Report from Dagstuhl Seminar 14202

JA4AI – Judgment Aggregation for Artificial Intelligence

Edited by

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Abstract

This report documents the programme and the outcomes of Dagstuhl Seminar 14202 on "Judgment Aggregation for Artificial Intelligence". Judgment aggregation is a new group decision-making theory that lies in the intersection of logic and social choice; it studies how to reach group decisions on several logically interconnected issues by aggregation of individual judgments. Until recently research in judgment aggregation was dominated by its originating context of philosophy, political science and law. Presently, however we are witnessing increasing work in judgment aggregation from researchers in computer science. Since researchers from such diverse disciplinary backgrounds working on judgment aggregation each publish within their own discipline with virtually no cross-discipline cooperation on concrete projects, it is essential that they are given an opportunity to connect to each other and become aware of the workings of the other side. This seminar has provided such an opportunity.

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1 Executive Summary

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Judgment aggregation is a group decision-making theory, developed in the last decade, that studies how to reach group decisions on logically interconnected issues by aggregation of individual decisions on those issues. The interest of computer science in group reasoning and decision-making theories is driven by the increase of distribution of information and computation as features of various Internet-based services that dominate the information technology market.

Judgment aggregation studies collective decision-making as a process whereby individual opinions concerning the acceptance or rejection of a set of issues are aggregated into one collective judgment. The problem is for the aggregation process to preserve, in a non-trivial way, some 'rational' aspects of the individual to-be-aggregated stances like, in particular, logical consistency. A wealth of results have highlighted how the rationality of a collective decision may clash with other desirable properties of a process of aggregation one may wish to require (*e.g.*, anonymity of the voters, independence of the aggregated issues, to mention a few).

Judgment aggregation research, originally studied in law, was propelled into other disciplines with its establishment as a separate discipline from preference aggregation in the early 2000's. The first half of the decade was marked by studies of aggregation properties that cannot be jointly satisfied by one aggregation function, usually referred to as 'impossibility results'. These studies were mostly conducted by researchers from political science, law, economics, mathematics, and philosophy. The second half of the decade witnessed an increase of interest in judgment aggregation of researchers from artificial intelligence (AI), specifically knowledge representation and reasoning (KR), and multi-agent systems (MAS).

Research on judgment aggregation, from the computer scientific perspective, has splintered in many directions, with scholars pursuing very different lines of research: judgment aggregation and logic, judgment aggregation and complexity theory, judgment aggregation and relations to preference aggregation, judgment aggregation and belief merging, judgment aggregation and argumentation, to mention a few. At the same time work in judgment aggregation has diversified in non-computer science disciplines: judgment aggregation and deliberation, judgment aggregation and strategic voting, judgment aggregation and probabilistic opinion pooling, to mention a few. Despite the common research thread, having so many disciplines involved make it difficult to keep track of the research advancements across all domains.

The goal of this Dagstuhl seminar was to give researchers across the contributing disciplines an integrated overview of the current research and interests in judgment aggregation and of its emerging trends, and by doing this, to kick-start a lasting interdisciplinary network bridging the computer science/humanities divide in the field. To accomplish this goal, we structured the seminar around four types of events:

- Invited tutorials – three invited overview talks aimed to introduce the interdisciplinary audience to the origins and advancements of judgment aggregation in law, political science and computer science.
- Contributed talks – fourteen contributed talks of thirty minutes each.
- Networking sessions – two free networking sessions.
- Rump session – open to all participants to present new ideas.

The topics of the invited talks were chosen so as to give a foundation of the disciplines in which judgment aggregation originated and was formalised, as well as to motivate the interest of judgment aggregation for computer science. Although we expected that all of the participants would be familiar with at least one of these foundational topics, we also expected them to be unfamiliar with at least one as well. The tutorial lectures aimed to homogenise the background knowledge in judgment aggregation among the participants.

The contributed talks aimed to introduce the community with the recent work of the speakers. We accommodated fourteen talks, possibly compromising on the length of the talk itself in the interest of allowing space for questions. We are happy to observe that there was a lively debate after each of the talks, which we expect shall contribute towards advancement of each of the presented works.

Given the short period of three days and prior Dagstuhl experience of the organisers, we decided to not structure the networking session and simply allow for a time for the participants to talk to each other and get to know about each other's work and interests. The enthusiastic discussions following the contributed talks typically continued into the networking sessions.

The rump session was free for a last-minute sign up to all participants. Each interested person was given a five-minute time slot to present an idea that emerged during the seminar or a work in progress. A third of the participants took this opportunity to present. This was a very lively and well received part of the seminar. In retrospect, a similar session would have been well received also at the beginning of the seminar, giving the participants more time to discuss the presented ideas.

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3 Invited Tutorials

3.1 Judgment Aggregation on Common Law Courts

Lewis A. Kornhauser (New York University, US)

Common law courts develop legal rules through the adjudication of specific controversies by collegial courts. These courts decide the case before them but, also, develop over time a complex of legal rules, structured around doctrine. The process of rule emergence differs across common law legal systems. In the majoritarian process of the United States, the court aggregates judgments across both doctrinal issues and case outcomes. As is well-known, these two aggregations may, and sometimes do, conflict. How should a court resolve this conflict? A common law process naturally suggests itself to a common law court; that process proceeds incrementally. It considers the context, the dispute in which the conflict arises, and balances the reasons that weigh in favour of each procedure.

3.2 Judgment Aggregation and Social Choice Theory

Christian List (London School of Economics, UK)

This talk provided an introductory review of the theory of judgment aggregation in relation to three classic impossibility findings from social choice theory: Arrow's impossibility theorem about pairwise independent aggregation, the Gibbard-Satterthwaite theorem about non-manipulable aggregation, and Sen's theorem about respecting rights. The talk introduced the paradoxes of majority voting that originally motivated the field, and proceeded to show how some of the well-known problems of social choice theory re-emerge in the context of judgment aggregation. The aim was to familiarise participants whose background is in computer science with the theory of judgment aggregation and its broader social-choice-theoretic context.

3.3 Judgment Aggregation and Artificial Intelligence

Jérôme Lang (University Paris Dauphine, FR)

This talk provided an overview of the possible interest of Artificial Intelligence in judgment aggregation and vice versa, as well as an overview of work in judgment aggregation done from the computer science perspective. Judgment aggregation can be seen as having in its crux the problem of resolving inconsistencies: between individual majorities, as well as between the judgment set supported by the majority and the logic relation among the issues on which the judgments are cast. A significant part of the research in Artificial Intelligence and logic is about resolving inconsistencies (of various kinds): nonmonotonic reasoning, belief revision and belief merging, reasoning about action and change, paraconsistency, inconsistency debugging,

etc. Applying judgment aggregation to various fields of AI (and beyond) makes sense to problems where aggregating information may lead to conflicts that we have to resolve, such as argumentation, situation assessment in multiagent systems, crowdsourcing and collective annotation of linguistic resources, merging ontologies etc. While the interest in judgment aggregation from the perspective of law, economics, political science and mathematics is focused on identifying inconsistencies among properties of judgement aggregation functions and characterisation of functions, from a computer science perspective, the focus is more on the engineering aspects of judgment aggregation, namely how can judgments be aggregated, how computationally efficient and scalable are the methods used for this purpose.

4 Overview of Talks

4.1 Judgment Aggregation in Multi-Agent Argumentation

Edmond Awad (Masdar Institute – Abu Dhabi, AE)

Joint work of Awad Edmond, Richard Booth, Fernando Tohmé, Iyad Rahwan

Given a set of conflicting arguments, there can exist multiple plausible opinions about which arguments should be accepted, rejected, or deemed undecided. We study the problem of how multiple such judgments can be aggregated. We define the problem by adapting various classical social- choice-theoretic properties for the argumentation domain. We show that while argument-wise plurality voting satisfies many properties, it fails to guarantee the collective rationality of the outcome, and struggles with ties. We then show more general results, proving multiple impossibility results on the existence of any good aggregation operator. Moreover, we study whether restricting the domain of argument-wise plurality voting to classical semantics allows us to escape the impossibility result. Finally, we list graph-theoretic restrictions under which argument-wise plurality rule does produce collectively rational outcomes. In addition to identifying fundamental barriers to collective argument evaluation, our results open up the door for a new research agenda for the argumentation and computational social choice communities.

4.2 Complexity of Manipulation, Bribery, and Control in Judgment Aggregation for Premise-Based Quota Rules

Dorothea Baumeister (Heinrich-Heine-Universit at D usseldorf, DE)

Joint work of Baumeister, Dorothea; Erdélyi, Gábor; Erdélyi, Olivia; Rothe, Jörg
Main reference D. Baumeister, G. Erdélyi, O. J. Erdélyi, J. Rothe, "Computational Aspects of Manipulation and Control in Judgment Aggregation," in Proc. of the 3rd Int'l Conf. on Algorithmic Decision Theory, LNCS, Vol. 8176, pp. 71–85, Springer, 2013.
URL http://dx.doi.org/10.1007/978-3-642-41575-3_6

Endriss et al. [1] initiated the complexity-theoretic study of problems related to judgment aggregation. We extend their results for manipulating two specific judgment aggregation procedures to a whole class of such procedures, namely to uniform premise-based quota rules. In addition, we consider incomplete judgment sets and the notions of top-respecting

and closeness-respecting preferences introduced by Dietrich and List [2]. This complements previous work on the complexity of manipulation in judgment aggregation that focused on Hamming-distance-induced preferences only, which we also study here. Furthermore, inspired by work on bribery and control in voting [3] we introduce and study the closely related issues of bribery and control in judgment aggregation.

References

1 U. Endriss, U. Grandi, and D. Porello. Complexity of judgment aggregation. Journal of Artificial Intelligence Research, 45, 481–514, 2012.
2 F. Dietrich and C. List. Strategy-proof judgment aggregation. Economics and Philosophy, 23(3):269-300, 2007.
3 J. Bartholdi III, C. Tovey, and M. Trick. How hard is it to control an election? Mathematical and Computer Modelling, 16(8/9):2740, 1992.

4.3 Binary Aggregation by Selection of the Most Representative Voter

Umberto Grandi (University of Padova, IT)

Joint work of Grandi, Umberto; Endriss, Ulle
Main reference U. Endriss, U. Grandi, "Binary Aggregation by Selection of the Most Representative Voter," in Proc. of the 28th AAAI Conf. on Artificial Intelligence (AAAI'14), pp. 668–674, AAAI Press, 2014.
URL http://www.aaai.org/ocs/index.php/AAAI/AAAI14/paper/view/8272

In binary aggregation, each member of a group expresses yes/no choices regarding several correlated issues and we need to decide on a collective choice that accurately reflects the views of the group. A good collective choice will minimise the distance to each of the individual choices, but using such a distance-based aggregation rule is computationally intractable. Instead, we explore a class of low complexity aggregation rules that select the most representative voter in any given situation and return that voter's choice as the outcome.

4.4 Model-Theoretic and Universal-Algebraic Accounts of Aggregation

Frederik S. Herzberg (Universität Bielefeld, DE)

Main reference F. Herzberg, "Aggregating infinitely many probability measures," Theory and Decision, published online March 2014.
URL http://dx.doi.org/10.1007/s11238-014-9424-5

This paper explores the recent use of model theory and universal algebra in the theories of judgement aggregation and probabilistic opinion pooling. We review the model-theoretic approach to judgement aggregation and its potential for applications. Aggregators satisfying Arrovian responsiveness axioms on sufficiently rich agendas turn out to be restricted ultraproduct constructions, generalising an earlier result by Lauwers and van Liedekerke [1]. Ultraproduct constructions are also useful in the extension of McConway's theory of probabilistic opinion pooling [2] to the case of infinite profiles of probability measures. Dietrich and List [3] have proposed a theory of propositional-attitude aggregation, which unifies both

judgement aggregation and probabilistic opinion pooling. We prove a one-to-one correspondence between aggregators satisfying Arrovian responsiveness axioms (on sufficiently rich agendas) and MV-algebra homomorphisms.

References

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3 Dietrich, F. and List, C. (2010). The aggregation of propositional attitudes: Towards a general theory. volume 3 of Oxford Studies in Epistemology, pages 215–234. Oxford University Press, Oxford.

4.5 Two Theories of Logical Aggregation: On the Links between Belief Merging and Judgment Aggregation

Sébastien Konieczny (Artois University – Lens, FR)

Joint work of Everaere, Patricia; Konieczny, Sebastien; Marquis, Pierre
Main reference P. Everaere, S. Konieczny, P. Marquis, "Counting votes for aggregating judgments," in Proc. of the 2014 International Conf. on Autonomous Agents and Multi-agent Systems (AAMAS'14), pp. 1177–1184, Int'l Foundation for Autonomous Agents and Multiagent Systems, 2014.
URL http://dl.acm.org/citation.cfm?id=2617388.2617436

There are two theories of aggregation of logical formulas. The first one, merging, has been developed in AI as an extension of belief revision. The second one, judgment aggregation, has been introduced by works in political philosophy and social choice theory. In this work we investigate the links between these two theories both in the general case and in the fully informed case (where the agenda contains all the possible interpretations). This allows us to illustrate the correspondences or incompatibilities between the rationality properties proposed in these two theories.

4.6 A Collective Argument Dilemma as Judgement Aggregation

Yixi Li (Sun Yat-sen University – Guangzhou, CN)

The legal provisions always show various degrees of acceptability. Despite the difficulty of describing the acceptability of a legal provision, it is commonly agreed that a legal provision is unacceptable if it is against some rules. We have described a Legislative Dilemma where neither of two contradictory behaviours leads to a breach of a legal provision. In other words, if one behaviour is the purpose of a legal provision, the justification of the other contradictory behaviour means the unacceptability of this legal provision.

4.7 The max-min Method for Judgment Aggregation

Xavier Mora (Autonomus University of Barcelona, ES)

Joint work of Mora, Xavier; Camps, Rosa; Saumell, Laia
Main reference R. Camps, X. Mora, L. Saumell, "A general method for deciding about logically constrained issues," Annals of Mathematics and Artificial Intelligence, 64(1):39–72, 2012.
URL http://dx.doi.org/10.1007/s10472-012-9292-z

We discussed the general method of judgment aggregation that we introduced in [1]. This method can be seen as a maximin procedure for revising a system of (collective) degrees of belief in accordance with the existing logical constraints and for arriving at a decision that complies with these constraints. We looked at the main idea of this method, its advantages and limitations, and its application to a variety of examples (some of which are dealt with in [2]).

The main idea of the revision procedure is using the logical constraints in all possible ways to derive belief on every issue. This is done in accordance with the so-called peiorem principle. Belief is derived separately in favour and against each issue. Decisions are taken by the balance of belief.

The advantages of this method include: a quite general character, ability to deal with incomplete information, respect for consistent majority decisions, respect for unanimity on an issue, a property of monotonicity, decisions are robust under small perturbations, decisions have a quantified degree of confidence.

Its limitations are concerned with: complexity depending on the constraints, constraints must be checked for a certain condition to guarantee that decisions are unquestionable.

Its applications include: preferential voting, preferential-approval voting, other social-choice procedures, aggregation of equivalence relations (cluster analysis).

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2 R. Camps, X. Mora, L. Saumell, 2014. Social choice rules driven by propositional logic. Ann. Math. Artif. Intell. 70: 279–312.

4.8 Complexity of Optimal Lobbying in Threshold Aggregation

Ilan Nehama (The Hebrew University of Jerusalem, IL)

Main reference I. Nehama, "Complexity of optimal lobbying in threshold aggregation," in Proc. of the 2013 Int'l Conf. on Autonomous Agents and Multi-agent Systems, pp. 1197–1198, Int'l Foundation for Autonomous Agents and Multiagent Systems, 2013.
URL http://dl.acm.org/citation.cfm?id=2485140

Optimal Lobbying is the problem a lobbyist or a campaign manager faces in a full-information voting scenario of a multi-issue referendum when trying to influence the result. The Lobby is faced with a profile that specifies for each voter and each issue whether the voter approves or rejects the issue, and seeks to find the smallest set of voters it must influence to change their vote, for a desired outcome to be obtained. This computational problem also describes problems arising in other scenarios of aggregating complex opinions, such as principal-agents incentives scheme in a complex combinatorial problem, and bribery and manipulation

in Truth-Functional Judgement Aggregation. We study the computational complexity of Optimal Lobbying when the issues are aggregated using an anonymous monotone function and the family of desired outcomes is an upward-closed family. We analyse this problem with regard to two parameters: the minimal number of supporters needed to pass an issue, and the size of the maximal minterm of the desired set. We show that for the extreme values of the parameters, the problem is tractable, and provide algorithms. On the other hand, we prove intractability of the problem for the non-extremal values, which are common values for the parameters.

4.9 Weighing Experts, Weighing Sources: The Diversity Value

Klaus Nehring (University of California – Davis, US)

Joint work of Nehring, Klaus; Guerdjikova, Ani

A decision maker has to come up with an aggregate judgment based on the individual opinions submitted by a set of information sources. Provided that the decision maker is committed to an aggregation rule expressed as a weighted average, how should he determine the weight assigned to each source? We consider this problem, when the decision maker has an assessment of the reliability of each subset of sources given by a reliability function. Reliability functions are assumed to have the properties of diversity functions in the sense of Nehring and Puppe (2002). In particular, non- additive reliability functions capture perceptions of similarity between sources We propose a rule called the Diversity value, which associates with each reliability function a (set of) weight vector(s). The Diversity value selects those weights which best approximate the relative reliability of sources in the sense of a generalised Kullback-Leibler distance. Notably, the Diversity value obeys the Similarity Principle which requires that larger weights should be assigned to sources which are viewed as more distinct. We provide an axiomatisation of the Diversity value. We discuss its aggregation properties and show that a version of the No-Show Paradox and violations of Reinforcement are typical features of the model.

4.10 The Median Rule in Judgement Aggregation

Marcus Pivato (Trent University, CA)

Joint work of Pivato, Marcus; Nehring, Klaus

Let K be a set of logically interconnected propositions or "issues". A "view" is an assignment of a truth-value to each issue in K. However, not all views are admissible; some may violate the logical relationships between the different issues in K. A "judgement aggregation rule" is a function which takes a collection of admissible views as input, and produces an admissible view as output.

As is well-known, the "majority" rule (which simply agrees with the majority on each issue) often yields logically inconsistent views. This raises the question: which (consistent) judgement aggregation rule is the "best approximation" of the majority view? We propose

that the "median rule" fits this description. The median rule chooses the admissible view which minimizes the average Hamming distance to the views of the voters. In the special case of preference aggregation, it becomes the Kemeny rule.

We axiomatically characterise the median rule as the only judgement aggregation rule satisfying three axioms: Extended Supermajority Efficiency, Reinforcement, and Upper Hemicontinuity. "Supermajority efficiency" means (roughly) that the rule tries to agree with the majority view in as many issues as possible; furthermore, if it can only agree with a majority in one out of two issues, it will choose the larger majority. "Extended supermajority efficiency" extends this principle to the case where the rule is applied to solve many aggregation problems simultaneously. "Reinforcement" means that, if two subpopulations independently choose the same view using the rule, then the combined population should also choose this view using this rule. "Upper hemicontinuity" means that the outcome is invariant under small perturbations; equivalently, it means that an outcome reflecting the will of an "overwhelming majority" of voters cannot be changed by a small minority.

After precisely stating the above result, we discussed some other axiomatic characterisations of the median rule, and other judgement aggregation rules which generalise it.

4.11 Modelling Collective Rationality in Non-Classical Logics. A Possibility Result

Daniele Porello (Italian National Research Council – Trento, IT)

Main reference D. Porello, "A proof-theoretical view of collective rationality," in Proc. of the 23rd Int'l Joint Conf. on Artificial Intelligence (IJCAI'13), pp. 317–323, AAAI Press, 2013.
URL http://dl.acm.org/citation.cfm?id=2540128.2540175

The notion of collective rationality in judgment aggregation is mainly modelled by means of classical propositional logic. In this work, we adapt the model of judgment aggregation in order to account for a number of definitions of collective rationality grounded on a number of non-classical logics. We extend therefore the map of possibility and impossibility results in judgement aggregation to non-classical logics. In particular, we show that there are logics for which the majority rule always returns rational outcomes. Finally, we discuss how the choice of a logic determines the epistemic commitments that we expect from collective agents and we argue in favour of a weaker non-classical view of collective rationality.

4.12 Unanimity Overruled: Majority Voting and the Burden of History

Clemens Puppe (KIT – Karlsruher Institut für Technologie, DE)

Sequential majority voting over interconnected binary propositions can lead to the overruling of unanimous consensus. We characterise, within the general framework of judgement aggregation, under what circumstances this happens for some sequence of the voting process. It turns out that the class of aggregation spaces for which this difficulty arises is very large, including the aggregation of preference orderings over at least four alternatives, the

aggregation of equivalence relations over at least four objects, resource allocation problems, and most committee selection problems.

We also ask whether it is possible to design respect for unanimity by choosing appropriate decision sequences. Remarkably, while this is not possible in general, it can be accomplished in interesting special cases. Adapting and generalising a classic result by Shepsle and Weingast, we show that respect for unanimity can indeed be thus guaranteed in case of the aggregation of weak orderings, strict orderings and equivalence relations.

4.13 Pre-Vote Negotiations

Paolo Turrini (Imperial College London, GB)

Joint work of Grandi, Umberto; Grossi, Davide; Turrini, Paolo

Main reference U. Grandi, D. Grossi, P. Turrini, "Pre-vote negotiations and binary voting with constraints," arXiv:1404.5433v1 [cs.GT], 2014.
URL http://arxiv.org/abs/1404.5433v1

This talk was about voting games on possibly interconnected issues, where voters might hold a principled opinion about a subset of the issues at stake while willing to strike deals on the remaining ones, and can influence one another before casting their ballots in order to obtain an individually more favourable outcome. The authors analyse voters' rational behaviour in a two-phase game, allowing players to undergo a negotiation phase before their vote, and showing under what conditions undesirable equilibria can be removed as an effect of the pre-vote phase.

4.14 Universal and Symmetric Scoring Rules for Binary Relations

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

Are Plurality voting, the Kemeny rule, Approval voting, and the Borda Mean Dichotomy rule actually all versions of the same voting rule? Yes, in a sense. We consider functions F that assign real number scoring weights $F(R_1, R_2)$ to pairs of binary relations on a finite set A of alternatives, serving as symmetric measures of similarity between R_1 and R_2. Any such F induces a symmetric binary relational scoring rule F – a highly abstract form of aggregation rule that allows arbitrary binary relations as ballots R_1 and as aggregated outcomes R_2. The resulting level of generality is surprisingly effective. By restricting the classes of relations allowed as ballots and elections outcomes, F yields scoring rules of a more familiar and concrete kind. The symmetric assignment FH, for example, arises from an inner product in a simple and natural way, and restrictions of the induced scoring rule script-FH yield all the aforementioned familiar voting rules. Moreover, the inner product formulation yields a Euclidean form of distance rationalisation for script-FH, resulting in a universal distance rationalisation for all concrete scoring rules obtained as restrictions.

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