Report from Dagstuhl Seminar 15241

Computational Social Choice: Theory and Applications

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Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 15241 "Computational Social Choice: Theory and Applications". The seminar featured a mixture of classic scientific talks (including three overview talks), open problem presentations, working group sessions, and five-minute contributions ("rump session"). While there were other seminars on related topics in the past, a special emphasis was put on practical applications in this edition.

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1 Executive Summary

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Computational social choice is an interdisciplinary research area dealing with the aggregation of preferences of groups of agents in order to reach a consensus decision that realizes some social objective. Economists typically view markets as an optimal mean for coordinating the activities and allocation of resources across a group of heterogeneous agents based on their utilities or preferences. By contrast, the methods of social choice, broadly defined, focus on coordination mechanisms that do not rely on prices, monetary/resource transfer or market structures, while still defining social objectives that account for individual preferences. Some classic (but certainly not exhaustive) topics of study in social choice topics include:

- voting procedures, where a single alternative must be taken given the preferences of individuals group members;
- fair division, which deals with the distribution of goods among a group reflecting individual preferences and fairness criteria;
- matching problems, in which agents/items are matched in a way that respects both preferences and other constraints.

The theoretical treatment of these problems is concerned with the existence of solutions which could be defended on normative grounds. In classical social choice, desirable solution concepts satisfy certain properties, such as: efficiency, non-discriminatory treatment of agents;

envy-freeness; stability (or equilibrium) with respect to incentives; non-manipulability; and a variety of others. Over the past 15 years, the computational properties of these solution concepts have emerged as critically important to their theoretical viability and practical impact. Computer scientists in both AI and theoretical computer science have developed efficient algorithms for realizing certain social choice functions, proven the computational intractability of others, studied the theoretical and practical communication requirements of these procedures, and developed computational tools to sharpen our understanding of incentives, manipulation, and other important phenomena. Applying a computational lens to these theoretical investigations has led to breakthroughs that have supported a variety of real-world applications like web-page ranking, fair buy-sell/exchange protocols, and the development of much more socially efficient exchanges for organ transplantation.

At the same time, the era of networked communication and "big data" has made it easier than ever to infer people's preferences and have them engage with ever larger groups. This has opened up tremendous opportunities for the application of social choice to a wider range of "lower stakes, higher frequency" group decisions. Hence, it introduces new challenges for social choice – many mechanisms for the problems above have been designed using assumptions that – while suitable for "high stakes" domains like political voting, or matching in labor markets and organ donations – are entirely untenable in other domains.

The objective of the seminar was to continue the series of meetings on theoretical computational social choice previously held in Dagstuhl, but the emphasis was on problems which have practical relevance. We have addressed in particular three lines of works concerning issues in social choice: voting, matching, and fair division. The seminar brought together 41 researchers from 18 countries and various fields such as computer science, mathematics, social choice theory, economics, political sciences, and industry. The meeting gathered both participants focusing on the theoretical foundations of computational social choice, and those seeking to apply social choice mechanisms to real-world problems of both the high-stakes/low-frequency and the low-stakes/high-frequency variety.

The technical program of the seminar included overview talks, regular seminar talks, a rump session and slots for communication and work on open problems. The three overview talks presented open questions and challenges in multiwinner voting (complemented by a panel discussion), economics and computation, and in matching in the context of assignments of teachers to schools. The 26 regular seminar talks covered the three lines of work concerning voting, matching, and fair division/resource allocation. Current trends in these fields as reflected by the contributions include allocation of indivisible items under ordinal preferences, the study of well-behaved preference structures (e.g. single-peaked, single-crossing), multiwinner elections, mixed voting systems, and several highly challenging special cases of matching problems. Challenges from real-world applications included online fair division for the distribution of food donations to a food bank, assignments of referees to papers for scientific reviewing, peer grading in massive online open courses, online voting and online participation, sharing cars, junior doctor allocation, and house swapping. Furthermore, several online platforms dedicated to social choice were presented and discussed during the seminar. Precious feedback was collected by the teams of developers.

The program offered the possibility to present open problems and provided slots for working groups on these topics as well as a final session for presentation of outcomes. Several working groups were formed some of which obtained first results during the seminar week. The research projects initiated in these groups are still ongoing. Many participants also used these slots for collaboration with their co-authors that were present at the seminar.

The rump session consisted of 17 five minute contributions, ranging from announcements of events related to the community, over presentation of tools for preference aggregation and online voting, preference libraries for datasets, applications like sharing cars, to short research talks and presentations of open problems.

To conclude, the seminar acknowledged that more and more contributions in computational social choice are driven by real world issues, with many potential applications for industry and policy making. It confirmed that theoretical considerations enable, justify and guarantee the quality of practical applications. Conversely, the specific features and constraints of applications provide novel theoretical challenges and new directions for foundational research.

The participants greatly appreciated the time devoted to working group sessions and benefited from the seminar in various ways: by learning about new problems, many of them being directly inspired from real world issues; by being introduced to several existing tools; by having the possibility to interact and to develop new collaborations. A next event will be the COMSOC workshop in Toulouse in June 2016. It will be co-located with the meeting of the COST Action IC1205 “Computational Social Choice”, and one day will be devoted to applications and interactions with industry, in line with the 15241 Dagstuhl seminar.

We would like to thank all participants for their contributions, discussions, ideas and collaborations, making this seminar a very productive and enjoyable one. In particular, we sincerely thank the team of Schloss Dagstuhl for the great support and excellent organization.

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3 Overview of Talks

3.1 Two Desirable Fairness Concepts for Allocation of Indivisible Objects under Ordinal Preferences

Haris Aziz (NICTA – Sydney, AU)

Joint work of Aziz, Haris; Gaspers, Serge; Mackenzie, Simon; Walsh, Toby
Main reference H. Aziz, S. Gaspers, S. Mackenzie, T. Walsh, "Two Desirable Fairness Concepts for Allocation of Indivisible Objects under Ordinal Preferences," Manuscript, 2014.
URL https://dl.dropboxusercontent.com/u/30901094/fair_overview.pdf

Fair allocation of indivisible objects under ordinal preferences is an important problem. Envy-freeness is not only incompatible with Pareto optimality but it also NP-complete to achieve. In view of this predicament, we first frame allocation of indivisible objects as randomized assignment with integrality requirements. We then use the stochastic dominance relation to devise two natural notions of proportionality. Since an assignment may not exist even for the weaker notion of proportionality, we propose relaxations of the concepts – optimal weak proportionality and optimal proportionality. For both concepts, we propose algorithms to compute fair assignments under ordinal preferences. Both new fairness concepts appear to be desirable in view of the following: they are compatible with Pareto optimality, admit efficient algorithms to compute them, are based on proportionality, and are guaranteed to exist.

3.2 Challenges in Online Participation

Dorothea Baumeister (Heinrich-Heine-Universität Düsseldorf, DE)

URL http://www.fortschrittskolleg.de

In the interdisciplinary graduate school "Online Participation" researchers from computer science, business economics, communication science, political science, law, and sociology work together with several industry partners to analyze the potential of online participation. Up to now most online participation projects are organized as a simple forum, which is an inadequate representation for a discussion. The concepts of argumentation frameworks give the possibility to formalize a discussion, they are however not suitable for non-experts in this field. One central topic in this project is to develop an online tool that provides a convenient solution to this problem, where on the one hand the discussion is more structured than in a simple forum, but on the other hand is also applicable for ordinary users. In this talk I will present some first ideas of how this may be achieved, and point out some challenges both from a practical and a theoretical point of view.

3.3 Integer programming methods for special college admissions problems

Péter Biró (Hungarian Academy of Sciences – Budapest, HU)

Joint work of Biró, Péter; McBride, Iain
Main reference P. Biró, I. McBride, "Integer Programming Methods for Special College Admissions Problems," in Proc. of the 8th Int'l Conf. on Combinatorial Optimization and Applications (COCOA'14), LNCS, Vol. 8881, pp. 429–443, Springer, 2014.
URL http://dx.doi.org/10.1007/978-3-319-12691-3_32

We develop Integer Programming (IP) solutions for some special college admission problems arising from the Hungarian higher education admission scheme. We focus on four special features, namely the solution concept of stable score-limits, the presence of lower and common quotas, and paired applications. We note that each of the latter three special feature makes the college admissions problem NP-hard to solve. Currently, a heuristic based on the Gale-Shapley algorithm is being used in the application. The IP methods that we propose are not only interesting theoretically, but may also serve as an alternative solution concept for this practical application, and other similar applications.

3.4 Taming the Whale. Lessons learned about online voting and real people

Sylvain Bouveret (LIG – Grenoble, FR)

Joint work of Bouveret, Sylvain; Blanch, Renaud; Karanikolas, Nikos; Cos, Corentin
URL http://whale3.noiraudes.net/

Whale is an online voting system where people can vote on different alternatives, using rankings, scores, or approval ballots, and see the results given by different voting rules. The aim of this talk is to give some lessons (or questions) learned from observing laypeople using the system. From these observations we derive three challenges for online voting (or poll) systems: the first one concerns voting and data visualization, the second concerns the need for taking into account incomplete preferences and the third one is about voting and combinatorial domains.

3.5 How to Divide Things Fairly

Steven J. Brams (New York University, US)

Joint work of Brams, Steven J.; Kilgour, D. Marc; Klamler, Christian
Main reference S. . Brams, D. M. Kilgour, C. Klamler, "How to Divide Things Fairly," Manuscript, 2014.
URL http://www.politics.as.nyu.edu/docs/IO/2578/SA9.pdf

We analyze a simple sequential algorithm (SA) for allocating indivisible items that are strictly ranked by n ≥ 2 players. It yields at least one Pareto-optimal allocation which, when $n = 2$, is envy-free unless no envy-free allocation exists. However, an SA allocation may not be maximin or Borda maximin – maximize the minimum rank, or the Borda score, of the items received by a player. Although SA is potentially vulnerable to manipulation, it would be difficult to manipulate in the absence of one player's having complete information about the other players' preferences. We discuss the applicability of SA, such as in assigning people to committees or allocating marital property in a divorce.

3.6 The Paradox of Voting Systems

Steven J. Brams (New York University, US)

Joint work of Brams, Steven J.; Potthoff, Richard F.
Main reference S. J. Brams, R. F. Potthoff, "The Paradox of Grading Systems," Manuscript, 2015.
URL http://www.politics.as.nyu.edu/docs/IO/2578/GradingParadox.pdf

We distinguish between (i) voting systems in which voters can rank candidates and (ii) those in which they can grade candidates, such as approval voting, in which voters can give two grades – approve (1) or not approve (0) – to candidates. While two grades rule out a discrepancy between the average-grade winners, who receive the highest average grade, and the superior-grade winners, who receive more superior grades in pairwise comparisons (akin to Condorcet winners), more than two grades allow it. We call this discrepancy between the two kinds of winners the paradox of grading systems, which we illustrate with several examples and whose probability we estimate for sincere and strategic voters through a Monte Carlo simulation. We discuss the trade-off between (i) allowing more than two grades, but risking the paradox, and (ii) precluding the paradox, but restricting voters to two grades.

3.7 Fishburn's Maximal Lotteries: A randomized rule that is immune to splitting electorates, cloning alternatives, abstention, and crude manipulation.

Felix Brandt (TU München, DE)

Joint work of Aziz, Haris; Brandt, Felix; Brandl, Florian; Brill, Markus; Hofbauer, Johannes; Seedig, Hans Georg

This talk summarizes a number of recent papers on maximal lotteries, a randomized voting rule that was proposed by Fishburn in the 1980s. Maximal lotteries satisfy various consistency conditions, economic efficiency, computational efficiency, participation, and a weak variant of strategyproofness.

3.8 Control and Bribery for Approval Voting through Two Edge Cover Generalizations

Robert Bredereck (TU Berlin, DE)

Joint work of Bredereck, Robert; Talmon, Nimrod
Main reference R. Bredereck, N. Talmon, "NP-hardness of two edge cover generalizations with applications to control and bribery for approval voting," Information Processing Letters, 116(2):147–152, 2015.
URL http://dx.doi.org/10.1016/j.ipl.2015.09.008

We close three gaps with respect to the computational complexity of voting problems by showing NP-hardness of two generalizations of the Edge Cover problem, which were conjectured to be polynomial-time solvable. More precisely, our results imply that 2-Approval Constructive Control by Adding Weighted Voters, 2-Veto Constructive Control by Deleting Weighted Voters, and k-Veto-$Bribery for k from $\{2, 3\}$ are (strongly) NP-complete.

Given an undirected graph and an integer q, the Edge Cover problem asks for a subgraph with at most q edges such that each vertex has degree at least one. Both generalizations introduce weights on the edges and an individual demand $b(v)$ for each vertex v. The first generalization, named Simple b-Edge Weighted Cover, requires the edge set to have a total weight of at most q while each vertex v is to be adjacent to at least $b(v)$ edges. The second generalization, named Simple Weighted b-Edge Cover, requires the edge set to contain at most q edges while each vertex v is to be adjacent to edges of total weight at least $b(v)$.

3.9 Computing the Optimal Game

Markus Brill (Duke University – Durham, US)

Joint work of Brill, Markus; Freeman, Rupert; Conitzer, Vincent
Main reference M. Brill, R. Freeman, V. Conitzer, "Computing the Optimal Game," in Proc. of the 2nd Workshop on Exploring Beyond the Worst Case in Computational Social Choice (EXPLORE'15), held as part of the 14th Int'l Conf. on Autonomous Agents and Multiagent Systems (AAMAS'15), to appear; pre-print available from workshop webpage.
URL http://www.explore-2015.preflib.org/wp-content/uploads/2015/04/paper_8.pdf

In many multiagent environments, a designer has some, but limited control over the game being played. In this paper, we formalize this by considering incompletely specified games, in which some entries of the payoff matrices can be chosen from a specified set. We show that it is NP-hard for the designer to decide whether she can make her choices so that no action in a given set gets played in equilibrium. Hardness holds even in zero-sum games and even in weak tournament games (which are symmetric zero-sum games whose entries are all -1, 0, or 1). The latter case is closely related to the necessary winner problem for a social-choice-theoretic solution concept. We then give a mixed-integer linear programming formulation for weak tournament games and evaluate it experimentally.

3.10 Aggregating partial rankings with applications to peer grading in MOOCs

Ioannis Caragiannis (CTI & University of Patras, GR)

Joint work of Caragiannis, Ioannis; Krimpas, George A.; Voudouris, Alexandros A.

We investigate the potential of using ordinal peer grading for the evaluation of students in massive online open courses (MOOCs). According to such grading schemes, each student receives a few assignments (by other students) which she has to rank. Then, a global ranking (possibly translated into numerical scores) is produced by combining the individual ones. This is a novel application area for social choice concepts and methods where the important problem to be solved is as follows: how should the assignments be distributed so that the collected individual rankings can be easily merged into a global one that is as close as possible to the ranking that represents the relative performance of the students in the assignment? Our main theoretical result suggests that using very simple ways to distribute the assignments so that each student has to rank only k of them, a Borda-like aggregation method can recover a $1 - O(1/k)$ fraction of the true ranking when each student correctly ranks the assignments she receives. Experimental results strengthen our analysis further and also demonstrate that the same method is extremely robust even when students have imperfect capabilities as graders. Our results provide strong evidence that ordinal peer grading can be a highly effective and scalable solution for evaluation in MOOCs.

3.11 House swapping with engaged and divorcing pairs

Katarína Cechlárová (Pavol Jozef Šafárik University – Košice, SK)

Joint work of Cechlárová, Katarína; Fleiner, Tamás; Jankó, Zsuzsanna

We study a modification of a housing market that allows engaged pairs and divorcing couples. An engaged pair owns two houses and wants to move together into one house, while a divorcing couple owns one house and needs two different houses. We show that the problem to maximize the number of moving agents is inapproximable but fixed parameter tractable.

3.12 Assignment of teachers to schools – a new variation on an old theme

Katarína Cechlárová (Pavol Jozef Šafárik University – Košice, SK)

Several countries more or less successfully use centralized matching schemes for assigning teachers to vacant positions at schools. We explore combinatorial and computational aspects of a possible similar scheme motivated by the situation characteristic for Slovak and Czech education system where each teacher specializes in two subjects. We present a model that takes into consideration that schools may have different capacities for each subject and show that its combinatorial structure leads to intractable problems even under several strong restrictions concerning the total number of subjects, partial capacities of schools and the number of acceptable schools each teacher is allowed to list. We propose several approximation algorithms. Finally, we present integer programming models and their application to real data.

3.13 Parliamentary Voting Procedures: Agenda Control, Manipulation, and Uncertainty

Jiehua Chen (TU Berlin, DE)

Joint work of Bredereck, Robert; Chen, Jiehua; Niedermeier, Rolf; Walsh, Toby
Main reference R. Bredereck, J. Chen, R. Niedermeier, T. Walsh, "Parliamentary Voting Procedures: Agenda Control, Manipulation, and Uncertainty," in Proc. of the 24th International Joint Conference on Artificial Intelligence (IJCAI'15), pp. 164–170, AAAI Press, 2015.
URL http://ijcai.org/papers15/Abstracts/IJCAI15-030.html

We study computational problems for two popular parliamentary voting procedures: the amendment procedure and the successive procedure. While finding successful manipulations or agenda controls is tractable for both procedures, our real-world experimental results indicate that most elections cannot be manipulated by a few voters and agenda control is typically impossible. If the voter preferences are incomplete, then finding possible winners is NP-hard for both procedures. Whereas finding necessary winners is coNP-hard for the amendment procedure, it is polynomial-time solvable for the successive one.

3.14 Structure in Dichotomous Preferences

Edith Elkind (University of Oxford, GB)

Many hard computational social choice problems are known to become tractable when voters' preferences belong to a restricted domain, such as those of single-peaked or single-crossing preferences. However, to date, all algorithmic results of this type have been obtained for the setting where each voter's preference list is a total order of candidates. The goal of this paper is to extend this line of research to the setting where voters' preferences are dichotomous, i.e., each voter approves a subset of candidates and disapproves the remaining candidates. We propose several analogues of the notions of single-peaked and single-crossing preferences for dichotomous profiles and investigate the relationships among them. We then demonstrate that for some of these notions the respective restricted domains admit efficient algorithms for computationally hard approval-based multi-winner rules.

3.15 Multiwinner Voting: New Perspectives and New Challenges

Piotr Faliszewski (AGH University of Science & Technology – Krakow, PL)

Joint work of Faliszewski, Piotr; Elkind, Edith; Skowron, Piotr; Slinko, Arkadii; Lang, Jérôme
Main reference E. Elkind, P. Faliszewski, P. Skowron, A. Slinko, "Properties of Multiwinner Voting Rules," in Proc. of the 13th Int'l Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS'14), pp. 53–60, IFAAMAS/ACM, 2014.
URL http://dl.acm.org/citation.cfm?id=2615743

In a multiwinner election we are given a set of candidates, a set of voters with their preferences regarding the candidates, and a positive integer K. A multiwinner voting rule picks a group of some K candidates. However, as opposed to the case of single-winner elections where it is clear that the voting rule should pick a candidate that is in some sense "the best one", the goal of a multiwinner voting rule depends on the particular application. Some natural applications include:

(a) Shortlisting: We want to pick a group of K candidates that we will inspect further and pick the best one from them (shortlisting happens, for example, when we want to decide who to hire and we focus on some group of promising applicants).

(b) Picking a representative committee: Parliamentary elections are the most natural example here. We are picking a group of K members of a parliament. The elected candidates should represent the society well.

(c) Picking items for users to share: A natural example includes picking what movies to put in the airplane's entertainment system to maximize the satisfaction level of the passengers.

Each of these applications requires a voting rule with different properties. For example, if we have two similar candidates then a rule used for shortlisting should either pick them both or reject them both, whereas a rule for movie selection should perhaps pick one of them, but certainly not both.

In this tutorial we will present several prominent multiwinner voting rules, discuss some recent results (with the focus on axiomatic properties and the complexity of winner determination), and present some avenues for future research. In particular, it is quite clear that the search for interesting multiwinner rules has only started!

3.16 Participation and Strategyproofness: Insights via SAT Solving

Christian Geist (TU München, DE)

Joint work of Brandl, Florian; Brandt, Felix; Geist, Christian; Hofbauer, Johannes
Main reference F. Brandl, F. Brandt, C. Geist, J. Hofbauer, "Strategic Abstention Based on Preference Extensions: Positive Results and Computer-Generated Impossibilities," in Proc. of the 24th International Joint Conference on Artificial Intelligence (IJCAI'15), pp. 18–24, AAAI Press, 2015.
URL http://ijcai.org/papers15/Abstracts/IJCAI15-010.html

Similar to the well-known and much studied problem of strategic misrepresentation, a common flaw of some voting rules, known as the no-show paradox, is that agents may obtain a more preferred outcome by abstaining from an election. We study both these types of strategic manipulation (misrepresentation and abstention) for set-valued, majoritarian voting rules based on Kelly's and Fishburn's preference extensions. We survey a range of recent results, both positive and negative. For example, we show that, whenever there are at least five alternatives, every Pareto-optimal voting rule suffers from both types of manipulation with respect to Fishburn's extension. This is achieved by reducing the statement to finite – yet very large – problems, which are encoded as formulae in propositional logic and then shown to be unsatisfiable by a SAT solver. We also provide human-readable proofs which we extracted from minimal unsatisfiable cores of the formulae. On the positive side, we prove that every voting rule that satisfies a natural condition cannot be manipulated with respect to Kelly's extension and discover discriminating examples of such rules.

3.17 Open Problems: Identifying k-majority Digraphs

Christian Geist (TU München, DE)

Joint work of Brandt, Felix; Geist, Christian; Seedig, Hans Georg
Main reference F. Brandt, C. Geist, H. G. Seedig, "Identifying k-Majority Digraphs via SAT Solving," in Proc. of the 1st Workshop on Exploring Beyond the Worst Case in Computational Social Choice (EXPLORE'14), held as part of the 13th Int'l Conf. on Autonomous Agents and Multiagent Systems (AAMAS'14), to appear; pre-print available from workshop webpage.
URL http://www.explore14.preflib.org/wp-content/uploads/2014/03/paper_8.pdf

Many hardness results of computational social choice make use of the fact that every directed graph may be induced as the pairwise majority relation of some preference profile. However, this fact requires a number of voters that is almost linear in the number of alternatives. For the general question of how many voters it takes to induce a given majority graph many answers have been given (e.g, by McGarvey, 1953; Stearns, 1959; Erdos and Moser, 1964; Fiol, 1992), but quite a few questions remain open.

3.18 Pnyx: A Powerful and User-friendly Tool for Preference Aggregation

Christian Geist (TU München, DE)

Joint work of Brandt, Felix; Chabin, Guillaume; Geist, Christian
Main reference F. Brandt, G. Chabin, C. Geist, "Pnyx: A powerful and user-friendly tool for preference aggregation," in Proc. of the 14th Int'l Conf. on Autonomous Agents and Multi-Agent Systems (AAMAS'15), pp. 1915–1916, IFAAMAS/ACM, 2015.
URL http://dl.acm.org/citation.cfm?id=2773502
URL http://pnyx.dss.in.tum.de

Pnyx is an easy-to-use and entirely web-based tool for preference aggregation that does not require any prior knowledge about social choice theory. The tool is named after a hill in Athens called Pnyx, which was the official meeting place of the Athenian democratic assembly and is therefore known as one of the earliest sites in the creation of democracy. Pnyx is available at pnyx.dss.in.tum.de.

3.19 Role Based Hedonic Games

Judy Goldsmith (University of Kentucky – Lexington, US)

Joint work of Spradling, Matthew; Goldsmith, Judy
Main reference SM. Spradling, J. Goldsmith, "Stability in Role Based Hedonic Games," in Proc. of the 28th Int'l Florida Artificial Intelligence Research Society Conf. (FLAIRS'15), pp. 85–90, AAAI Press, 2015.
URL http://www.aaai.org/ocs/index.php/FLAIRS/FLAIRS15/paper/view/10383

In the hedonic coalition formation game model called Roles Based Hedonic Games (RBHG), agents view teams as compositions of available roles. An agent's utility for a partition is based upon which role she fulfills within the coalition and which additional roles are being fulfilled within the coalition. We consider optimization and stability problems for settings with variable power on the part of the central authority and on the part of the agents. We prove most of these problems to be NP-complete or coNP-complete. We introduce heuristic methods for approximating solutions for a variety of these hard problems. We validate heuristics on real-world data scraped from League of Legends games.

3.20 Gibbard-Satterthwaite Games

Umberto Grandi (Toulouse 1 Capitole University, FR)

Joint work of Elkind, Edith; Grandi, Umberto; Rossi, Francesca; Slinko, Arkadii
Main reference E. Elkind, U. Grandi, F. Rossi, A. Slinko, "Gibbard-Satterthwaite Games," in Proc. of the 24th Int'l Joint Conf. on Artificial Intelligence (IJCAI'15), pp. 533–539, AAAI Press, 2015; pre-print available from author's webpage.
URL http://ijcai.org/papers15/Abstracts/IJCAI15-081.html
URL http://www.irit.fr/~Umberto.Grandi/publications/ElkindEtAlIJCAI2015.pdf

The Gibbard-Satterthwaite theorem implies the ubiquity of manipulators – voters who could change the election outcome in their favor by unilaterally modifying their vote. In this paper, we ask what happens if a given profile admits several such voters. We model strategic interactions among Gibbard–Satterthwaite manipulators as a normal-form game. We classify the 2-by-2 games that can arise in this setting for two simple voting rules, namely Plurality and Borda, and study the complexity of determining whether a given manipulative vote weakly dominates truth-telling, as well as existence of Nash equilibria.

3.21 The McKelvey Uncovered Set and Pareto Optimality

Paul Harrenstein (University of Oxford, GB)

Joint work of Brandt, Felix; Geist, Christian; Harrenstein, Paul

We consider the notion of Pareto optimality under the assumption that only the pairwise majority relation is known and show that the set of necessarily Pareto optimal alternatives coincides with the McKelvey uncovered set. In fact, every majority relation admits a single consistent profile in which precisely all covered alternatives are Pareto dominated. As a consequence, the McKelvey uncovered set constitutes the coarsest Pareto optimal majoritarian social choice function.

3.22 Maximin Envy-Free Division of Indivisible Items

Christian Klamler (Universität Graz, AT)

Joint work of Brams, Steven J.; Kilgour, D. Marc; Klamler, Christian

Assume that two players have strict rankings over an even number of indivisible items. We propose algorithms to find allocations of these items that are maximin – maximize the minimum rank of the items that the players receive – and are envy-free and Pareto-optimal if such allocations exist. We show that neither maximin nor envy-free allocations may satisfy other criteria of fairness, such as Borda maximinality. Although not strategy-proof, the algorithms would be difficult to manipulate unless a player has complete information about its opponent's ranking. We assess the applicability of the algorithms to real-world problems, such as allocating marital property in a divorce or assigning people to committees or projects.

3.23 Consistent House Allocation with Existing Tenants

Bettina Klaus (University of Lausanne, CH)

Joint work of Karakaya, Mehmet; Klaus, Bettina; Schlegel, Jan Christoph

Abdulkadiroglu and Sonmez (1999) introduced the house allocation with exiting tenants model and the class of YRMH-IGYT (you request my house – I get your turn) rules. Sonmez and Unver (2010) showed that a rule for house allocation problems with existing tenants is Pareto-optimal, individually-rational, strategy-proof, weakly neutral, and consistent if and only if it is a YRMH-IGYT rule. The class of YRMH-IGYT rules is a subclass of the class of TTC (top trading cycles) rules (based on priority structures). We characterize the subclass of all TTC rules that are consistent by a new acyclicity requirement for the underlying priority structure and thereby extend previous results by Ergin (2000) and Kesten (2006) for house allocation (without existing tenants). Finally, we analyze what happens when we drop weak neutrality and consider rules satisfying Pareto-optimality, individual-rationality, strategy-proofness, and consistency.

3.24 School Choice: Nash Implementation of Stable Matchings through Rank-Priority Mechanisms

Flip Klijn (CSIC – Barcelona, ES)

Joint work of Jaramillo, Paula; Kayi, Çagatay; Klijn, Flip

We study the school choice problem (Abdulkadiroglu and Sonmez, 2003) where students are to be matched to schools through a clearinghouse. We focus on the class of rank-priority mechanisms, to which the Boston (or immediate acceptance) mechanism belongs. We provide a necessary and sufficient condition for the Nash implementation of the set of stable matchings.

3.25 To approve or not to approve: This is not the only question

Annick Laruelle (Ikerbasque – Bilbao, ES)

Joint work of Alcantud, José Carlos R.; Laruelle, Annick
Main reference J. C. R. Alcantud, A. Laruelle, "Dis&approval voting: a characterization," Social Choice and Welfare, 43(1):1–10, 2014.
URL http://dx.doi.org/10.1007/s00355-013-0766-7

In polls many citizens express some dissatisfaction with politicians. Usual ways to voice this dissatisfaction in elections are absenteeism, spoiled or blank votes, or voting for a fringe candidate. Why can citizens only vote in favor of a single candidate and not against a candidate? Why can't voters express their opinion on every candidate? Alcantud and Laruelle (2014) study a method that permits to express dissatisfaction and express an opinion on each candidate. Under the disapproval rule the voter is asked to cast a positive, null or negative vote on each candidate. The candidate who obtains the highest difference between the number of positive votes and the number of negative votes is elected. In this presentation we discuss the potential advantage of this method, and further lines of research.

3.26 The IAC Probability of a Divided Verdict in a Simple U.S. Presidential Type Election

Michel Le Breton (University of Toulouse I, FR)

Joint work of de Mouzon, Olivier; Laurent, Thibault; Le Breton, Michel; Lepelley, Dominique

During the talk, we presented an asymptotic estimate of the probability $\phi(n)$ of a divided verdict in a U.S. presidential type election in the simplest possible unbiased setting when the phenomenon can occur: three equipopulated districts with n voters per district. The novelty of this paper, in contrast to all the existing literature (IC and IAC^*), is to assume that votes are drawn result from an IAC (Impartial Anonymous Culture) probability model. In the IC and IAC^* settings, $\phi(n)$ converge to a finite limit which is $3\frac{\arccos(\frac{\sqrt{3}}{3})}{\pi} - \frac{3}{4} \simeq 16.226\%$ for IC and $\frac{1}{8} = 12.5\%$ for IAC^*. Through the use of numerical methods, it is conjectured that $\sqrt{n}\,\phi(n)$ converges to a limit when n (the size of the electorate in one district) tends to infinity. It implies that $\phi(n)$ converge to 0. It is also demonstrated that: $\phi_m(n) \leq \phi(n)$ where $\phi_m(n) = O\left(\frac{1}{\sqrt{n}}\right)$ and an upper bound $\phi_M(n)$ is also introduced whose convergence properties are examined.

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3.27 Matching in Practice: Junior Doctor Allocation in Scotland

David Manlove (University of Glasgow, GB)

Joint work of Irving, Rob; Kwanashie, Augustine; Manlove, David; McBride, Iain

Matching problems typically involve assigning agents to commodities, possibly on the basis of ordinal preferences or other metrics. These problems have large-scale applications to centralized matching schemes in many countries and contexts. In this short talk I will describe the matching problems featuring in the allocation of junior doctors to Scottish hospitals, as part of the Scottish Foundation Allocation Scheme (SFAS). I will outline the computational methods for their solution and give an overview of results arising from real data connected with SFAS. Algorithms arising from this research were deployed by the National Health Service Education for Scotland as part of SFAS between 1999-2012.

3.28 OWAs for Voting and Matching

Nicholas Mattei (UNSW – Sydney, AU)

Motivated by the common problem of assigning referees to papers for conference organizing and reviewing we survey the existing work and complexity of assignment problems when one or both sides of the market have maximum and minimum capacity constraints. This setting has a number of practical real world applications beyond conference reviewing including shift work assignment and other one (and two) sided assignment settings where one (or both) sides have capacity constraints. Drawing inspiration from various rules used in voting, we use order weighted averages (OWAs) to implement a novel and flexible assignment mechanism which allows one to balance the trade-off between egalitarian and utilitarian objectives. We show that this problem can be solved in polynomial time and report on a set of experiments using real world data from conferences.

3.29 Approximation Algorithms for Power Allocation Problems in AC Electric Systems

Trung Thanh Nguyen (Masdar Institute – Abu Dhabi, AE)

Joint work of Elbassioni, Khaled; Nguyen, Trung Thanh
Main reference K. Elbassioni, T. T. Nguyen, "Approximation Schemes for Binary Quadratic Programming Problems with Low cp-Rank Decompositions," arXiv:1411.5050v1 [cs.DS] , 2014.
URL http://arxiv.org/abs/1411.5050v1

Yu and Chau [AAMAS2013] introduced the Complex Demand Knapsack Problem (CKP), a variant of KP with (one) quadratic constraint motivated by the allocation of power in

Alternating Current (AC) electric systems. Formally, there is a set of users with power demands, each demand is characterized by two components, active power and reactive power. A typical way for expressing the power demand is to use complex numbers of which the real and imaginary parts correspond to the active and reactive power, whereas the magnitudes express as the so-called apparent power. Each user i will give a certain utility if her demand is fulfilled. The goal is to maximize the sum of utilities of the chosen users such that the magnitude of the sum of satisfied demands should not exceed the capacity. Yu and Chau [AAMAS2013] gave a $\frac{1}{2}$-approximation algorithm for CKP and this was improved recently by Chau et al. [AAMAS2014] to a polynomial-time approximation scheme (PTAS); this is the best result we can hope for given that a fully PTAS for the problem does not exist unless P=NP (Woeginger [SODA99]). In this work, we investigate a scenario with more than one number of quadratic constraints as it captures the model of allocating powers in multiple periods. In addition, we consider more general objective functions such as submodular functions and sum-of-ratio functions (i.e., sum of ratios of linear functions). Our contributions are as follows: for the linear objective function and a fixed number of quadratic constraints, we propose a PTAS based on the convex-programming method, which relies on the polynomial solvability of the corresponding convex relaxation problem. Also, we obtain a $(1/e - \epsilon)$-approximation algorithm for the submodular case, for any constant $\epsilon > 0$, by using the geometric approach; the key idea is to make use of the geometry of the problem to reduce it to a multi-dimensional knapsack problem, which can be solved using enumeration and dynamic programming for the linear objective case, or LP-rounding for the submodular case. Finally, we develop a PTAS for the sum-of-ratios objective function under the condition that the number of ratios is constant, by following the multi-objective approach.

3.30 Economics and Computation: Five Challenges in Algorithmic Game Theory, Computational Social Choice, and Fair Division

Joerg Rothe (Heinrich-Heine-Universität Düsseldorf, DE)

Joint work of Rothe, Joerg; Baumeister, Dorothea; Elkind, Edith; Erdelyi, Gabor; Faliszewski, Piotr; Hemaspaandra, Edith; Hemaspaandra, Lane A.; Lang, Jérôme; Lindner; Claudia; Rothe; Irene
Main reference J. Rothe (Ed.), 'Economics and Computation: An Introduction to Algorithmic Game Theory, Computational Social Choice, and Fair Division," ISBN 978-3-662-47904-9, Springer Texts in Business and Economics, Springer, 2016.
URL http://www.springer.com/de/book/9783662479032

In this survey talk, I present five challenges from various areas at the interface of economics and computer science. These challenges are also described in the new book: "Economics and Computation: An Introduction to Algorithmic Game Theory, Computational Social Choice, and Fair Division" J. Rothe (editor and co-author). Springer Texts in Business and Economics, Springer-Verlag, in press, to appear in 2015.

3.31 Refining the complexity of the sports elimination problem

Ildikó Schlotter (Budapest University of Technology & Economics, HU)

Joint work of Potpinková, Eva; Cechlárová, Katarína; Schlotter, Ildikó
Main reference K. Cechlárová, E. Potpinková, I. Schlotter, "Refining the complexity of the sports elimination problem," Discrete Applied Mathematics, Vol.. 199, pp. 172–186, 2016; pre-print available from author's webpage.
URL http://dx.doi.org/10.1016/j.dam.2015.01.021
URL http://www.cs.bme.hu/~ildi/pub/sport.pdf

The sports elimination problem asks whether a team participating in a competition still has a chance to win, given the current standings and the remaining matches to be played among the teams. This problem can be viewed as a graph labeling problem, where arcs receive labels that contribute to the score of both endpoints of the arc, and the aim is to label the arcs in a way that each vertex obtains a score not exceeding its capacity. We investigate the complexity of this problem in detail, using a multivariate approach to examine how various parameters of the input graph (such as the maximum degree, the feedback vertex/edge number, and different width parameters) influence the computational tractability. We obtain several efficient algorithms, as well as certain hardness results.

3.32 Voting Manipulation Games from Epistemic Game Theory Perspective

Arkadii Slinko (University of Auckland, NZ)

So far the main tool for analyzing voting games have been the concept of Nash equilibrium. The concept of Nash equilibrium – as prediction of rational behavior – assumes that individuals have unlimited computing capabilities and can resolve the infinite loops arising from logical reasoning: I think that he thinks that I think that etc. In reality, players' reasoning goes only to a finite depth. Level-k models were introduced by Stahl and Wilson (1994, 1995) to describe experimental data better. Selten (1998) wrote: "Boundedly rational strategic reasoning seems to avoid circular concepts. It directly results in a procedure by which a problem solution is found."

I will show how level-k models can be used to analyze voting manipulation games. In particular, I will show that L_2 voters have to play the game that was previously called Gibbard-Satterthwaite game by Elkind-Grandi-Rossi-Slinko (2015). In particular, for such a voter for some voting rules it will be coNP-hard to decide whether a given manipulation strategy weakly dominates her sincere strategy.

3.33 Online Fair Division: Modelling a Food Bank problem

Toby Walsh (UNSW – Sydney, AU)

I discuss online models of fair division designed to capture different features of a real world charity problem. Food is donated to a food bank and must be allocated to different charities. This allocation problem has many traditional features. We want to allocate food fairly between the different charities that feed different sectors of the community. In addition, the allocation does not use money as these are all charities. However, the problem also has other features not traditionally found in the academic literature on fair division. One of the main novelties is that it is online. Food is donated throughout the day and we must start allocating and distributing it almost immediately, before we know what else will be donated.

3.34 Private and Efficient Repeated Allocation

Jia Yuan Yu (IBM Research – Dublin, IE)

Joint work of Corless, Martin; Häusler, Florian; Griggs, Wynita; Shorten, Robert; Stüdli, Sonja; Wirth, Fabian; Yu, Jia Yuan
Main reference W. Griggs, J. Y. Yu, F. Wirth, F. Haeusler, R. Shorten, "On the Design of Campus Parking Systems with QoS guarantees," arXiv:1506.02818v1 [math.OC], 2015.
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URL http://arxiv.org/abs/1404.5064v3

An unknown number of agents consumes a common good resource in a repeated fashion. We show that if the agents control their consumptions according to a certain policy, then these consumptions converge to a socially efficient allocation. This is achieved without communicating any of the utility functions of the agents, and with very limited broadcast signals from a central authority. We present one such policy for divisible goods and one for indivisible goods.

3.35 Aggregating binary relations: universal scoring rules via inner product

William S. Zwicker (Union College – Schenectady, US)

Are plurality voting, the Kemeny rule, approval voting, the Borda count, and the mean rule all versions of the same aggregation rule? Yes, in a sense. The *median procedure* is a well known method (see e.g. [1], [11]) for aggregating binary relations (on some finite set A of alternatives) that belong to a class $\mathcal{C}_I$ of *feasible inputs* into a binary relation (on the same set A) belonging to a possibly different class $\mathcal{C}_O$ of *feasible outputs*. By relaxing the assumption that $\mathcal{C}_I \subseteq \mathcal{C}_O$ and exploiting the classes $\mathcal{D}$ of *dichotomous weak orders* (weak orders with exactly two indifference classes) and $\mathcal{U}$ of *univalent orders* (dichotomous weak orders whose "top" I-class is a singleton), we show that each of the aforementioned rules[1] can be obtained as a restriction of the median procedure to appropriate classes $\mathcal{C}_I$ and $\mathcal{C}_O$.

Our approach throughout is to view the median procedure itself as a generalized *relational* scoring rule in which each "ballot" R_i in $\mathcal{C}_I$ assigns a real number scoring weight $F(R_i, R)$ to each binary relation R on A; the outcome of the amalgamation is then the $R \in \mathcal{C}_O$ accumulating the greatest total weight, as summed over all ballots. This generalizes the more traditional definition of *scoring rule*, in which ballots award scoring weights to individual alternatives in A, rather than to binary elations on A; the idea is thus similar to the generalizations considered in [5], [6], [15], [17], and [19]. The scoring weights are given by a Euclidean inner product $F(R_i, R) = \mathcal{J}(R_i) \cdot \mathcal{J}(R)$, where $\mathcal{J}$ embeds binary relations on A as vertices of a hypercube in some suitable Euclidean space $\Re^k$. This inner product formulation yields a Euclidean form of *distance rationalization* that is universal, in that the same metric is used for each restriction of the median rule, as well as a *mean proximity* representation that is similarly universal.[2] The median procedure itself is generated by the "hypercube" embedding $\mathcal{J}$ in particular. Alternative embeddings give rise to different sets of rules obtained via the same restriction process. One such alternative uses a permutahedron in place of a hypercube, and yields the Borda count as a *social welfare function* (in which the outcome is a ranking of alternatives) as one of its restrictions; the hypercube seems to be capable of capturing only the *social choice function* form of Borda (in which the outcome is a winning alternative). In general, however, the possibility of interesting alternatives to the hypercube embedding has not been well explored.

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[1] Although most of these are voting rules, the Mean rule (see [7]) is not, nor is the form of cluster analysis considered in [1]; more generally, the applicability of the median procedure to amalgamation goes well beyond its application to voting rules.

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4 Working Groups

4.1 Working group: Course Allocation

KatarínaCechlárová, Bettina Klaus, David Manlove, Jiehua Chen, Péter Biró, Nicholas Mattei, and Haris Aziz

The problem we worked on was concerned with matching applicants to courses in the presence of quotas (on both sides of the market), ordinal preferences of applicants over courses, and course pre-requisites.

Formally, there is a set A of applicants and a set C of courses. Each applicant and course has a quota, indicating the maximum number of entities of the other type that it can be matched to. Each applicant finds acceptable a subset of the courses and ranks this subset in strict order of preference. Thus applicants have ordinal preferences over individual courses. These preferences extend lexicographically to subsets of courses. So for example if applicant a_1 prefers c_1 to c_2 to c_3 to c_4 then she prefers $\{c_1, c_4\}$ to $\{c_2, c_3\}$ according to the lexicographic rule.

There is a directed acyclic graph $D = (C, A)$ whose vertices correspond to the courses, and an arc (c_i, c_j) means that c_i is a pre-requisite for c_j. Thus an applicant cannot be assigned c_j unless she is also assigned c_i. In the basic model we assume that the pre-requisites are the same for all applicants, but in generalizations the directed graph may differ from one applicant to another. In special cases of the basic model we may restrict the structure of D.

The problem is to find a Pareto optimal matching. We looked at three generalizations of the serial dictatorship mechanism and found that two always constructed Pareto optimal matchings, whilst one did not in some cases. Katka also showed that the problem of finding a maximum cardinality Pareto optimal matching is NP-hard. Among the further questions to be investigated are the following: (i) is there a strategy-proof mechanism for generating all Pareto optimal matchings; (ii) is it possible to determine in polynomial time whether a given matching is Pareto optimal?

4.2 Working group: (Control and) Bribery in k-Approval Voting – Open Problems

Robert Bredereck, Judy Goldsmith, and Gerhard Woeginger

Our project was to identify and resolve open problems with respect to computational complexity for Control and Bribery in k-Approval Voting. To this end, we took [1] as our starting point.

We first discovered that all open questions concerning election control have already been solved in [2], but we did not find results for the bribery questions. The main open problem left was the computational complexity of (priced, uniform) bribery for 2-Approval. Given is an election (C, V) with C being the set of candidates and V being the set of voters, a preferred candidate $p \in C$, a price function $w : V \to \mathbb{N}$ and some budget B. The question is whether one can make p become a winner of the 2-approval election by bribing voters with total cost of at most B. Whereas this problem is strongly NP-hard for 3-Approval and trivially solvable for 1-Approval (Plurality), the 2-Approval case was still open.

Within the seminar, we translated the core of the problem into a graph problem and showed this to be polynomial-time solvable. To identify the border between tractability and intractability more precisely, we also looked at a slightly more general variant of the problem where the price of bribing a voter also depends on the bribed vote. We showed that this non-uniform bribery model is already NP-hard for 2-Approval whereas it remains polynomial-time solvable for 1-Approval.

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4.3 Working Group: Mixed Voting Systems

Vincent Merlin and Michel Le Breton

For the elections of parliaments, political science traditionally distinguishes between proportional systems, and systems that use plurality or majority. However, Blais and Massicote (1999) pointed out that one fifth of countries uses mixed voting systems to elect their first (or unique) chamber. Most of these rules, on the top of electing part of the members of the parliament in districts (using a plurality or majority formula), also elects supplementary members at large in broader jurisdictions (such as regions, states, landers, or the country itself) using another formula. However, social choice theory, as well as computer science, has paid little attention to the study of the systems that try to combine different electoral principles. The objective of this group was to present several of these mixed voting rules, and to promote their study in the computational social choice community. Le Breton presented in detail one of the rare theoretical papers on the subject, due to Paul Edelman (2005): in this paper he evaluated the power (or influence) of the voters when they have to choose between two parties in their districts. However, on the top of electing D members of the parliament locally, L extra seats are attributed at large to the party that obtains a majority of the ballot at the national level. Generalization and extension of this result were also outlined by Michel Le Breton. Nevertheless, the issues on this topic remain numerous: Which voting model shall we use to describe the behavior of the voters when they may cast more than one ballot? How to measure the power of the voters when there are several ways (local, national) to influence the outcome? What are the properties of these systems? Which property do they fail to fulfill? Can we even propose axiomatic characterizations of such systems? What are the manipulation and control strategies for these systems, and what are their complexity? How can we translate the models of bribery and lobbying to this context? Given that many projects of electoral reforms (e.g. France, Italy) propose to move towards mixed voting systems, the researchers present at the session agreed that the subject was of crucial importance in the field and needed further investigations.

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5 Rump Session

The rump session featured the announcement by Umberto Grandi of the sixth workshop in the series of COMSOC workshops. Pnyx, a tool for preference aggregation, was presented by Christian Geist, and Nicolas Mattei reported on PrefLib, a reference library of preference data and links. Several research talks were presented:

- Vincent Merlin took the example of the Eurovision European Song Contest to illustrate the problem of the determination of potential and necessary winners for scoring rules.
- Edith Elkind reported on joint work with her PhD student Dominik Peters on a hardness result for single-peaked preferences on trees.

- Ioannis Caragiannis talked about the optimal parliament problem, whose composition maximizes the number of issues for which the majority of the parliament and the public opinion agree on.
- Jérôme Lang defined the "Dagstuhl boat trip problem", a specific hedonic game with a Stackelberg flavor, in the style of the problem [1] which was born at Dagstuhl seminar 12101 on computational social choice, and motivated participants for collaboration on this problem.
- Umberto Grandi presented several issues that remain open in the literature on opinion diffusion on networks, such as existence of convergence, or search for the most influential nodes.
- Steven Brams presented the "catch-up game", where two players alternate choosing subsets of numbers, without replacement, from $\{1, 2, \ldots, n\}$ such that each player's running sum is equal to or greater than – but not more than by the smallest new number he chooses – his opponent's running sum on the last turn.
- Piotr Faliszewski referred to the domain restriction VI for approval votes by E. Elkind and M. Lackner. He showed that dichotomous preference profiles that are not VI can be obtained from single-crossing ones and asked for an efficient algorithm to recognize these.
- Péter Biró raised the question of the search for an optimal matching when preferences are uncertain.
- Jia Yuan Yu proposed two open problems: How should one assign parking spots to cars in a fair fashion so that each driver is inconvenienced as equally as possible, and how could ride-sharing (matching travelers) be used to avoid bursty arrivals at congested roads.
- Judy Goldsmith talked on generating CP-nets in an independent and identically distributed way.
- Flip Klijn presented results he recently obtained with P. Jaramillo and C. Kayi about the possibility to induce truth telling for the stable matchings generated by rank-priority mechanisms.
- Nicolas Maudet talked about the length of paths that items can take, when traded from agent to agent in distributed resource allocation settings.
- Michel le Breton reported on results he obtained with T. Laurent, D. Lepelley and O. De Mouzon on the likelihood of election inversions in two-tier voting systems.
- Annick Laruelle presented the "disapproval rule" which enables voters to express their dissatisfaction with candidates, in contrast to absenteeism, spoiled or blank votes, or voting for a fringe candidate.

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