Designing Participatory Budgeting Mechanisms Grounded in Judgment Aggregation

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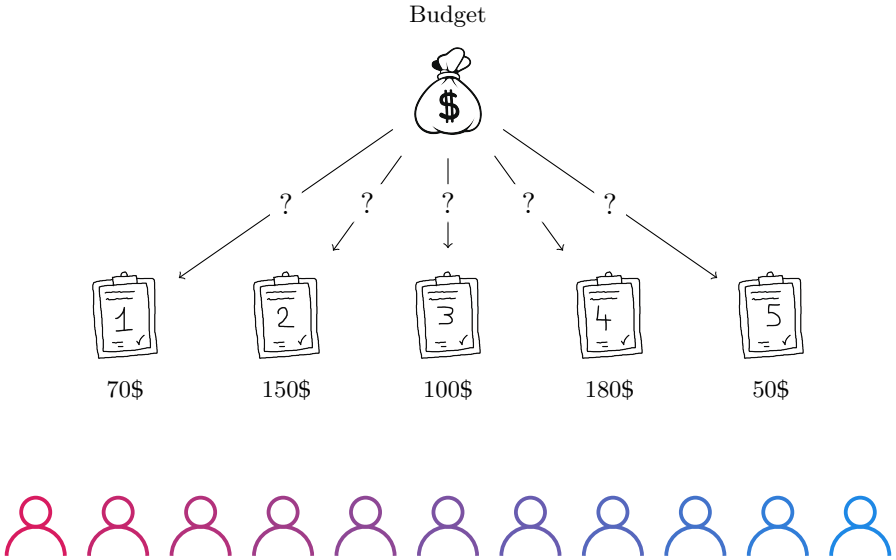
Participatory Budgeting



Our Approach to Participatory Budgeting

Two facts about the study of participatory budgeting in (computational) social choice:

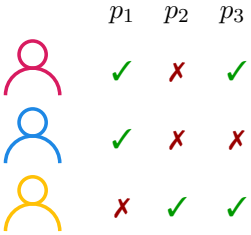
- It is based on generalizing multiwinner voting;
- It requires to redefine everything for every new feature added to the based model.

Instead of generalizing existing frameworks, can we consider participatory budgeting as a restriction of some expressive framework that conserves nice properties?

Judgment Aggregation or Binary Aggregation

Judgment aggregation is an expressive aggregation framework where binary decisions are to be made over a set of issues:

- There is a set of issues;
- Agents submit approval ballots over this set;
- Using a judgment aggregation rule, an outcome is determined based on the ballots;
- The outcome must satisfy an integrity constraint over the issues.



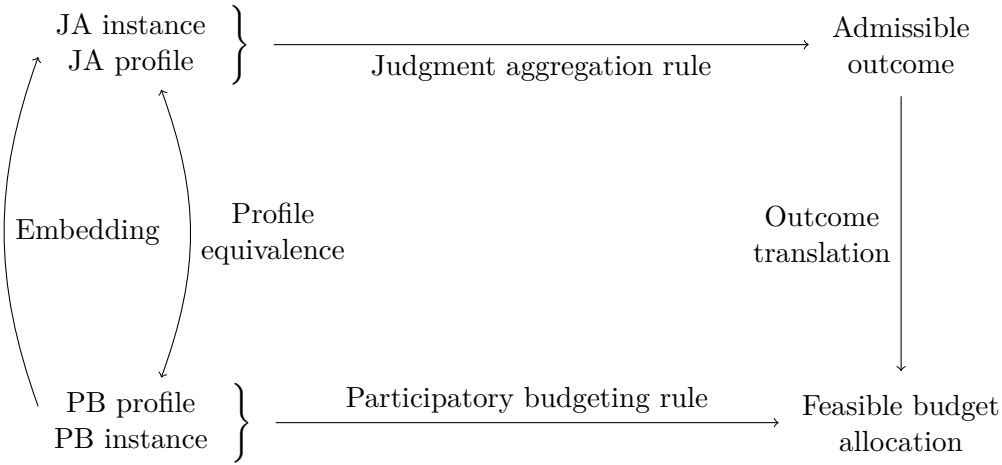
Assume the following constraint:

$$\Gamma = (p_1 \to \neg p_3) \wedge (p_2 \to \neg p_3)$$

The admissible outcomes are then:

$$\emptyset \qquad p_1 \qquad p_2 \qquad p_3 \qquad p_1, p_2$$

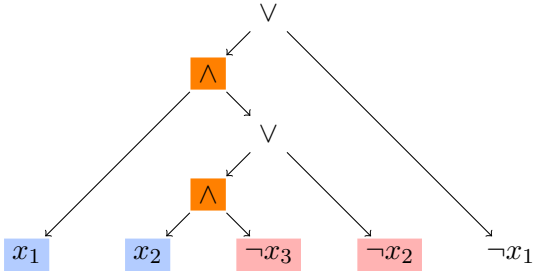
Overall Idea of the Embedding



The Main Pitfall: Computational Complexity

Problem: computing the outcome of judgment aggregation rules usually is Θ_2^P-complete.

↪ But not when the integrity constraint is represented as a *DNNF circuit*.



De Haan "Hunting for Tractable Languages for Judgment Aggregation" *KR* (2018)

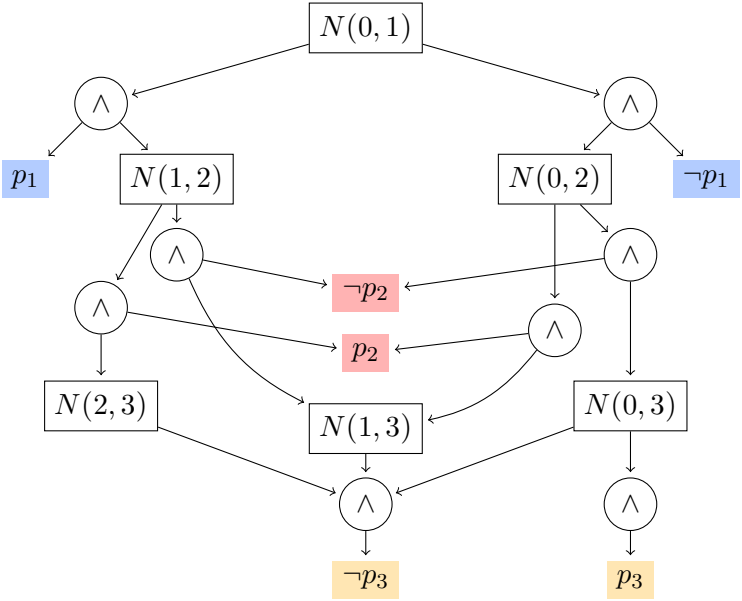
Encoding Participatory Budgeting into DNNF Circuits

$B = 2$

$c = 1$

$c = 1$

$c = 2$



Easily Extending the Framework

Our approach allows for great flexibility. Our basic PB setting extends the usual one on two points: We work with *several resources* and with *irresolute rules*.

Moreover, adding extra constraints can easily be done and only requires redefining the proper embedding into DNNF circuits. We give two examples:

- *Dependencies between projects*: whether some projects can be selected depends on the status of, potentially several, other projects;
- *Quotas over categories of projects*: projects are gathered in some categories and there are upper and lower bounds on what can be accepted from each category.

In both cases, deciding whether there is a feasible budget allocation is *NP-complete*. However, we provide *parameterized embeddings* that can be used in these extending settings.

Exhaustiveness

Because of the way negation is handled in judgment aggregation, all JA rules fail the main requirement of exhaustiveness.

A participatory budgeting rule is *exhaustive* if there is no project that has not been selected but that could be funded with the leftover money.

We propose two ways of overcoming that:

- Hard-coding exhaustiveness in the constraint (only tractable for one resource);
- Introducing asymmetric judgment aggregation rules that treats positive and negative literals differently:

$$F_{asy}(\Gamma, \boldsymbol{A}) = \underset{\text{Admissible } J}{\operatorname{argmax}} \sum_{\substack{\ell \in J \\ \ell \text{ is positive}}} f(\boldsymbol{A}, \ell) + \epsilon$$

Monotonicity Axioms for Participatory Budgeting

Other axioms for participatory budgeting can also be studied for JA rules. Asymmetric rules overall behave similarly to known rules for PB on monotonicity axioms.

	Kemeny rule		Slater rule		Leximax rule	
	Usual	Asymmetric	Usual	Asymmetric	Usual	Asymmetric
Exhaustiveness	✗	✓	✗	✓	✗	✓
Limit Monotonicity	✗	✗	✗	✗	✗	✗
Discount Monotonicity	✓	✓	✓	✓	✓	✓
Splitting Monotonicity	✗	✓	✗	✓	✗	✓
Merging Monotonicity	✗	✗	✗	✗	✗	✗

We extended these axioms to irresolute rules (universal extension).

Talmon and Faliszewski "A framework for approval-based budgeting methods" *AAAI* (2019)

Conclusion

We presented how participatory budgeting can be embedded into a tractable fragment of judgment aggregation. In particular, we showed:

- An embedding for multi-resources participatory budgeting into DNNF circuits;
- More involved embeddings for instances with dependencies and/or quotas;
- How to enforce exhaustiveness on the judgment aggregation side;
- How JA rules behave with respect to other PB axioms.

On the future works side, two main ideas are worth mentioning:

- Can recent works on project interaction be approached the same way?
- Can we find some proportionality requirements for JA rules?

Simon Rey, Ulle Endriss and Ronald de Haan. *Designing Participatory Budgeting Mechanisms Grounded in Judgment Aggregation*. Proc. of the 17th International Conference on Principles of Knowledge Representation and Reasoning (KR), 2020.