Computational Social Choice 2022

Ulle Endriss

Institute for Logic, Language and Computation

University of Amsterdam

[http://www.illc.uva.nl/~ulle/teaching/comsoc/2022/]

Review: Judgment Aggregation

We have had eight lectures on judgment aggregation. A good part of the material is covered in the two expository papers cited below.

Let us briefly recall the main ideas . . .

C. List. The Theory of Judgment Aggregation: An Introductory Review. *Synthese*, 2012.

U. Endriss. Judgment Aggregation. In F. Brandt *et al.* (eds.), *Handbook of Computational Social Choice*. Cambridge University Press, 2016.

Formal Models

We used two closely related formal models:

- *Formula-based judgment aggregation*

  - Need to accept/reject pairs of formulas in agenda
  - Rationality defined in terms of logical consistency

- *Binary aggregation with integrity constraints*

  - Need to accept/reject issues (no internal structure)
  - Rationality stated explicitly in terms of integrity constraints

Which is better depends on context. Also possible to combine the two.

Extension: *rationality/input* and *feasibility/output constraints*

Aggregation Rules

We saw a number of different approaches to defining aggregation rules:

- Majority rule, (uniform) quota rules

- Premise-based rules (for different choices of premises)

- Conclusion-based rule (only discussed for the doctrinal paradox)

- Optimisation rules (highly complex): Kemeny, Slater

Only rules in the latter group can guarantee *collective rationality*.

Not discussed in any detail: how to *break ties*.

Application Scenarios

We focused on JA in the abstract, but it can be used to model various forms of collective decision making:

- decision making in judicial courts
- decision making by experts
- coordination and decision making in multiagent systems
- collective annotation via crowdsourcing
- embedding of preference aggregation into JA is possible

The latter allows importing ideas from voting theory, a much more mature area of research.

Methodology: Philosophical Perspective

We did not emphasise this point very much in the course, but each of the axioms constraining "reasonable" rules that we considered can and should be argued for on normative grounds:

- nondictatoriality
- anonymity
- neutrality
- independence
- monotonicity
- unanimity
- strategyproofness
- …

Methodology: Mathematical Perspective

Our main mathematical tool has been the *axiomatic method*.

Types of results (about axioms only):

- *Characterisation* of rules: quota rules, majority rule

Types of results (about interaction with rationality requirements):

- *Impossibility* results: some combinations of axioms are impossible to achieve (for sufficiently rich agendas)

- *Safety* results (universal agenda characterisation): all rules satisfying certain axioms are collectively rational for sufficiently poor agendas

- Existential *agenda characterisation:* there exists a rule satisfying certain axioms that is collectively rational *iff* the agenda is sufficiently poor

Methodology: Computational Perspective

Considering aggregation as an algorithmic problem, we analysed the computational complexity of determining the outcome for several aggregation rules (*outcome determination problem*):

- Easy: quota rules (low polynomial)
- Hard: Kemeny rule (complete for parallel access to NP)
- Depends: premise-based rules (depends on restrictions to agenda)

Also other problems arising in JA require algorithms:

- Checking *safety*: highly intractable (e.g., for the majority rule)
- Strategic *manipulation:* NP-hard for the premise-based rule
- Various forms of *bribery* and *control*

Complexity classes seen: P, NP, coNP, $\Theta_2^p = \mathsf{P}_{||}^{\mathsf{NP}}$, $\Pi_2^p = \mathsf{coNP}^{\mathsf{NP}}$

Not discussed, but important: practical *algorithms* for all of this

Methodology: Game-Theoretical Perspective

The lecture on strategic behaviour in judgment aggregation hinted at connections to game theory and mechanism design:

- Agents may lie when reporting their judgment
- Question of how to best model individual *preferences*
- *Strategyproofness* possible, but rare for attractive rules

Methodology: Probabilistic Perspective

We have been very brief on this, but it is clear that in principle JA can be interpreted as a means for *truth-tracking* (epistemic approach).

To do so we can use probabilistic methods to estimate the most likely ground truth given the observed opinions of the agents.

Literature still sparse. Two examples cited below.

S. Hartmann and J. Springer. Judgment Aggregation and the Problem of Tracking the Truth. *Synthese*, 2012.

Z. Terzopoulou and U. Endriss. Optimal Truth-Tracking Rules for the Aggregation of Incomplete Judgments. SAGT-2019.

Methodology: Logical Perspective

We only worked with *classical propositional logic* in this course, but generalisations to *other logics* are possible and potentially interesting.

Two examples cited below.

F. Dietrich. A Generalised Model of Judgment Aggregation. *Social Choice and Welfare*, 2007.

D. Porello. A Proof-Theoretical View of Collective Rationality. IJCAI-2013.

Conclusion

This concludes the lectures on judgment aggregation.

- Young research area: while there have been a couple of precursors in the literature, the field is really only about two decades old.
  - Still possible to get a good global view of the field.
  - Clear opportunities for making original contributions yourself.

- Methods used in JA reflect use of methods more widely in computational social choice.