Making Choices

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The ILLC

The ILLC (the Institute for Logic, Language and Computation), is an interdisciplinary research institute that belongs to both the Faculty of Science and the Faculty of Humanities.

Besides logic, ILLC research touches on a range of disciplines:

- Mathematics
- Computer Science and Artificial Intelligence
- Linguistics and Computational Linguistics
- Philosophy
- Cognitive Science

Recent work also addresses problems coming from Economics and Politics: e.g., Game Theory, *Social Choice Theory*, ...

Aggregation of Individual Rankings

Expert 1: $\triangle \succ \bigcirc \succ \square$

Expert 2: $\bigcirc \succ \square \succ \triangle$

Expert 3: $\square \succ \triangle \succ \bigcirc$

Expert 4: $\square \succ \triangle \succ \bigcirc$

Expert 5: $\bigcirc \succ \square \succ \triangle$

$?$

Aggregation of Individual Judgments

	p	$p \rightarrow q$	q
Judge 1:	True	True	True
Judge 2:	True	False	False
Judge 3:	False	True	False
	?		

Aggregation of Votes in a Referendum

	fund museum?	*fund school?*	*fund metro?*
Voter 1:	Yes	Yes	No
Voter 2:	Yes	No	Yes
Voter 3:	No	Yes	Yes
	?		

Constraint: we have money for *at most two projects*

Binary Aggregation

The last example is actually pretty general. We can rephrase many aggregation problems as problems of *binary aggregation:*

Do you rank option $\square$ *above option* $\triangle$*?*	Yes/No
Do you believe formula "$p \to q$*" is true?*	Yes/No
Do you want the new school to get funded?	Yes/No

Each problem domain comes with its own *rationality constraints:*

Rankings should be transitive and not have any cycles.

The accepted set of formulas should be logically consistent.

We should fund at most two projects.

The *paradoxes* we have seen show that the *majority rule* does not *lift* our rationality constraints from the *individual* to the *collective* level.

- Which aggregation rules lift which rationality constraints?

The Axiomatic Method

- Pioneered by Kenneth J. Arrow (Nobel Prize Economics, 1972).
- Examples for "*axioms*" (= desirable properties of aggregators):
  - **Anonymity:** outcomes should be invariant under permutations of the voters
  - **Unanimity:** if all voters agree on X, then X should also be adopted for the social choice
  - **Independence:** the social choice regarding X should only depend on the individual choices regarding X
- Axioms can be used to *characterise* (classes of) aggregation rules.

Lifting Rationality Constraints

In our work we try to understand the connections between

- the (logical) *language* required to express *rationality constraints*
  e.g., full propositional logic can express $\neg(\texttt{museum} \wedge \texttt{school} \wedge \texttt{metro})$
- the *axioms* characterising the aggregation rule,
  e.g., *unanimity*, *independence*, ...

An example for the type of result we can obtain:

> **Theorem 1 (Grandi and E., 2010)** *An aggregation rule F will lift all rationality constraints expressible as a conjunction of literals if and only if F satisfies the unanimity axiom.*

Last Slide

This was an example for work in *Computational Social Choice*, the application of tools from algorithmics, complexity theory, logic, knowledge representation, etc. to problems of social choice.

For an introduction to the field, consult our paper in the *AI Magazine*. For the technical results on lifting rationality constraints, consult the paper with Umberto Grandi. Both are available from my website:

http://www.illc.uva.nl/~ulle/pubs/

Y. Chevaleyre, U. Endriss, J. Lang, and N. Maudet. Preference Handling in Combinatorial Domains: From AI to Social Choice. *AI Magazine*, 29(4):37–46, 2008.

U. Grandi and U. Endriss. Lifting Rationality Assumptions in Binary Aggregation. *Proc. 24th AAAI Conf. on Artificial Intelligence (AAAI-2010)*, AAAI Press, 2010.