 **Coffee Break**

15:30 - 16:15 **Invited Talk** "Pareto Optimal Allocation under Uncertain Preferences" Haris Aziz, Péter Biró, Ronald de Haan, and **Baharak Rastegari**

16:15 - 16:40 **CSF Award and Algorithms Award**

16:40 - 18:00 **Poster Presentation Session 2**

All papers as in Poster Presentation Session 1 (except for Jonah Peranson and Christian Haas).

19:00 **Dinner**

MATCH-UP 2019 Abstracts

Abstracts are sorted in order of presentation in the program (with all poster abstracts at the end).

Stability Against Robust Deviations in the Roommate Problem

Daisuke Hirata[1], Yusuke Kasuya[2], and **Kentaro Tomoeda**[3]

[1]Hitotsubashi University; [2]Kobe University; [3]University of Technology Sydney

26 May 14:15

We propose a new solution concept in the roommate problem, based on the "robustness" of deviations (i.e., blocking coalitions). We call a deviation from a matching robust up to depth k, if none of the deviators gets worse off than at the original matching after any sequence of at most k subsequent deviations. We say that a matching is stable against robust deviations (for short, SaRD) up to depth k, if there is no robust deviation up to depth k. As a smaller k imposes a stronger requirement for a matching to be SaRD, we investigate the existence of a matching that is SaRD with a minimal depth k. We constructively demonstrate that a SaRD matching always exists for $k = 3$, and establish sufficient conditions for $k = 1$ and 2.

Robust Group Strategy-Proofness

Steven Kivinen[1] and Norovsambuu Tumennasan[2]

[1]Higher School of Economics; [2]Dalhousie University

26 May 14:40

Strategy-proofness (SP) is a sought-after property in social choice functions because it ensures that agents have no incentive to misrepresent their private information in the interim stage. On the other hand, group strategy-proofness (GSP) is a notion that is applied to the ex-post stage but not to the interim one. Thus, we propose a new notion of GSP, coined robust group strategy-proofness (RGSP), which ensures that no group benefits by deviating from truth-telling in the interim stage. We show that Vickrey auctions satisfy RGSP. In the problem of allocating indivisible objects, an acyclicity condition on the priorities is both necessary and sufficient for the deferred acceptance rule to satisfy RGSP but is only necessary for the celebrated top trading cycles rule. For the allocation of divisible private goods among agents with single-peaked preferences (Sprumont, 1991), only free disposal, fixed path rules satisfy RGSP within the class of sequential allotment rules.

Robust Design in Monotonic Matching Markets: A Case for Firm-Proposing Deferred-Acceptance

Lars Ehlers[1] and Jordi Massó[2]

[1] Université de Montréal; [2]Universitat Autònoma de Barcelona and Barcelona GSE

We study two-sided matching markets among workers and firms. Workers seek one position at a firm but firms may employ several workers. In many applications those markets are monotonic: leaving positions unfilled is costly as for instance, for hospitals this means not being able to provide full service to its patients. A huge literature has advocated the use of stable mechanisms for clearinghouses. The interests among workers and firms are polarized among stable mechanisms, most famously the firm-proposing DA and the worker-proposing DA. We show that for the firm-proposing DA ex-ante incentive compatibility and ex-post incentive compatibility are equivalent whereas this is not necessarily true for the worker-proposing DA. The firm-proposing DA turns out to be more robust than the worker-proposing DA under incomplete information when incentives of both sides of the market are important.

Parameterizing Stable Matching Problems

Ildi Schlotter[1]

[1] Budapest University of Technology and Economics

Recently, a growing number of researchers have studied computationally hard stable matching problems using the framework of parameterized complexity in order to develop efficient algorithms. After a brief introduction to parameterized complexity, I survey these results. My talk focuses on the question of choosing a parameter, and provides examples of the most common approaches for parameterization in the surveyed papers. My talk will also argue in favor of a multidimensional view on the complexity landscape of problems in the area of stable matchings.

Stable Noncrossing Matchings

Suthee Ruangwises[1] and Toshiya Itoh[2]

[1]Tokyo Institute of Technology; [2]Tokyo Institute of Technology

Given a set of n men represented by n points lying on a line, and n women represented by n points lying on another parallel line, with each person having a list that ranks some people of opposite gender as his/her acceptable partners in strict order of preference. In this problem, we want to match people of opposite genders to satisfy people's preferences as well as making the edges not crossing one another geometrically. A *noncrossing blocking pair* of a matching M is a pair (m, w) of a man and a woman such that they are not matched with each other but prefer each other to their own partners in M, and the segment (m, w) does not cross any edge in M. A *weakly stable noncrossing matching* (WSNM) is a noncrossing matching

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that does not contain any noncrossing blocking pair. In this paper, we prove the existence of a WSNM in any instance by developing an $O(n^2)$ algorithm to find one in a given instance.

Refugee Resettlement

David Delacrétaz[1], Scott Duke Kominers[2], and Alexander Teytelboym[3]

[1]University of Oxford; [2]Harvard Business School; [3]University of Oxford

Over 100,000 refugees are permanently resettled from refugee camps to hosting countries every year. Nevertheless, refugee resettlement processes in most countries are *ad hoc*, accounting for neither the priorities of hosting communities nor the preferences of refugees themselves. Building on models from two-sided matching theory, we introduce a new framework for *matching with multidimensional constraints* that models refugee families' needs for multiple units of different services, as well as the service capacities of localities. We propose four refugee resettlement mechanisms and new solution concepts that can be used by resettlement agencies under various institutional and informational constraints. Our mechanisms can improve match efficiency, incentivize refugees to report where they would like to settle, and respect priorities of localities thereby encouraging them to accept more refugees in the long run.

Matching Problem of Civil Service

Ashutosh Thakur[1]

[1]Stanford GSB

Using a matching theory perspective, I analyze the extent to which existing and alternative Indian Civil Service state assignment mechanisms can yield balance across three dimensions of interest: quality, embeddedness, and quota. I find that a recent change in the matching mechanism in 2008 has systematically skewed assignments by assigning relatively poor quality bureaucrats to disadvantaged states: regions with external foreign conflict, states with internal political strife, and newly-formed states. This paper i) analyzes the causes of these imbalances, ii) assesses the impact of this mechanism change on state capacity, development outcomes, and bureaucratic performance, and iii) highlights trade-offs in implementing alternate mechanisms. Global balance in quality across states is a unique constraint which arises when applying matching to political economy settings, as the mechanism designer is a paternalistic central planner. Thus, less is left to the market compared to most canonical matching applications. On the other hand, the use of matching in political economy is also novel, and careful understanding of how different matching mechanisms address underlying correlations in the data has far-reaching consequences for bureaucratic performance and development outcomes.

Trading Networks with General Preferences

Jan Christoph Schlegel[1]

[1]City, University of London

We establish several structural results for the set of competitive equilibria in bilateral trading networks with transfers in the case of imperfectly transferable utility and frictions: The lattice theorem, the rural hospitals theorem, the existence of side-optimal equilibria, compactness of the set of equilibria and a group-incentive-compatibility result hold without the assumption of quasi-linear utility in transfers. While our results are developed in a trading network model, they also imply analogous (and new) results for exchange economies with combinatorial demand and for two-sided matching markets with transfers.

International Kidney Exchanges Programmes: Optimisation and Games

Péter Biró[1]

[1]Hungarian Academy of Sciences and Corvinus University of Budapest

The main results of two recent papers on international kidney exchanges will be presented in this talk. In the first paper (Biro-Gyetvai-Mincu-Popa-Verma: IP Solutions for International Kidney Exchange Programmes) we give integer programming formulations for solving international kidney exchange problems, where the optimisation goals and constraints may be different in the participating countries and various feasibility criteria may apply for the international cycles and chains. We also conduct simulations showing the long-run effects of international collaborations for different pool sizes and national restrictions on cycle-lengths. In the second paper (Biro-Kern-Palvolgyi-Paulusma: Generalized Matching Games for International Kidney Exchange, to appear in the proceedings of AAMAS 2019) we study a TU-game that is motivated by international kidney exchanges. In our setting, the solution is restricted to two-way exchanges, transplant quality matters, and a compensation scheme is used to balance the benefits of the cooperation for the countries involved. We study the computational complexity of the problem of finding a core solution of the corresponding TU-game, and the problem of computing matchings that provide a number of transplants for each country close to its target fair share. We illustrate the effect of such a compensation scheme with long-term simulations.

Pareto Optimal Coalitions of Fixed Size

Ágnes Cseh[1], Tamás Fleiner[2], and Petra Harján[3]

[1]Hungarian Academy of Sciences; [2]Hungarian Academy of Sciences, Budapest University of Technology and Economics; [3] Budapest University of Technology and Economics

We tackle the problem of partitioning players into groups of fixed size, such as allocating eligible students to shared dormitory rooms. Each student submits preferences over the other individual students. We study several settings, which differ in the size of the rooms to be filled, the orderedness or completeness of the preferences, and the way of calculating the value of a coalition—based on the best or worst roommate in the coalition. In all cases, we determine the complexity of finding a Pareto optimal assignment, and the complexity of verifying Pareto optimality for a given assignment.

Balanced Stable Marriage: How Close is Close Enough?

Sushmita Gupta[1], Sanjukta Roy[2], Saket Saurabh[3], and Meirav Zehavi[4]

[1]National Institute of Science Education and Research, India; [2]The Institute of Mathematical Sciences, HBNI, Chennai, India; [3]University of Bergen, and The Institute of Mathematical Sciences, HBNI, Chennai, India; [4]Ben-Gurion University

Balanced Stable Marriage (BSM) is a central optimization version of the classic Stable Marriage (SM) problem. We study BSM from the viewpoint of Parameterized Complexity. The input of BSM consists of n men, n women, and an integer k. Each person a has a (sub)set of acceptable partners, $A(a)$, who a ranks strictly; $p_a(b)$ denotes the position of acceptable partner b in a's list. The goal is to decide if there exists a stable matching μ s.t. the quantity $\mathrm{Bal}(\mu) = \max \sum_{(m,w)\in\mu} p_m(w), \sum_{(m,w)\in\mu} p_w(m)$ is at most k. In SM, all stable matchings match the same set of agents, $A^\star$ which can be computed in poly-time. As $\mathrm{Bal}(\mu) \geq |A^\star|$ for any stable matching μ, BSM is trivially fixed-parameter tractable (FPT) with respect to k. Thus, a natural question is whether BSM is FPT with respect to $t = k - |A^\star|$. From this perspective, we draw a line between tractability and intractability in relation to the target value. This line separates additional natural parameterizations higher/lower than ours (e.g., automatically resolving parameterization $t = k - |A^\star|$). The two extreme stable matchings are the man-optimal μ_M and woman-optimal μ_W. Let $O_m = \sum_{(m,w)\in\mu_M} p_m(w)$, and $O_w = \sum_{(m,w)\in mu_W} p_w(m)$. In this work, we prove that

- BSM parameterized by $t = k - \min\{O_m, O_w\}$ admits (1) a kernel where the number of people is O(t), and (2) a parameterized algorithm whose running time is single exponential in t.

- BSM parameterized by $t = k - \max\{O_m, O_w\}$ is W-hard.

Flexibility in House Allocation and Housing Markets

Madhav Raghavan[1]

[1]University of Lausanne

A desirable allocation rule allows agents some measure of control over their own assignments, in terms of how it responds to changes in their reported preferences. We propose a particular notion of this control: an agent is *swap-sovereign* over a pair of houses under a rule at a profile of preferences if she is assigned one of the houses at that profile and the other house when she instead reports preferences that simply swap the positions of the two houses. A pair of agents is *mutually swap-sovereign* over their assignments at a profile if their assignments are exchanged when they together report such 'swap preferences'. We use these concepts to propose a notion of 'flexibility' of an allocation rule. An allocation rule is *strongly flexible* if any pair of houses has a swap-sovereign agent, and is *flexible* if any pair of houses has either a swap-sovereign agent or mutually swap-sovereign agents. We show for housing markets that the *top-trading-cycles rule* is the unique *strategy-proof*, *non-bossy*, *individually rational* and *flexible* rule. In house allocation problems, we show that *dictatorial rules* are uniquely *strategy-proof*, *strongly flexible* and *envy non-bossy*. Moreover, given strategy-proofness and strong flexibility, the degree of dictatorship in this class of rules essentially depends on the degree of non-bossiness imposed. In particular, we characterise the important subclasses of *sequentially dictatorial* (additionally *non-bossy*) and *serially dictatorial* (additionally *pair-non-bossy* and *pair-sovereign*) rules.

Endowment Manipulations in Probabilistic Assignment Problem

Yuki Tamura[1]

[1]University of Rochester

For probabilistic assignment, we investigate the existence of rules which satisfy efficiency, the "endowment lower bound", one of several types of endowment manipulations. There are indeed various ways in which an agent can manipulate his endowment. An agent may manipulate a rule on his own, or in conjunction with others. We study three types of individual endowment manipulations and seven types of coordinated endowment manipulations. We prove a combination of positive and negative results concerning the existence of rules satisfying efficiency, the endowment lower bound, and each one of these manipulations. Each of "exchange-proofness", "withdrawing-proofness", "pre-delivery-proofness", and "merging-proofness" are incompatible with efficiency, the endowment lower bound, and a weak fairness property. We propose two rules, which both satisfy efficiency and the endowment lower bound, and each of them is immune to certain types of endowment manipulations.

Equivalent Choice Functions and Stable Mechanisms

Jan Christoph Schlegel[1]

[1]City, University of London, UK

We study conditions for the existence of stable and group-strategy-proof mechanisms in a many-to-one matching model with contracts if students' preferences are monotone in contract terms. We show that "equivalence", properly defined, to a choice profile under which contracts are substitutes and the law of aggregate holds is a necessary and sufficient condition for the existence of a stable and group-strategy-proof mechanism.

Centralized Matching with Incomplete Information

Marcelo Ariel Fernandez[1] and Leeat Yariv[2]

[1]Johns Hopkins University; [2]Princeton University

We study the impacts of incomplete information on centralized one-to-one matching markets. We focus on the commonly used Deferred Acceptance mechanism (Gale and Shapley, 1962). We characterize settings in which many of the results known when information is complete are overturned. In particular, small (complete-information) cores may still be associated with multiple outcomes and incentives to mis-report, selection of equilibria can affect the set of individuals who are unmatched i.e., there is no analogue for the Rural Hospital Theorem, and agents might prefer to be on the receiving side of the algorithm underlying the mechanism. Nonetheless, when either side of the market has assortative preferences, incomplete information does not hinder stability and results from the complete-information setting carry through.

Simultaneous Search: Beyond Independent Successes

Ran I. Shorrer[1]

[1]Penn State

A key decision commonly faced by students is how to optimally choose their portfolio of college applications. Students are often advised to apply to a combination of "reach," "match," and "safety" schools. Empirically, when reductions in the cost of application permit students to apply to more schools, they expand the range of selectivity of schools to which they apply both upwards and downwards. However, this ubiquitous practice of diversification is difficult to reconcile with existing theoretical analyses of search decisions. To solve this, I develop a generalized framework for simultaneous search problems in which students' optimal behavior generates these patterns. My framework generates many predictions that are consistent with empirical findings on school choice. The important departure that I make from existing models is that admissions decisions are not independent.

Deferred Acceptance and Regret-free Truth-telling: A Characterization Result

Marcelo Ariel Fernandez[1]

[1]Johns Hopkins University

In this paper I analyze centralized matching markets and rationalize why the arguably most heavily used mechanism in applications, the deferred acceptance mechanism, has been so successful in practice, despite the fact that it provides participants with opportunities to game the system. Accounting for the lack of information that participants typically have in these markets in practice, I introduce a new notion of behavior under uncertainty that captures participants aversion to experience regret. I show that participants optimally choose not to manipulate the deferred acceptance mechanism in order to avoid regret. Moreover, the deferred acceptance mechanism is the unique mechanism within an interesting class (quantile stable) to induce honesty from participants in this way.

Balanced Exchange in a Multi-Object Shapley-Scarf Market

Péter Biró[1], **Flip Klijn**[2], and Szilvia Pápai[3]

[1]Hungarian Academy of Sciences and Corvinus University of Budapest; [2]Institute for Economic Analysis (CSIC) and Barcelona GSE; [3]Concordia University and CIREQ

We study markets in which each agent is endowed with multiple units of an indivisible and agent-specific good. Monetary compensations are not possible. An outcome of a market is given by a circulation which consists of a balanced exchange of goods. Agents only have (responsive) preferences over the bundles they receive.

We prove that for general capacity configurations there is no circulation rule that satisfies individual rationality, Pareto-efficiency, and strategy-proofness. We characterize the (so-called irreducible) capacity configurations for which the three properties are compatible, and show that in this case the Circulation Top Trading Cycle (cTTC) rule is the unique rule that satisfies all three properties. We also explore the incentive and efficiency properties of the cTTC rule for general capacity configurations.

Finally, we introduce and study the family of so-called Segmented Trading Cycle (STC) rules. These rules are obtained by first distributing agents' endowments over a number of different smaller markets (the market segments), then applying the standard Top Trading Cycle algorithm within each market segment separately, and finally lumping together the induced circulations. We show that STC rules are individually rational, strategy-proof, and nonbossy. For irreducible capacity configurations the family of STC rules collapses to the cTTC rule which then is also group-strategy-proof.

Competing for Priorities in School Choice

Greg Leo[1] and **Martin Van der Linden**[2]

[1]Vanderbilt University; [2]Utah State University

We present a model in which students can influence their priority in a school choice mechanism through a first-stage costly effort game. We show that efficiency improvements to the mechanism can lead to net efficiency losses if they come at the price of increased allocative inequalities, which in turn increase competition in the effort stage. We apply these results to the deferred and immediate acceptance mechanisms (DA and IA) and show that, even when DA is more allocatively efficient than IA, IA may remain more efficient overall because it features less inequalities between students with high and low priorities.

Information Acquisition Costs in Matching Markets

Nicole S. Immorlica[1], Jacob D. Leshno[23], and **Irene Y. Lo**[4]

[1]Microsoft Research New England; [2]University of Chicago Booth School of Business; [3]Microsoft Research New England; [4]Stanford University

In matching markets, such as college admissions and medical residency, the efficiency of the marketplace depends on its ability to effectively guide applicants in searching through options and forming their preferences. We provide a model of many-to-one matching that formally incorporates students preference formation through costly information acquisition. The model captures the harm of requiring students to submit a full preference list in advance, and rationalizes students tendency to delay making decisions.

We ask whether markets can facilitate optimal information acquisition for each student. We find that the matching constraint can lead to *information deadlocks*, as students need information to decide which information to gather. Consequently, even sequential matching mechanisms are limited in their ability to coordinate search. Instead, we show that historical market information can be used with simple mechanisms to achieve approximately optimal outcomes. In markets without historical information, a bootstrapping method together with flexible capacities can alleviate unnecessary costs and break the deadlock. Our results help explain why many established matching markets perform well despite informational frictions.

Efficient and (Pretty) Fair Course Assignment with Quotas

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28 May
11:05

We consider the problem of assigning students to courses which is arguably one of the most common instances of object assignment without money. It is well-known that it is impossible to combine the three properties strategyproofness, efficiency and fairness. In other applications, fairness (or envy-freeness) is emphasized over efficiency; however, for large-scale course assignment applications efficiency appears to be the primary consideration. A second feature of most course assignment is that courses must be allocated a minimum number of students. We introduce modifications of the Top Trading Cycles algorithm which significantly reduce the instances of justified envy while accommodating minimum capacities. Our improvements are based on the following two observations: TTC myopically chooses which students will trade and students may trade even after they are guaranteed their top choice. We leverage field data from a large-scale course assignment application and show that our algorithm significantly reduces the amount of justified envy while still maintaining efficiency and strategyproofness for students.

An Algorithm for Strong Stability in the Student-Project Allocation Problem with Ties

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28 May
11:30

The *Student-Project Allocation problem with lecturer preferences over Students* (SPA-S) involves assigning students to projects based on student preferences over projects, lecturer preferences over students, and the maximum number of students that each project and lecturer can accommodate. This classical model assumes that preference lists are strictly ordered. We study a variant of SPA-S where ties are allowed in the preference lists of students and lecturers, which we refer to as the *Student-Project Allocation problem with lecturer preferences over Students with Ties* (SPA-ST). We investigate the concept of *strong stability* in this context. Informally, a matching is *strongly stable* if there is no student and lecturer l such that if they decide to form a private arrangement outside of the matching via one of l's proposed projects, then neither party would be worse off and at least one of them would strictly improve. We describe the first polynomial-time algorithm to find a strongly stable matching or to report that no such matching exists, given an instance of SPA-ST. Our algorithm runs in $O(m^2)$ time, where m is the total length of the students' preference lists.

Strategy-Proof Approximation Algorithms for the Stable Marriage Problem with Ties and Incomplete Lists

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In the stable marriage problem, a mechanism that always outputs a stable matching is called a *stable mechanism*. One of the well-known stable mechanisms is the man-oriented Gale-Shapley algorithm (MGS). MGS is known to be a *man-strategy-proof mechanism* (i.e., strategy-proof to the men's side) but not a woman-strategy-proof mechanism. Roth has shown that there is no stable mechanism that is simultaneously man-strategy-proof and woman-strategy-proof.

In this paper, we extend these results to the stable marriage problem with ties and incomplete lists (SMTI). In SMTI, one instance can have stable matchings of different sizes, and it is natural to consider the problem of finding a largest stable matching, called MAX SMTI. We say that a stable-mechanism is *c-approximate-stable mechanism* if it always returns a stable matching of size at least $1/c$ of a largest one. We also consider a restricted variant of MAX SMTI, which we call MAX SMTI-1TM, where only men's lists can contain ties.

Our results are summarized as follows: (i) MAX SMTI admits both a man-strategy-proof 2-approximate-stable mechanism and a woman-strategy-proof 2-approximate-stable mechanism. (ii) MAX SMTI-1TM admits a woman-strategy-proof 2-approximate-stable mechanism. (iii) MAX SMTI-1TM admits a man-strategy-proof 1.5-approximate-stable mechanism. All these results are tight in terms of approximation ratios. Also, all these strategy-proofness apply to strategy-proofness against coalitions.

Efficient and Incentive-Compatible Liver Exchange

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Liver exchange has been practiced in small numbers, mainly to overcome blood-type incompatibility between patients and their living donors. A donor can donate either his smaller left lobe or the larger right lobe, although the former option is safer. Despite its elevated risk, right-lobe transplantation is often utilized due to size-compatibility requirement with the patient. We model liver exchange as a market-design problem, focusing on logistically simpler two-way exchanges. We introduce an individually rational, Pareto-efficient, and incentive-compatible mechanism that truthfully elicits the right-lobe-donation willingness of donors and exchange participation willingness of compatible pairs under general patient preferences over compatible liver grafts. Construction of this mechanism requires new technical tools regarding bilateral exchanges under partial-order-induced preferences. Through simulations we show that not only liver exchange can increase the number of transplants by more than 30%, it can also increase the share of the safer left-lobe transplants.

Matching for the Israeli "Mechinot" Gap-Year Programs: Handling Rich Diversity Requirements

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We describe our experience with designing and running a matching market for the Israeli "Mechinot" gap-year programs. The main conceptual challenge in the design of this market was the rich set of diversity considerations, which necessitated the development of an appropriate preference-specification language along with corresponding choice-function semantics, which we also theoretically analyze to a certain extent. This market was run for the first time in January 2018 and matched 1,607 candidates (out of a total of 2,580 candidates) to 35 different programs, and has been adopted by the Joint Council of the "Mechinot" gap-year programs for the foreseeable future.

Recourse in Kidney Exchange Programs

Valentin Bartier[1], Yves Crama[2], **Bart Smeulders**[3], and Frits C.R. Spieksma[4]

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Mathematical optimization techniques have established themselves as an important and indispensable tool in guiding decisions in kidney exchange programs. We focus on the issue of dealing with incompatibilities that may reveal themselves *after* an intended transplant has been identified. The problem to decide which patient-donor pairs in a kidney exchange program should undergo a *cross-match* test is modelled as a two-stage stochastic optimization problem. We prove that this selection problem is NP-hard even if the maximum cycle length is at most 2. We give an integer programming formulation of this so-called selection problem, and describe a solution method based on Benders decomposition. We extensively test various solution methods, and observe that the solutions, when compared to solutions found by recourse models, lead to an improvement in the expected number of transplants. We also investigate the computational efficiency of our approach as a function of different parameters, such as maximum cycle length and the presence of altruists.

Obvious Dominance and Random Priority

Marek Pycia[1] and **Peter Troyan**[2]

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We characterize the full class of obviously strategy-proof mechanisms in environments without transfers as clinch-or-pass games that we call millipede games. Some millipede games are simple and widely used in practice, while others may be complex, requiring agents to perform lengthy backward induction, and are rarely observed. We introduce a class of simplicity concepts that encompasses obvious strategy-proofness and show that sufficiently demanding simplicity concepts eliminate these complex millipede games. We characterize the well-known Random Priority mechanism as the unique mechanism that is efficient, fair, and simple to play, thereby explaining its popularity in practical applications.

Subgame Perfect Equilibria under the Deferred Acceptance Algorithm

Keisuke Bando[1] and **Yasushi Kawase**[2]

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We analyze a subgame perfect equilibrium (SPE) of an extensive game with perfect information induced by the firm-oriented deferred acceptance (DA) algorithm in a one-to-one matching market between firms and workers. When no agents are strategic, the resulting outcome is the firm-optimal stable matching. We show that the worker-optimal stable matching is the unique SPE outcome when only workers are strategic. By contrast, multiple SPE outcomes may exist, possibly including unstable matchings when only firms are strategic. We show that every firm weakly prefers any SPE outcome to the worker-optimal stable matching and that the matching induced by Kesten's efficiency-adjusted DA algorithm can be achieved as a SPE. When both workers and firms are strategic, we also show that the worker-optimal stable matching is still the unique SPE outcome. Our results reveal that the workers' strategic behavior yields a reversal property in a dynamic implementation of the firm-oriented DA algorithm.

Optimizing Reserves in School Choice: A Dynamic Programming Approach

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We introduce a new model of school choice with reserves in which a social planner is constrained by a limited supply of reserve seats and tries to find an optimal matching according to a social welfare function. In the case where there is one class of targeted students, we construct the optimal distribution of reserves via a dynamic programming algorithm. Due to the modular nature of the dynamic program, the mechanism is *strategy-proof* for reserve-eligible students.

Strategy-proof, Envy-free and Pareto Efficient Online Mechanisms for Fair Division with Additive Valuations

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We consider fair division problems where indivisible items arrive one by one in an online fashion and are allocated immediately to agents with additive utilities over these items. Many existing offline mechanisms do not work in this online setting. In addition, existing axiomatic results often do not transfer to the online setting. For example, offline mechanisms exist that are Pareto efficient and envy-free in expectation, but this is impossible in an online setting as new items can always arrive that cause envy or Pareto inefficiency. We propose here three new online mechanisms, as well as consider the axiomatic properties of three previously proposed online mechanisms. We characterize the classes of online mechanisms that are strategy-proof, and return envy-free and Pareto efficient allocations, as well as combinations of these properties. We also identify an important impossibility result concerning Pareto efficient and envy-free mechanisms. Finally, these online mechanisms can be applied to offline problems by presenting items one by one.

An Alternative Approach to Asylum Assignment

Gian Caspari[1]

[1]Boston College

This paper proposes an alternative way to determine responsibility for asylum claims in the European Union, based on the preferences of asylum seekers and priorities of member states. In accordance with current practices, member states keep control over their process for determining eligibility, and asylum seekers are restricted to a single application. Wait times for asylum status decisions are incorporated into a static model, and a stable and asylum seeker strategy proof mechanism is described. From a theoretical perspective the hidden substitutes framework is applied. In the second part, the set-up is extended to a dynamic matching with contracts framework. For the results of the first part to go through, member states have to commit to all previous period assignments, so that every asylum seeker is matched only once upon initial participation.

Matching with Myopic and Farsighted Players

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We study stable sets for marriage problems under the assumption that players can be both myopic and farsighted. We introduce the new notion of the pairwise myopic-farsighted stable set. For the special cases where all players are myopic and where all players are farsighted, our concept predicts the set of matchings in the core. When myopic and farsighted players interact, it is possible that outcomes outside the core can be supported. When all men are myopic and the top choice of each man is a farsighted woman, we show that the singleton consisting of the woman-optimal stable matching is a pairwise myopic-farsighted stable set. The same result holds when all women are farsighted.

Pareto Optimal Allocation under Uncertain Preferences

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The assignment problem is one of the most well-studied settings in economics and multi-agent resource allocation. We consider the problem with the additional feature that agents' preferences involve uncertainty. The setting with uncertainty leads to a number of interesting questions including the following ones. How to compute an assignment with the highest probability of being Pareto optimal? What is the complexity of computing the probability that a given assignment is Pareto optimal? Does there exist an assignment that is Pareto optimal with probability

one? We consider these problems under five natural uncertainty models. For all of the models, we present a number of algorithmic and complexity results highlighting the differences and similarities in the complexity of the models. In our study we also present some general characterization and algorithmic results that apply to large classes of uncertainty models.

Poster Presentation Paper Abstracts

Design and Implementation of the Genetic Counseling Admissions Match

Jonah Peranson[1]
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We report on the design and implementation of the Genetic Counseling Admissions Match, the first centralized two-sided matching program for admissions into masters-level graduate schools in North America. The ability to accommodate scholarships/financial aid and complex program-specific diversity requirements were key to the design. Furthermore, we implemented a CONtact For Identified Ranking Mistakes (CONFIRM) messaging system used to limit the extent and impact of participants making mistakes in their rankings. The matching program successfully filled 99.5% of available positions with positive experiences reported by applicants and programs, both by first-time market participants as well as repeat participants that participated in the recruitment process in previous years without a centralized matching program.

Legal Assignments, the EADAM (Efficiency Adjusted Deferred Acceptance Mechanism) Algorithm

Yuri Faenza[1] and Xuan Zhang[2]
[1]Columbia University [2]Columbia University

Gale and Shapleys college admission problem and the concept of stability (Gale and Shapley 1962) have been extensively studied, applied, and extended. In the context of school choice, mechanisms often aim to obtain an assignment that is more favorable to students, thus shifting the focus from stability to (constrained) Pareto efficiency for students. In this paper, we investigate two such extensions legal assignments (Morrill, 2016) and EADAM with consent (Kesten, 2010) through the lens of the classical theory of stable matchings. We prove that legal assignments coincide with stable assignments in a subinstance and show how to obtain the latter in time linear in the number of the original set of edges. A key tool for this result is a pair of algorithms which find the school-optimal and student-optimal legal assignments. We then generalize our algorithms to obtain the output of EADAM with any given set of consenting students without sacrificing the running time, hence improving over the time complexity of algorithms for EADAM previously known in the literature. This is confirmed in computational experiments.

Preprocessing in Matching Problems

Maxence Delorme[1], Sergio Garcìa[2], Jacek Gondzio[3], Joerg Kalcsics[4], David Manlove[5], and **William Pettersson**[6]

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Stable Marriage with Ties and Incomplete lists, or SMTI, is the problem of pairing together agents from two disjoint sets based on their preferences, which may contain ties and be incomplete. The resulting pairing, or matching, should be stable — that is, there should be no two agents who would prefer to not join with their assigned partner but instead pair with each other. Stable matchings can be found in polynomial time using e.g. the Gale-Shapley algorithm.

However, the goal in SMTI is often to find a maximum cardinality stable matching. This problem is called MAX-SMTI, and is NP hard. We present theorems that recognise when an agent will be matched in any stable matching, and also which other agents this agent will never be matched to. These theorems then allow us to preprocess instances of SMTI, pruning away preferences that are not in any stable matching.

We give a number of heuristics for detecting some preprocessing, and a polynomial time algorithm guaranteed to find optimal preprocessing according to our theorems. Computational experiments are performed on each of these, and the timing results show that preprocessing can have a significant effect on the time taken to solve instances of the problem.

Unpopularity Factor in the Marriage and Roommates Problems

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Given a set A of n people, we consider the *Roommates Problem* (RP) and *Marriage Problem* (MP) where each person has a list that ranks a subset of A as his/her acceptable partner in order of preference. Ties among two or more people are allowed in the lists. In RP there is no further restriction, while in MP only people with opposite genders can be matched. For a pair of matchings X and Y, we say a person prefers X to Y if he/she prefers the person matched by X to the person matched by Y, and let $\phi(X, Y)$ denote the number of people who prefer X to Y. Define an *unpopularity factor* $u(M)$ of a matching M to be the maximum ratio $\phi(M', M)/\phi(M, M')$ among all possible other matchings M'. In this paper, we develop an algorithm to efficiently compute the unpopularity factor of a given matching. The algorithm runs in $O(m\sqrt{n}\log^2 n)$ time for RP and in $O(m\sqrt{n}\log n)$

time for MP, where m is the total length of people's preference lists. We also generalize the notion of unpopularity factor to the weighted setting where people are given different voting weights, and show that our algorithm can be slightly modified to support that setting as well with the same runtime.

A General Framework for Stable Roommate Problems: A Preliminary Report

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The Stable Roommate problem (SR) is characterized by the preferences of agents over other agents as roommates: each agent ranks all others in strict order of preference.

A solution to SR is then a partition of the agents into pairs so that each pair shares a room, and there is no pair of agents that would block this matching (i.e., who prefers the other to their roommate in the matching). Unlike the famous Stable Marriage problem (SM) introduced by Gale and Shapley, in general, there is no guarantee to find a solution to SR problems.

Like SM, there are interesting variations of SR studied in the literature. For instance, SRI considers incomplete preferences, egalitarian SRI further tries to maximize the total satisfaction of preferences of all agents, while almost SRI tries to minimize the total number of blocking pairs. These optimization variations are computationally hard problems.

We introduce a formal framework that is general enough to solve many variations of SR declaratively, with the possibility of guaranteed optimality with respect to the given optimization criteria. This framework is based on Answer Set Programming (ASP)—a knowledge representation and reasoning paradigm with an expressive formalism and efficient solvers. The idea is to formalize SR (and its variations) as a "program" in a nonmonotonic logical language of ASP, and to find its solutions by computing models (called "answer sets") of the program using "ASP solvers".

School choice with priority levels: Constrained Efficient and Fair Assignment

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We explore the classic trade-off at the heart of the school choice problem, between Pareto efficiency and fairness (or stability).

We introduce the notion of priority levels: some priorities are stronger than others. There are 3 priority levels. At the highest priority level, priorities need to be respected always. At the second priority level, priorities can be violated in order to avoid an actual violation of efficiency. At the third and lowest priority level, priorities can be violated in order to avoid a potential violation of efficiency. The first and last options are compatible with truth-telling.

In this framework, we obtain the Constrained Efficient and Fair Assignment (CEFA) mechanism, which handles this trade-off in the most optimal way.

CEFA reduces to Deferred Acceptance (DA) when all priorities are at the highest priority level, and to Efficiency-Adjusted Deferred Acceptance (EADAM) when all priorities are at the second priority level.

CEFA does not reduce to Top Trading Cycles (TTC). It performs better in terms of (constrained) fairness than TTC (or any other existing efficient mechanism).

Preference Manipulation in Two-Sided Matching - Strategic Behavior and Robustness of Solution Algorithms

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Whereas research in Two-Sided Matching has often focused on efficient computation of solutions with desirable properties, an aspect which has received less attention is the strategic behavior of participants. Many common solution algorithms in Two-Sided Matching are not strategy-proof, i.e., yield incentives for some of the participants to misstate their actual preferences. Such manipulation of preferences can have serious detrimental effects on the overall outcome, as misstated preferences can lead to an unraveling of basic properties such as the stability of the solution. To better understand the potential effects of preference manipulation, this article considers both the potential benefits (and drawbacks) of different strategies for the participants, as well as the overall effect on the solution quality. Using a simulation-based approach to consider a variety of different scenarios and solution algorithms, the article shows that while preference manipulation can be slightly beneficial in some cases, the potential drawbacks for manipulating participants can be severe. In addition, solutions calculated under manipulated preferences are often not stable under true preferences.

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