Report from Dagstuhl Seminar 17261

Voting: Beyond Simple Majorities and Single-Winner Elections

Edited by

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Abstract

This report documents the program and the outcomes of Dagstuhl Seminar 17261 "Voting: Beyond simple majorities and single-winner elections". The seminar featured five survey talks, a series of classic scientific presentations, working group discussions, open problems sessions (with the first one used to establish working groups and the last one to present their results). The seminar was mostly focused on multiwinner elections (from discussions of their algorithmic properties to political-science considerations), but the topics of real-life voting experiments and strategic behavior received attention as well.

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1 Executive Summary

Dorothea Baumeister
Piotr Faliszewski
Annick Laruelle

Computational social choice is an interdisciplinary field of research, focused on the issue of aggregating preferences of agents–perhaps self-interested and strategic – and providing them with joint decisions. Computational social choice combines the tools and approaches of social choice theory, computer science (with particular focus on artificial intelligence and theoretical computer science), economics, political science, and operations research. The distinctive feature of computational social choice–as opposed to the classic social choice theory – is that computational considerations (e.g., efficiency of computing outcomes of the preference aggregation processes) are given significant attention. Further, researchers working on computational social choice often study virtual elections where either people vote through electronic means (such as in Doodle polls for scheduling of meetings) or the elections are used as a tool and the votes are derived automatically in some way (e.g., voting can be used as a selection procedure in a genetic algorithm). Nonetheless, the two research areas are deeply connected and there is significant interaction between them.

One of the most classic problems studied within (computational) social choice regards conducting a single-winner election. For example, consider the situation where members of some society wish to choose their president. They collect the set of candidates (who usually have to register well ahead of time, typically by gathering necessary popular support), then the candidates run their campaigns, argue who would be the best president, air commercials, etc. Eventually, the voters form their preferences (either they simply decide who would be the best president, or they form rankings of the candidates, or they decide on a set of acceptable presidents, depending on the voting rule used) and, on the election day, they cast their votes. In the end, an electoral commission gathers the votes and applies an agreed upon voting rule to decide who would be the next president.

Due to the fantastic progress in social choice (since the middle of the twentieth century) and in computational social choice (over the last fifteen years or so), essentially all the stages of the above-described process are quite well understood. However, In the modern world – especially in the era of ubiquitous use of social media – it appears that there is a great range of preference aggregation settings where the classic approach falls short. For example, consider a situation where a company wants to hire a team of specialists. There may be quite a large number of possible candidates to employ (as opposed to the few candidates in a typical presidential election), each of the candidates may have quite different skills and abilities, various employees may either complement each other or be counter-productive if teamed up (as opposed to our presidential election, where we pick a single person for the whole task). Finally, the recruiting committee typically consists of just a few people (few voters, as opposed to the millions of people voting for presidents), but their preferences might have a very involved structure (for example, if we hire a specialist in X then we also need a specialist in Y, but otherwise a specialist in Z would suffice; on top of that, each member of the recruitment committee may judge candidates' abilities differently).

The goal of the seminar was to bring together researchers who work on various aspects of aggregation problems that go beyond the classic high-stake, rarely conducted, single-winner elections, and to discuss the following issues:

1. Scenarios with multiple winners and/or settings where each aggregation outcome may consist of separate entities (e.g., multi-winner elections and single-winner elections in combinatorial domains).
2. Various non-typical ways of expressing preferences, going from (variants of) non-binary preferences to settings where the agents can express complex statements, including conditional ones (e.g., CP-nets).

The seminar also dealt with some real-world applications, such the question of drawing constituency boundaries in the United States of America or the choice of the voting rule in EU Council of Ministers.

The seminar brought together 42 researchers from 14 countries, working in artificial intelligence, theoretical computer science, mathematics, economics, social choice, and political science. Discussions regarding the new challenges in the area of preference aggregation should fertilize research in all these areas.

The technical program of the seminar was structured over five working groups. On the first day the participants were invited to give 5-minute presentations of research topics that they found interesting and, based on those presentations, the organizers suggested five working groups:

- Working Group 1: Voting Experiments.
- Working Group 2: Understanding Diversity in Multiwinner Elections.
- Working Group 3: Aggregation Procedures with Nonstandard Input and Output Types.
- Working Group 4: Voting in Larger Contexts.
- Working Group 5: Proportionality in Multiwinner Elections.

The seminar attendees accepted these groups and each chose one to participate in the discussions. During the seminar each group met twice for extended discussions. Also, one afternoon was free for unstructured discussions (of which many were used for in-depth discussions of topics initiated during the working group discussions). Finally, on the last day of the seminar representatives of each group presented the results of their discussions (which ranged from making actual technical contributions to presenting research agendas for future work[1]). The working groups were supported by 21 regular scientific presentations, and extended presentation of the real-life experiments regarding French presidential elections, and 6 survey talks.

The seminar acknowledged that there are new, exciting research topics regarding computational social choice. In particular, multiwinner elections were represented very prominently and it became clear that work on them has only started. We hope and believe that one of the effects of the seminar was convincing many more people (also outside of the core computational social choice community) that studying more general forms of elections (such as multiwinner elections, or elections with nonstandard input formats) is important and promising.

Given the personal feedback we received, we believe that the participants were very happy with the setting of working groups (from the process of forming them based on surveyed interest, through actual meetings, to presentation of results). We also receive very strong, positive feedback regarding leaving one afternoon unstructured, for the participants to use as they preferred. We have seen many ad-hoc discussions, meetings of coauthors, and problem-solving sessions. Indeed, it seems that for seminars with well-established communities, such an unstructured afternoon is far more useful than the traditional excursion (which, on the other hand, seems to be very effective for not as well-established communities).

We are very grateful to all the participants for their contributions, ideas, and discussions, which made this seminar truly enjoyable. We would also like to thank the Schloss Dagstuhl team for their support and excellent organization and patience.

[1] The organizers are already aware of three independent research projects that follow the agendas presented at the seminar.

2 Table of Contents

Working groups

3 Overview of Talks

3.1 Proportional Representation in Approval-based Committee Voting and Beyond

Haris Aziz (Data61 – Sydney, AU)

Proportional representation (PR) is one of the central principles in voting. Elegant rules with compelling PR axiomatic properties have the potential to be adopted for several important collective decision making settings. I survey some recent ideas and results on axioms and rules for proportional representation in committee voting.

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3.2 Voter Dissatisfaction in Committee Elections

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

Joint work of Toni Böhnlein, Lisa Rey, Oliver Schaudt, Ann-Kathrin Selker
Main reference Dorothea Baumeister, Toni Böhnlein, Lisa Rey, Oliver Schaudt, Ann-Kathrin Selker: "Minisum and Minimax Committee Election Rules for General Preference Types", in Proc. of the ECAI 2016 – 22nd European Conference on Artificial Intelligence, 29 August–2 September 2016, The Hague, The Netherlands, Frontiers in Artificial Intelligence and Applications, Vol. 285, pp. 1656–1657, IOS Press, 2016.
URL http://dx.doi.org/10.3233/978-1-61499-672-9-1656

In committee elections it is often assumed that voters only (dis)approve of each candidate or that they rank all candidates, as it is common for single-winner elections. We suggest an intermediate approach, where the voters rank the candidates into a fixed number of groups. This allows more diverse votes than approval votes, but leaves more freedom than in a linear order. A committee is then elected by applying the minisum or minimax approach to minimize the voters' dissatisfaction. We study the axiomatic properties of these committee election rules as well as the complexity of winner determination and show fixed-parameter tractability for our minimax rules.

3.3 Multiwinner Approval Voting: An Apportionment Approach

Steven J. Brams (New York University, US)

Joint work of Steven J. Brams, D. Marc Kilgour, Richard F. Potthoff
Main reference Steven J. Brams, D. Marc Kilgour, Richard F. Potthoff: "Multiwinner Approval Voting: An Apportionment Approach", Preprint, 2017.

We extend approval voting so as to elect multiple candidates, who may be either individuals or members of a political party, in rough proportion to their approval in the electorate. We analyze two divisor methods of apportionment, first proposed by Jefferson and Webster, that iteratively depreciate the approval votes of voters who have one or more of their approved candidates already elected. We compare the usual sequential version of these methods with a nonsequential version, which is computationally complex but feasible for many elections. Whereas Webster apportionments tend to be more representative of the electorate than those of Jefferson, the latter, whose equally spaced vote thresholds for winning seats duplicate those of cumulative voting in 2-party elections, is more even-handed or balanced.

3.4 On the Tradeoff Between Efficiency and Strategyproofness in Probabilistic Social Choice

Felix Brandt (TU München, DE)

Joint work of Haris Aziz, Florian Brandl, Felix Brandt, Markus Brill, Christian Geist
Main reference Haris Aziz, Florian Brandl, Felix Brandt, Markus Brill: "On the tradeoff between efficiency and strategyproofness", Working paper, 2017.
URL http://dss.in.tum.de/files/brandt-research/stratlott_journal.pdf

Two fundamental notions in microeconomic theory are efficiency–no agent can be made better off without making another one worse off–and strategyproofness–no agent can obtain a more preferred outcome by misrepresenting his preferences. The conflict between these two notions is already apparent in Gibbard and Satterthwaite's seminal theorem, which states that the only single-valued social choice functions that satisfy non-imposition–a weakening of efficiency–and strategyproofness are dictatorships. This talk will be concerned with efficiency and strategyproofness in the context of social decision schemes, i.e., functions that map a preference profile to a probability distribution (or lottery) over a fixed set of alternatives. Depending on how preferences over alternatives are extended to preferences over lotteries, there are varying degrees of efficiency and strategyproofness. I will dicuss positive results for random serial dictatorship and maximal lotteries as well as a number of impossibility theorems, one of which was recently shown using computer-aided solving techniques.

3.5 On Coalitional Manipulation for Multiwinner Elections: Shortlisting

Robert Bredereck (TU Berlin, DE)

Joint work of Robert Bredereck, Andrzej Kaczmarczyk, Rolf Niedermeier
Main reference Robert Bredereck, Andrzej Kaczmarczyk, Rolf Niedermeier: "On Coalitional Manipulation for Multiwinner Elections: Shortlisting", in Proc. of the Twenty-Sixth International Joint Conference on Artificial Intelligence, IJCAI 2017, Melbourne, Australia, August 19-25, 2017, pp. 887–893, ijcai.org, 2017.
URL http://dx.doi.org/10.24963/ijcai.2017/123

Shortlisting of candidates – selecting a group of "best" candidates – is a special case of multiwinner elections. We provide the first in-depth study of the computational complexity of strategic voting for shortlisting based on the most natural and simple voting rule in this scenario, ℓ-Bloc (every voter approves ℓ candidates). In particular, we investigate the influence of several tie-breaking mechanisms (e.g. pessimistic versus optimistic) and group evaluation functions (e.g. egalitarian versus utilitarian) and conclude that in an egalitarian setting strategic voting may indeed be computationally intractable regardless of the tie-breaking rule. We provide a fairly comprehensive picture of the computational complexity landscape of this neglected scenario.

3.6 Lars Edvard Phragmén: The Man, the Myth, the Legend

Markus Brill (TU Berlin, DE)

I survey some contributions of Swedish mathematician Lars Edvard Phragmén (1863–1937) to the theory of multi-winner elections. Examples are taken from Svante Janson's arXiv paper titled "Phragmén's and Thiele's election methods" (arXiv:1611.08826 [math.HO]).

3.7 Proportional Rankings

Edith Elkind (University of Oxford, GB)

Joint work of Edith Elkind, Piotr Skowron, Martin Lackner, Markus Brill, Dominik Peters

We extend the principle of proportional representation to rankings: given approval preferences, we aim to generate aggregate rankings so that cohesive groups of voters are represented proportionally in each initial segment of the ranking. Such rankings are desirable in situations where initial segments of different lengths may be relevant, e.g., in recommender systems, for hiring decisions, or for the presentation of competing proposals on a liquid democracy platform. We define what it means for rankings to be proportional, provide bounds for well-known aggregation rules, and experimentally evaluate the performance of these rules.

3.8 How Should We Model Incomplete Information in Strategic Voting?

Ulle Endriss (University of Amsterdam, NL)

The Gibbard-Satterthwaite Theorem suggests that every reasonable voting rule is subject to strategic manipulation. But this result relies on the arguably unrealistic assumption that the manipulator has full information about the voting intentions of everybody else. Maybe, if we drop this assumption, better results are attainable? In this talk, I have reviewed a small number of contributions to the literature that are relevant to this kind of research agenda [1, 2, 3, 4, 5, 6]. I have also asked (but not answered conclusively) the question of what constitutes a good model of incomplete information in this context.

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3.9 Robustness Among Multiwinner Voting Rules

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

Joint work of Piotr Faliszewski, Andrzej Kaczmarczyk, Robert Bredereck, Rolf Niedermeier, Piotr Skowron, Nimrod Talmon

We investigate how robust are results of committee elections to small changes in the input reference orders, depending on the voting rules used. We find that for typical rules the effect of making a single swap of adjacent candidates in a single preference order is either that (1) at most one committee member can be replaced, or (2) it is possible that the whole committee can be replaced. We also show that the problem of computing the smallest number of swaps that lead to changing the election outcome is typically NP-hard, but there are natural FPT algorithms. Finally, for a number of rules we assess experimentally the average number of random swaps necessary to change the election result.

3.10 The Complexity of Campaigning

Judy Goldsmith (University of Kentucky – Lexington, US)

Joint work of Judy Goldsmith, Cory Siler, Luke Harold Miles
Main reference Cory Siler, Luke Harold Miles, Judy Goldsmith: "The Complexity of Campaigning", in Proc. of the Algorithmic Decision Theory - 5th International Conference, ADT 2017, Luxembourg, Luxembourg, October 25-27, 2017, Proceedings, Lecture Notes in Computer Science, Vol. 10576, pp. 153–165, Springer, 2017.
URL http://dx.doi.org/10.1007/978-3-319-67504-6_11

In "The Logic of Campaigning" [1], Dean and Parikh consider a candidate making campaign statements to appeal to the voters. They model these statements as Boolean formulas over variables that represent stances on the issues, and study optimal candidate strategies under three proposed models of voter preferences based on the assignments that satisfy these formulas. We prove that voter utility evaluation is computationally hard under these preference models (in one case, $\#P$-hard), along with certain problems related to candidate strategic reasoning. Our results raise questions about the desirable characteristics of a voter preference model and to what extent a polynomial-time-evaluable function can capture them.

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3.11 Apportionment as a Sequential Portfolio Allocation Method: Application to Northern Ireland

Bernard Grofman (University of California – Irvine, US)

Joint work of Brendan O'Leary, Jorgen Elklit, Bernard Grofman

There are three elements of the usual cabinet coalition bargaining game that need to be determined:

1. Which parties will be in government?
2. What (perhaps minimal/incomplete) policy platform can these parties agree upon?
3. How will cabinet portfolios be allocated? (The set of (junior) ministries may be flexible)

The process in Northern Ireland is quite different: on the one hand, incorporating both a diversity requirement (re Unionist and Nationalist representation in the governing coalition) and, on the other hand, making use of a proportional allocation algorithm to allocate ministerial portfolios in a fashion that does not actually require the agreement of the parties on which parties get which portfolio in any given instance, but only an agreement in advance on a quite abstract but always determinate rule as to the sequence of choice, with ministries are basically fixed in advance.

1. The leading unionist and the leading nationalist party will always be in government as the executive and deputy executive.
2. Cabinet portfolios will be allocated in accord with party vote shares to those parties that agree to be in government using the D'Hondt apportionment rule as a sequential allocation process, i.e., the largest party gets to be First Minister, the next largest Deputy First Minister and the next ministry is chosen by whichever party has the largest unallocated divisor quotient. Etc.
3. There is no overall agreement on government policy; roughly speaking, the party that controls a ministry controls the policy within the jurisdiction of that ministry.

We consider the properties of such a sequential allocation rule

3.12 Graph Theory Perspectives on Committee Representativeness

Bernard Grofman (University of California – Irvine, US)

Joint work of Scott L. Feld, Bernard Grofman

After briefly reviewing several centuries of work on theories of representation and offering a conceptual synthesis, we offer a new approach to determining the overall "representativeness"of a committee or legislature that combines representativeness with diversity. The basic ideas, presented for the first time, we believe, in Grofman and Feld (1988, unpublished) are similar in spirit to that of Chamberlin and Courant (1978), but draw on two seminal ideas in graph theory, the idea of a k-cover and the idea of a k-basis (Harary, Cartwright and Norman, 1965). Like Chamberlin and Courant, we abstract away from the mechanism by which representative are chosen to look at voter preferences about members of possible committees so as to build up evaluations of committees as a whole from voter evaluations of the individual committee members. We then look at a minimal k-cover which is the equivalent of a minimax version of Chamberlin and Courant. Because this approach yields too many feasible committees, we propose to narrow the selection by imposing a diversity requirement on the set of min-max committees, in terms of the idea of a minimal k-basis, a set whose members are maximally distinct from one another.

3.13 Mathematical and Computational Aspects of Constituency Boundary Drawing in the United States

Bernard Grofman (University of California – Irvine, US)

We consider mathematical and computational aspects of redistricting (constituency boundary drawing) in the United States, with particular attention to issues of partisan and racial gerrymandering and legal challenges to such gerrymandering involving expert witness testimony. We pay particular attention to issues tied to computer analysis, e.g., analysis of districting features such as compactness and computer simulation of all possible plans that satisfy certain legal criteria. We briefly discuss a pending partisan gerrymandering legal challenge to Wisconsin congressional districts that will be heard by the U.S. Supreme Court in Fall, 2017, and we offer a five-pronged test for unconstitutional partisan gerrymandering. We also look at how U.S. redistricting practices differ from those elsewhere in the democratic world.

3.14 Multi-Winner Elections: A Review

Marc Kilgour (Wilfrid Laurier University, CA)

A Multi-Winner Election is an election that is intended to select a subset of the candidates. What properties should that subset possess? In most multi-winner elections, it is desirable that the voters support strongly not only each individual elected candidate, but also the elected subset as a whole. In multi-winner elections, the desiderata of level of support and breadth of support are often in conflict, amply illustrated by the well-known "Tyranny of the Majority" problem.

Multi-winner elections can be classified according to whether the number of winners is fixed in advance (FNW), or variable – where the voters determine not only who wins, but also how many win (VNW). Common multi-winner elections are reviewed in light of this classification and the often-conflicting objectives of individual vs. group support.

Prominent among the reasons why it is difficult to find a good multi-winner election procedure is that ballots describe only individual candidates, and do not record any assessment of subsets of candidates. A voter simply cannot express nuances of preference, such as candidates who work well, or poorly, together.

One strategy to ensure diversity in the winning subset is to specify which subsets are admissible, or permitted to win the election. Another method is to select a procedure for counting the ballots that measures the level of support for individual candidates while penalizing candidates whose support lacks breadth.

Ballots available for multi-winner elections are reviewed, and the issue of strategy raised. Even for a sincere voter with well-defined utilities and linear preferences over subsets, it is not obvious how to fill out some ballots. In addition, even for an FNW election with sincere voters, the winning subset can depend on the particular ballot form chosen.

Some simple observations about the less-known category of VNW (Variable Number of Winners) elections are offered, including the work of Duddy and Piggins (and Zwicker) on aggregation. A new property is proposed that eliminates the possibility of ties. It is appropriate for a VNW election, including elevation to a hall of fame and short-listing, where the only objective is to identify the candidates with sufficient individual support.

Multi-winner elections are an important area of rapid scientific progress. Moreover, improving electronic capabilities have made multi-winner elections more common. If they are matched by improvements in procedures, there will be new options for efficient opinion-gathering and accurate expression and understanding of voters' opinions.

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3.15 Consistent Approval-Based Multi-Winner Rules

Martin Lackner (University of Oxford, GB)

Joint work of Martin Lackner, Piotr Skowron
Main reference Martin Lackner, Piotr Skowron: "Consistent Approval-Based Multi-Winner Rules", in CoRR, Vol. abs/1704.02453, 2017.
URL http://arxiv.org/abs/1704.02453

The goal of this talk is to provide an overview of recent work on approval-based multi-winner rules and discuss research directions. Approval-based multi-winner rules are voting rules that select a fixed-size group of candidates based on approval ballots. Such rules are applicable to a wide range of scenarios concerning group decision making and consequently may aim for widely diverging objectives.

In this talk, I introduce the class of counting rules and discuss axiomatic characterizations of rules in this class. In particular, I present axiomatic characterizations of three import consistent multi-winner rules: Proportional Approval Voting, Multi-Winner Approval Voting and Approval Chamberlin–Courant. These results demonstrate the variety of multi-winner rules and the different, orthogonal goals that multi-winner voting rules may pursue.

3.16 Voting in Combinatorial Domains

Jérôme Lang (University Paris-Dauphine, FR)

This talk addresses preference aggregation and voting on domains which are the Cartesian product (or sometimes, a subset of the Cartesian product) of finite domain values, each corresponding to an issue, a variable, or an attribute. Practical examples of voting on such combinatorial domains are multiple referenda, group configuration, and committee elections. The talk gives a structured survey of classes of methods for voting in combinatorial domains and relates them to classes of multiwinner elections rules. The talk mostly follows the handbook chapter J. Lang and L. Xia, "Voting in Combinatorial Domains", Chapter 9, Handbook of Computational Social Choice.

3.17 Voting Experiments: First Lessons from the 2017 French Presidential Election

Annick Laruelle (University of the Basque Country – Bilbao, ES), Sylvain Bouveret (LIG – Grenoble, FR), and Vincent Merlin (Caen University, FR)

Joint work of Annick Laruelle, Sylvain Bouveret, Vincent Merlin, Antoinette Baujard, Renaud Blanch, Herrade Igersheim, Jean-François Laslier, Isabelle Lebon

During the French presidential election in April 2017, a voting experiment was carried online (on the website https://vote.imag.fr/) and at five polling. Participants were proposed to test alternative voting procedure such as approval voting, evaluative voting, STV. The aims of this talk are to the reasons for realizing in situ experiments, to describe the experimental protocol and to give a few preliminary results and feedback. Above all, the aim is to raise discussions about what voting theory can learn from this kind of experiments.

3.18 Multiwinner Voting Rules in Practice: an Efficiency – Inequality Dilemma

Jean-Francois Laslier (Paris School of Economics, FR)

Multiwinner voting rules take as input preferences over candidates and return sets of candidates. These rules could be used for parliamentary election if electoral law would allow panachage across parties. Using survey data, we study six such rules that have been proposed in the literature and illustrate what they could produce using 73 political elections, each of whom has between 6 and 9 parties. We show in particular how these rules differentiate the ones from the others according to Proportionality, Efficiency, and Inequality.

3.19 Strategyproof Peer Selection using Randomization, Partitioning, and Apportionment

Nicholas Mattei (IBM TJ Watson Research Center – Yorktown Heights, US)

Joint work of Nicholas Mattei, Haris Aziz, Omer Lev, Jeffrey S. Rosenschein, Toby Walsh
Main reference Haris Aziz, Omer Lev, Nicholas Mattei, Jeffrey S. Rosenschein, Toby Walsh: "Strategyproof Peer Selection", in CoRR, Vol. abs/1604.03632, 2016.
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Peer review, evaluation, and selection is a fundamental aspect of modern science. Funding bodies the world over employ experts to review and select the best proposals of those submitted for funding. The problem of peer selection, however, is much more universal: a professional society may want to give a subset of its members awards based on the opinions of all members; an instructor for a MOOC or online course may want to crowdsource grading; or a marketing company may select ideas from group brainstorming sessions based on peer evaluation. We make three fundamental contributions to the study of procedures or mechanisms for peer selection, a specific type of group decision making problem studied in computer science, economics, and political science. First, we propose a novel mechanism that is strategyproof, i.e., agents cannot benefit by reporting insincere valuations. Second, we demonstrate the effectiveness of our mechanism by a comprehensive simulation based comparison with a suite of mechanisms found in the literature. Finally, our mechanism employs a randomized rounding technique that is of independent interest, as it solves the apportionment problem that arises in various settings where discrete resources such as parliamentary representation slots need to be divided proportionally.

3.20 The Optimal Voting Mechanism in the Council of the a Federal Union

Vincent Merlin (Caen University, FR)

Joint work of Michel Le Breton, Dominique Lepelley, Antonin Macé, Vincent Merlin
Main reference M. Le Breton, D. Lepelley, A. Macé, and V. Merlin. "Le Mécanisme Optimal de Vote au Sein du Conseil des Représentant d'un Système Fédéral, L'actualité Economique," 2017. To appear.

The main objective of this survey is to review the literature on the selection of a Council or a Committee in a Federal Union. We will assume that several autonomous authorities (cities, regions, states) have decided to form a federal union. We do not discuss here the reasons why the federation exists, nor the extent of its competencies. We posit that each authority is represented at the federal level by a unique representative. The example we have in mind is the Council of Minister of the EU, though it can easily be applied to other contexts (eg the US Electoral College, a parliament, etc.). In most of the paper, we also assume that the federation has to take only binary decisions. A representative will vote either 'yes' or 'no' on each issue (abstention is not allowed). In this context, we face a mechanism design problem: What is the best voting mechanism, in order to fulfill a given objective? Said differently, given the natural boundaries of the districts/cities/region/states, and the impossibility to organize a direct decision mechanism, what is the best two-tiers voting rule? More precisely, which weight should we award to each representative, and which quota should we use for the decision? As we will see, the answer to this question depends upon the criteria we adopt to judge upon the fairness of the decision, and upon the assumptions we retain to model the voting behavior of the citizens in each jurisdiction.

3.21 The Power, Success and Size of Voter Groups: Borda vs. Condorcet vs. Plurality Rule

Stefan Napel (Universität Bayreuth, DE)

The talk considers collective decisions between more than two options by a fixed number of shareholders or homogenous voter groups. The respective voting weights or sizes of the groups differ. Collective outcomes are then known to be highly sensitive to the adopted collective choice rule. How could one clarify if – and ideally quantify the extent to which – adoption of a particular rule benefits a given group a priori, assuming that voting weights and the number of alternatives are known while the specific alternatives and hence individual preference rankings are still open? Possible answers are complicated by big differences in the numbers of structurally distinct weight configurations across decision rules. For instance, with three groups and three alternatives, there are 51 distinct mappings from the 216 possible strict preference profiles to a single winner which can be supported by weighted Borda voting, but only 6 such equivalence classes of weights for plurality voting and 4 under Copeland's method; or 5255 vs. 34 vs. 9 equivalence classes of weight distributions with four groups. Investigation of the geometry of these equivalence classes is a novel and fascinating subject in itself.

3.22 The k-Kemeny Rule, and an Incompatibility between Proportionality and Strategyproofness

Dominik Peters (University of Oxford, GB)

In this talk, I discuss two topics. First, I describe some interesting complexity questions about the k-Kemeny rule recently introduced by Bill Zwicker; these mainly concern structured preferences and parameterized questions. The k-Kemeny rule selects a k-chotomous ordering that best represents the input preferences. For $k \geq 3$, this rule is NP-hard to evaluate. However, this problem becomes easy if the input preferences are single-peaked, or if they are purely cocyclic. An interesting challenge for future research would be to see whether these tractability results can be extended: is evaluation also easy for single-crossing preferences, or for other notions of structure? Is evaluation easy for almost cocyclic preferences? Further, many natural approximation and fixed-parameter questions are open for this interesting rule.

Second, I presented an impossibility theorem for approval-based multi-winner rules. In this setting, Approval Voting (AV), which returns the k candidates with highest approval scores, is strategyproof in a strong sense. However, AV is not proportional, and if a majority of voters agrees on k candidates, then the preferences of the minority are completely ignored by AV. On the other hand, Proportional Approval Voting (PAV), due to Thiele, satisfies a strong notion of proportionality (namely extended justified representation (EJR), as well as being a d'Hondt extension). One may wonder whether both of these virtues can be satisfied together: is there an approval-based multi-winner rule that is both proportional and strategyproof? Using a technique based on SAT solvers, I show that the answer is no. The incompatibility holds even for very weak notions of proportionality and of strategyproofness.

3.23 Evaluationwise Strategy-proofness

M. Remzi Sanver (University Paris-Dauphine, FR)

Joint work of Bora Erdamar, Shin Sato, M. Remzi Sanver

We consider manipulation of collective decision making rules in a framework where voters not only rank candidates but also evaluate them as "acceptable" or "unacceptable". In this richer informational setting, we adopt a new notion of strategy-proofness, called evaluationwise strategy-proofness, where incentives of manipulation exist if and only if a voter can replace an outcome which he finds unacceptable with an acceptable one. Evaluationwise strategy-proofness is weaker than strategy-proofness. However, we establish the prevalence of a logical incompatibility between evaluationwise strategy-proofness, anonymity and efficiency. On the other hand, we show possibility results when either anonymity or efficiency is weakened.

3.24 Practical Algorithms for Computing STV and Other Multi-Round Voting Rules

Sujoy Sikdar (Rensselaer Polytechnic Institute – Troy, US)

Joint work of Sujoy Sikdar, Chunheng Jiang, Hejun Wang, Lirong Xia, Zhibing Zhao
Main reference Chunheng Jiang, Sujoy Sikdar, Hejun Wang, Lirong Xia, Zhibing Zhao: "Practical Algorithms for Computing STV and Other Multi-Round Voting Rules", in Proc. of 4th Workshop on Exploring Beyond the Worst Case in Computational Social Choice, EXPLORE-2017, 2017.
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STV is one of the most commonly-used voting rules for group decision-making, especially for political elections. However, the literature is vague about which tie-breaking mechanism should be used to eliminate alternatives. We propose anytime algorithms for computing co-winners under STV, each of which corresponds to the winner under some tie-breaking mechanism. This problem is known as parallel-universes-tiebreaking (PUT)-STV, which is known to be NP-complete to compute. We conduct experiments on synthetic data and Preflib data, and show that standard search algorithms work much better than ILP. We explore improvements to the search algorithm with various features including pruning, reduction, caching and sampling. We use deep learning models to develop priority functions that further improve the performance of the search algorithms.

3.25 Proportionality under Multiwinner Rules

Piotr Skowron (TU Berlin, DE)

Joint work of Piotr Faliszewski, Nimrod Talmon, Piotr Skowron

We consider multiwinner election rules and discuss some of their properties. In particular we discuss the concept of proportional representation of multiwinner election rules. Informally, proportional representation requires that the extent to which a particular preference or opinion is represented in the outcome of elections should be proportional to the frequency with which this preference or opinion occurs within the population. We discuss several approaches which allow to better understand the nature of multiwinner rules with respect to proportional representation.

3.26 Gibbard-Satterthwaite Games for k-Approval Voting Rules

Arkadii Slinko (University of Auckland, NZ)

Joint work of Daniel Hughes, Francesca Rossi, Umberto Grandi, Arkadii Slinko

The Gibbard-Satterthwaite theorem implies the existence of voters, called manipulators, who can change the election outcome in their favour by voting strategically. When a given preference profile admits several such manipulators, voting becomes a game played by these voters, who have to reason strategically about each others' actions. To complicate the game even further, counter-manipulators may try to counteract potential actions of manipulators.

Previously, voting manipulating games have been studied mostly for Plurality rule. We extend this to k-Approval voting rules rules. However, unlike previous studies, we assume that voters are boundedly rational and do not think beyond manipulating or countermanipulating. In this paper we look for conditions on strategy sets of voting manipulation games that guarantee the existence of Nash equilibrium in pure strategies.

3.27 Relation Between Multiwinner Elections and k-Median Problems.

Krzysztof Sornat (University of Wroclaw, PL)

Joint work of Jarosław Byrka, Piotr Skowron, Krzysztof Sornat
Main reference Jaroslaw Byrka, Piotr Skowron, Krzysztof Sornat: "Proportional Approval Voting, Harmonic k-median, and Negative Association", in CoRR, Vol. abs/1704.02183, 2017.
URL http://arxiv.org/abs/1704.02183

In multiwinner elections we want to choose k winners that they somehow represents voters. In k-median problems we want to open k facilities that they somehow serve all clients. Voters has dissatisfaction from choosing particular candidate. Clients has cost of being served by particular facility. It is all the same! I will show examples of voting rules and k-median type of problems that are closely related. Then I will focus on approximation algorithms for such problems. Widely used technique for constructing approximation algorithms is linear programming relaxation with proper rounding procedures. I will present dependent rounding [1] that helps us in opening exactly k facilites (choose exactly k winners) keeping marginal probabilities of opening for each facility. Also I will show our last results on approximating the minimization version of Proportional Approval Voting (PAV) [2].

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3.28 Constructing a Democratically-Optimal Budget

Nimrod Talmon (Weizmann Institute – Rehovot, IL)

Joint work of Ehud Shapiro, Nimrod Talmon

The budget is the key means for effecting policy in democracies, yet its preparation is typically an opaque and arcane process, at the end of which the governing body is presented with a take-it-or-leave-it budget proposal. Participatory budgeting is making inroads in municipalities, but is typically limited to a small fraction of the total budget. Current participatory budgeting methods do not scale to entire budgets as they cannot handle quantitative budget items nor hierarchical budget construction. Here we apply the Condorcet principle to participatory budgeting and introduce the concept of a democratically-optimal budget – a budget within a given limit for which there is no other budget within this limit that is preferred by a majority of the voters. While a democratically-optimal budget does not always exist, we show an algorithm that, given a budget proposal, a budget limit, and a ranking of its items by voters, produces a democratically-optimal budget. Our method can handle quantitative budget items and supports hierarchical budget construction and thus may be applicable to entire budgets.

3.29 Aggregation and Orthogonal Decomposition

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

In voting, preferences (submitted as ballots, in any of a variety of formats) are aggregated into an election outcome; in cluster analysis, similarities and differences are aggregated into a partition of objects by type; in judgment aggregation, discordant views as to which logical statements are true and which false are aggregated into a logically consistent collective judgment; in short, there exist a variety of settings wherein information from multiple sources is aggregated into a collective decision. Barthélemy and Monjardet [1981] suggest the context of binary relations as a natural home for a general theory of aggregation, and recommend the median procedure, defined via a metric on relations, as a flexible method that, when restricted to various relational classes, yields a number of useful specific aggregation rules. We reformulate the median procedure in terms of inner product, and argue that two key orthogonal decompositions:

- Explain why certain interesting aggregation rules can be obtained as restrictions of the median procedure, while other, closely related rules cannot
- Suggest modifications to the median procedure to obtain related general procedures that yield some of these "missing" rules
- Identify a key source of disagreement among specific rules: components of information that play an active role in aggregation via some rules, but are irrelevant for others.
- Explain why polynomial time aggregation algorithms exist for some rules, while the aggregation problem is NP-complete for others
- Reveal, for large sub-family of aggregation rules that have been proposed over centuries, that these rules are less ad hoc, and more closely related to one another, than may first appear.

4 Working groups

4.1 Voting Experiments

Sylvain Bouveret (LIG – Grenoble, FR), Christian Klamler (Universität Graz, AT), Annick Laruelle (University of the Basque Country – Bilbao, ES), Jean-Francois Laslier (Paris School of Economics, FR), and Vincent Merlin (Caen University, FR)

Christian Klamler reported the experiment realised during regional elections in Austria. He explained the administrative difficulties met and the findings, in particular on the voting behavior. This experiment was compared to the French one realized by the other participants. Possible classifications of the candidates were discussed: popular/unpopular/polarized/medium versus exclusive/inclusive. Issues concerning the treatment of the data were raised, in particular the question of the bias, the robustness of the results. Tests to be realized were discussed, for instance the single-peakness of voters' preferences. We end up the discussion with lines for further research: how to do experiments in the future? In which types of elections? In which countries?

4.2 Understanding Diversity in Multiwinner Elections

Robert Bredereck (TU Berlin, DE), William Bailey (University of Kentucky – Lexington, US), Dorothea Baumeister (Heinrich-Heine-Universität Düsseldorf, DE), Ulle Endriss (University of Amsterdam, NL), Piotr Faliszewski (AGH University of Science and Technology – Krakow, PL), Bernard Grofman (University of California – Irvine, US), Martin Lackner (University of Oxford, GB), Sujoy Sikdar (Rensselaer Polytechnic Institute – Troy, US), Arkadii Slinko (University of Auckland, NZ), and Nimrod Talmon (Weizmann Institute – Rehovot, IL)

Diversity in voting is a multi-faceted issue which is widely neglected from the theoretical perspective in the area of Computational Social Choice. The discussion group identified several interesting questions and research directions in which issues of diversity play a role or may arise:

Diversity with respect to preferences. Are preferences in a profile diverse in the sense that they reflect a wide range of opinions? In this context, the main idea is to identify functions that measure the diversity of a preference profile. Natural approaches are based on the Kendall tau rank distance or on the positions of committee members in the voters' preferences with respect to natural multi-winner voting rules. This question has been studied, e.g., by Hashemi and Endriss [3].

Diversity with respect to external attributes. Assuming that committee members have additional attributes, is a chosen committee diverse with respect to these attributes? There are various natural applications including gender balanced committees or program selection processes aiming for a specific ratio of senior and junior researchers. External attributes, however, require the development of new formal models [2].

Diversity of (multi-winner) rules. Does a multi-winner rule translate diverse preferences into a diverse committee? Towards developing formal properties of diverse rules, our discussion group agreed that diverse rules should, to some extent, resist against "cloned candidates". The minimax version of Chamberlin Courant together with utilitarian tie-breaking is a rule which intuitively respects diversity quite well so that characterizations of that rules seem very interesting. Note that "blind rules cannot distinguish colors", i.e., if a rule is not aware of external attributes of candidates, it cannot take these into account *even* if voters' preferences are diverse with respect to these attributes. Furthermore, diversity of voting rules can be visualized in the two-dimensional euclidean domain with histogram plots as introduced by Elkind et al. [1]. Intuitively, diverse voting rules should reflect the general shape of distributions but ignore intensities.

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4.3 Aggregation Procedures with Nonstandard Input and Output Types

Dominik Peters (University of Oxford, GB), Sirin Botan (University of Amsterdam, NL), Jiehua Chen (Ben Gurion University of the Negev – Beer Sheva, IL), Marcin Dziubinski (University of Warsaw, PL), Jérôme Lang (University Paris-Dauphine, FR), Nicholas Mattei (IBM TJ Watson Research Center – Yorktown Heights, US), Jörg Rothe (Heinrich-Heine-Universität Düsseldorf, DE), M. Remzi Sanver (University Paris-Dauphine, FR), Gerhard J. Woeginger (RWTH Aachen, DE), and William S. Zwicker (Union College – Schenectady, US)

In this working group, we considered the design and analysis of voting rules that do not fall into the standard framework of taking as input either approval ballots or linear orders and returning as output either a set of winners or a linear order.

In particular, we made some progress in studying an open problem by Bill Zwicker, but did not settle it. This problem concerns the aggregation of a profile of equivalence relations into a consensus equivalence relation using the median procedure. This problem is known to be NP-hard. The question is whether hardness holds even if the input consists of equivalence relations each of which has at most 2 equivalence classes. An intermediate problem we considered is which weighted graphs can be constructed using profiles of such equivalence relations; here, we found a non-universality: some weighted graphs cannot be constructed using 2 equivalence classes only.

We also discussed some other problem settings. One setting that seemed very natural to us is the following: Consider the problem of selecting a set of several winners, for example papers to admit to a conference, students to admit to a PhD program etc. In these cases, there are several spots available, but the number of winners is not fixed, but endogenously determined. In such cases, a rule should identify a class of "obvious winners", a class of "obvious losers", and a class of candidates which belong to neither group. This latter, middle class should ideally be ranked in order of desirability, so that the deciding body can then choose where to draw the line. The design of good rules of this type is an interesting question for future work.

We also discussed some sensible rules that aggregate linear orders with an additional "bar" that identifies some initial segment of each voter's preference as their approval set. Several ways of using this information seem sensible, and a closer analysis should form an interesting starting point for further analysis.

4.4 Voting in Larger Contexts

Lisa Rey (Heinrich-Heine-Universität Düsseldorf, DE), Judy Goldsmith (University of Kentucky – Lexington, US), Marc Kilgour (Wilfrid Laurier University, CA), Stefan Napel (Universität Bayreuth, DE), Ann-Kathrin Selker (Heinrich-Heine-Universität Düsseldorf, DE), and Kristen Brent Venable (Tulane University – New Orleans, US)

In this group two questions were discussed: "Voting on ethical theories", proposed by K. Brent Venable and "Emotion manipulation", proposed by Judy Goldsmith. The former is based on the fact that a human beings' attitude to morality originates from various influences such as a local or religious law and follows different mentalities such as deantology or utilitariarism. In computer science the question arises how to consider these influences on decision making in for example self-driving cars or automated processes of granting credits or solving problems. While this question includes the fields of multi-criteria optimisation, negotiation, and machine learning, we considered decision making in the context of voting and discussed which properties a voting system should fulfil. On the one hand the voting system should be unanimous and abstain from electing the Condorcet loser. On the other hand the winner does not have to be at least one voter's favourite candidate, which is a desirable property in many other settings. The question can be extended to different context (Should the decision be different if there are children in the car?) or by including weights on the types of consequences. The latter, emotion manipulation, is based on the hypothesis that people vote differently under the influence of emotions. Angry voters tend to act while frightened voters tend to do careful research first. This observation is connected with observations of people with addictions. Amongst others, ideas were to formalise voting over time in this context, to consider to which extend the prevention of such behaviour is still democratic, or how this behaviour can be recognised in the voter's preferences. As an aim we considered a continuity of the voting rule with respect to its input, comparable to Condorcet-consistency, taking statistical models into account. This model should measure the impact of occurring changes. A theoretical analysis of changes on the election outcome could interdependent with a psychological study of the kind of the occurring changes in votes under different moods.

4.5 Proportionality in Multiwinner Elections

Piotr Skowron (TU Berlin, DE), Haris Aziz (Data61 – Sydney, AU), Steven J. Brams (New York University, US), Markus Brill (TU Berlin, DE), Edith Elkind (University of Oxford, GB), Svetlana Obraztsova (Nanyang TU – Singapore, SG), and Krzysztof Sornat (University of Wroclaw, PL)

In a multiwinner election the goal is to select a given-size committee, i.e., a subset of the set of candidates, based on the preferences of the voters over the candidates. Selecting a group of representatives for a given society is a prime example of multiwinner elections. In such cases, one often expects the election rule to follow the principle of proportionality, i.e., that sufficiently large homogeneous groups of voters are represented in a committee and that the numbers of representatives that such groups get in a committee are proportional to their sizes. The concept of proportionality is well-understood in the context of apportionment, i.e., when each voter votes for a single political party, and when parliamentary seats need to be distributed among political parties. Informally speaking, in the apportionment model the proportionality means that the number of seats assigned to a political party should be roughly proportional to the size of the electorate that voted for such a party [1].

The concept of proportionality of apportionment is helpful for understanding how proportional or disproportional are certain multiwinner rules [2]. Indeed, an instance of an apportionment can be also viewed as an instance of an approval-based multiwinner election, by assuming that a vote for a party is a vote approving all the members of the respective party. When viewed from this perspective, each multiwinner rule induces a certain apportionment method, and looking at which rules induce which apportionment methods can give us some insights into how proportional are these rules.

An interesting model which gives more flexibility to the voters than the classic apportionment setting, but less than the model of multiwinner elections, is when we allow the voters to approve multiple parties. Then, the concept of proportionality can be interpreted in a number of ways which we illustrate using the following example.

▶ **Example 1.** Assume there are four parties, A, B, C, and D, that we are looking for a committee of size $k = 10$, and that there are the following votes:

20 votes: $\{A\}$

60 votes: $\{B, C\}$

20 votes: $\{C, D\}$

The above notation means that 20 voters approve party A, 60 voters approve two parties: B and C, and 20 voters – parties C and D.

One approach to interpret a vote $\{B, C\}$ in the above example is that a voter who casts such a vote is perfectly happy if his vote supports party B or party C. With this approach, we can interpret the above instance as an approval-based multiwinner election, by assuming that a vote for $\{B, C\}$ corresponds to approving all members of B and all members of C. Next, we can apply one of the proportional approval-based multiwinner rules to such obtained instance. For instance, by applying Proportional Approval Voting (PAV) to the instance obtained from the profile from Example 1, we see that a solution which allocates 2 seats to party A, 6 seats to party B and 2 seats to party D is proportional.

One drawback of the previous interpretation is that party C can get no seats even though it is approved by 80% of voters. Thus, this interpretation does not provide fairness to the parties. This motivates another approach: a vote for $\{B, C\}$ shows an intention of distributing the voter's support equally between the two parties. If this is the case, we can say that the total support that parties A, B, C, and D received is equal to, respectively, 20, 30, 40, and 10. Thus, an allocation where these four parties get, respectively, 2, 3, 4, and 1 seat would be proportional.

Summarizing, an exploration of different approaches to designing and understanding systems of apportionment where voters can approve multiple political parties is an interesting line of research.

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