Online Participatory Budgeting
How to collectively make quick decisions on funding projects ?

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A possible application: CO2 emission quota

- A lab/ company wants to respect a CO2 quota
- Collective decision on which projects to fund
- Projects are presented online (not all together)
- Representatives vote on funding current project
- Example with 3 representatives and 4 projects

Recap

project	1	2	3	emissions (T)
	No	Yes	Yes	15
	Yes	No	Yes	6
	No	Yes	Yes	9
	Yes	No	No	3

Majority and threshold rules

Majority = Threshold of 50% (accepted if more votes than the threshold)
Several drawbacks

- incomplete policy (quota of 18T)
- unfair to minorities (quota of 21T)
- not optimal (quota of 9T)

Proportionality through priceability

We can divide the budget among the voters and

- (C1) Agents contribute only to projects they approve on
- (C2) Agents contribute only to projects in π
- (C3) Agents don't pay more than b
- (C4) Projects in π receive enough contribution to be funded
- (C5) No group supporting a project p is left with more than $c(p)$

Priceability: examples

Budget of 18T $\implies$ personal budgets of 6T

,  is priceable

project	1	2	3	price
	0	0	0	15
	3	0	3	6
	0	6	3	9
	0	0	0	3

 is not priceable $(2 \times 6 < 15)$

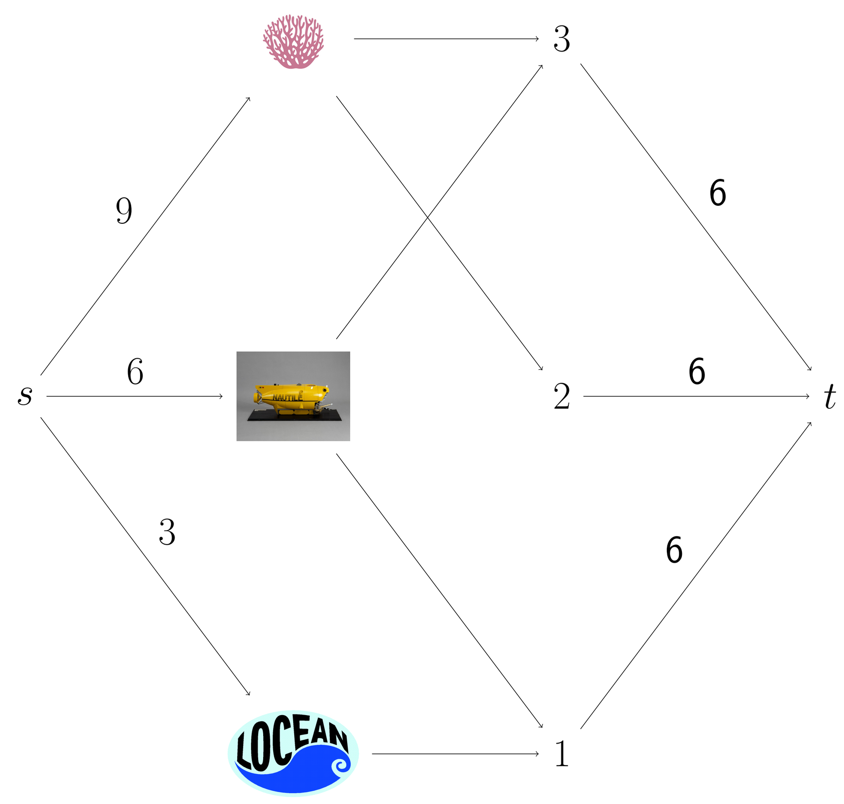
An algorithm for priceability (DO et al., 2022)
When a project is affordable by its supporters, it is selected and its price is divided between supporters.
One big drawback:

project	1	2	3	price
	0	0	0	15
	0	4.5	4.5	9
	4.5	0	1.5	6
	0	0	0	3

 cannot be afforded by 1 as he only has 1.5 left.

Strenghtening Priceability

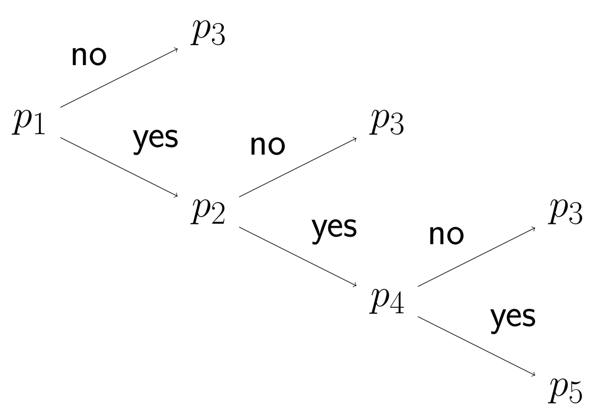
Efficient (E) priceability: priceability+ every contribution function satisfying (C1) to (C4) satisfies (C5)
New algorithm: When project p appears, if $\pi \cup \{p\}$ is priceable, p is selected and we use this price system.
We use capacity scaling algorithm, complexity $O(np^2 \log(b))$, see Ahuja and Orlin (1995)



Fair share and priceability

Local Fair Share $\simeq$ Priceability but costs are divided equally among voters
budget $b = 6T$

project	1	2	3	price
p_1	0	0	1	2
p_2	0	1	1	2
p_3	0	0	0	3
p_4	1	1	0	2
p_5	1	0	0	1



Justified Representation

Cohesiveness: For $S \subseteq N, Q \subseteq P$ if $\frac{|S|}{n} \geq \frac{c(Q)}{b}$ and $\forall i \in S, Q \subseteq A_i$
Proportionality: S is Q-cohesive, sat$_S(\pi) \geq$ sat$_S(Q)$.
Satisfaction Function: mapping from $\mathcal{P}(P)$ to $\mathbb{R}$
Different variations

- Perfect Justified Representation: sat$_S(\pi) = \min_{i \in S}$ sat$(A_i \cap \pi)$ Not always possible
- Extended Justified Representation: sat$_S(\pi) = \max_{i \in S}$ sat$(A_i \cap \pi)$
- Proportional Justified Representation: sat$_S(\pi) =$ sat$(\bigcup_{i \in S} A_i \cap \pi)$

α-Cohesiveness: For $S \subseteq N, Q \subseteq P$ if $\frac{|S|}{n} \geq \alpha \frac{c(Q)}{b}$ and $\forall i \in S, Q \subseteq A_i$
Proportionality: S is α-Q-cohesive, it deserves sat$_S(\pi) \geq$ sat$_S(Q)$ of the budget.

	JR	PJR	EJR
sat^{card}	**JR[**sat^{card}**]**	γ_b-**PJR[**sat^{card}**]**	γ_b-**EJR[**sat^{card}**]**
sat^{cost}	**2-JR[**sat^{cost}**]**	**2-PJR[**sat^{cost}**]**	τ_b-**EJR[**sat^{cost}**]**

$b/\gamma_b(\log_2(b/\gamma_b)+1) = b = \lfloor b/\tau_b H(b/\tau_b) \rfloor$
$b = 1000 \implies \gamma_b \simeq \tau_b = 8$

Ongoing: Experiments, measuring voter's satisfaction and fairness

We used pabulib (STOLICKI; SZUFA; TALMON, 2020) and pabutools (FALISZEWSKI et al., 2023)
Several measures:

- Average voter satisfaction
- Gini index of voter's satisfaction (0 $\implies$ perfect equality)
- Distance to fair Share

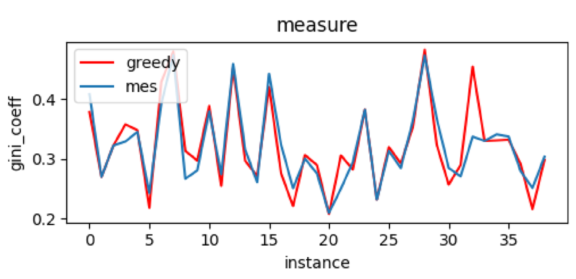


Figure 1 – Gini Index for MES(offline) and the Greedy Budgeting rule, for Amsterdam districts

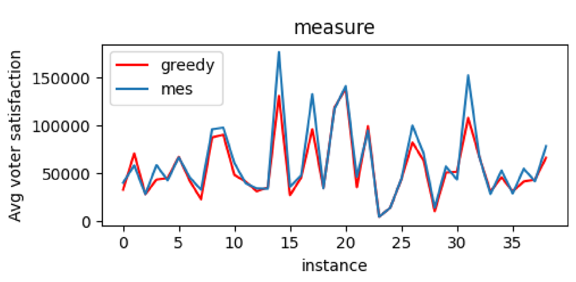


Figure 2 – Average voter satisfaction for MES(offline) and the Greedy Budgeting rule, for Amsterdam districts

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Real Application for LAMSADE: quota or tax for CO2 emissions ?

Decision under discussion in CL
Problem is different, several possible models

- Fair Allocation (CARDI; GOURVÈS; LESCA, 2021)
- Bankruptcy problem (ACOSTA; ALGABA; SÁNCHEZ-SORIANO, 2022; DURO; GIMÉNEZ-GÓMEZ; VILELLA, 2020; ZHOU; WANG, 2016)
- Next: Online claims problem ?

Classical notions: proportionality, maximin, envy-freeness, fair-share

Example: budget of 8 for 2

Claim	Agent	cost
IJCAI	PhD1	7
ECAI	PhD2	1
SAGT	PhD2	2

A porposition of a CO2 emissions tax system

Idea presented By Olivier Cailloux and Hugo Giblert in AG
Tax projects according to CO2 emissions
The tax should have some properties:

- Exceptions: Junior researchers should pay less than seniors
- Convexity: the more you pollute the more the lax increases
- Delays: One's history should vanish with time

$l_a^b = \sum_{i=0}^{a} c_i \lambda^{t_b - t_i}, \tau(v_n) = r(\alpha^{l_n^{tn}} - \alpha^{l_{n-1}^{tn}})$.
For senior researchers:

- $\lambda = \frac{\sqrt{2}}{2}$ (half-life 2 years)

For junior researchers:

- $\lambda = \frac{1}{2}$ (half-life 1 year)