# Towards Fairer Collective Decisions

## Habilitation Defense

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January, the 20th, 2025

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$$\Downarrow$$

Collective opinion, choice of an alternative...

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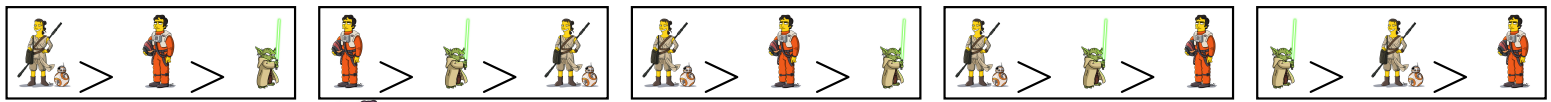





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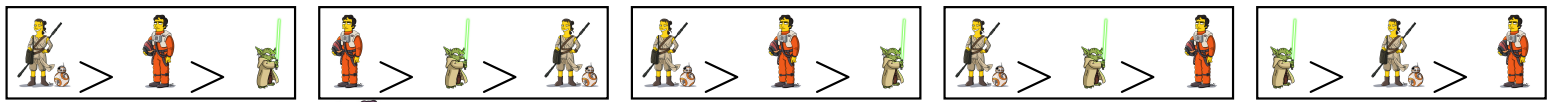


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**Applications:** political elections, middle or low-stake elections (*e.g* hire a new colleague), choose a restaurant...

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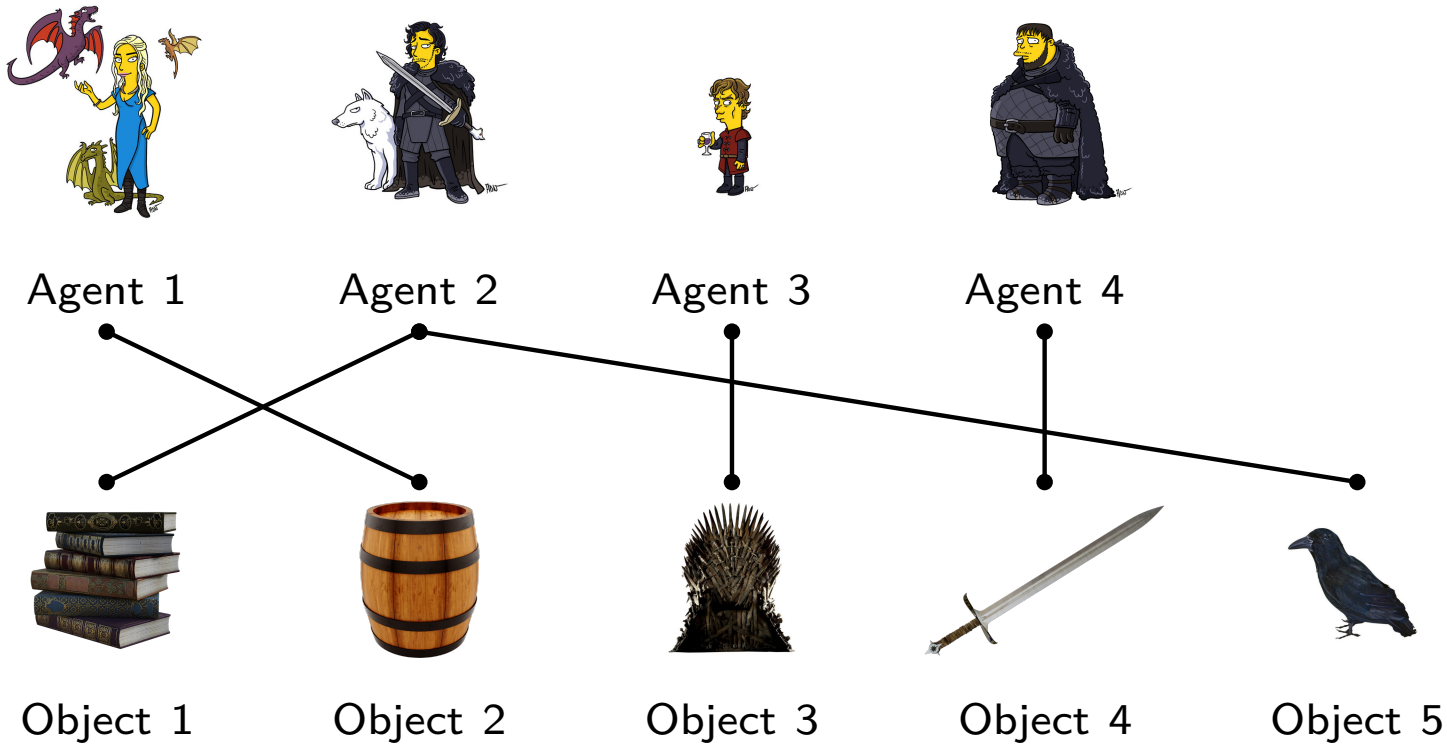

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**Applications:** dividing inheritance, allocating lab works to students, papers to reviewers, tasks to robots or machines, tasks in crowdsourcing systems...

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In this talk:

- Some of the topics I have been working on at LIG mostly **between 2011 and 2019**
- All these topics belong to the domain of **Computational Social Choice** (COMSOC) $\approx$ Social Choice Theory $\cap$ Computer Science

# Outline

1. **Fair enough: fairness beyond proportionality and envy-freeness**
2. **The unreasonable fairness of picking sequences**
3. **And the winner is... Alternative (fairer?) voting rules**

# Fair division

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## Fair enough: fairness beyond proportionality and envy-freeness

# The fair division problem

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- Each agent $a_i$ gives a score $w_i(o)$ to each object $o$
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# Two standard criteria

**Envy-freeness (EF) [Foley, 1967]**

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## Proportional share (PROP) [Steinhaus, 1948]

An allocation $\overrightarrow{\pi}$ satisfies **proportionality** if every agent gets at least $1/n^{\text{th}}$ of the total value of the objects, that is, $\forall a_i,\ u_i(\pi_i) \geq u_i(\mathcal{O})/n$.



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**Known facts:**

- $\overrightarrow{\pi}$ is EF $\Rightarrow$ $\overrightarrow{\pi}$ satisfies PROP
- An envy-free (resp. proportional) allocation may not exist
- Deciding whether an instance has an EF (resp. PROP) allocation is **NP**-complete [Lipton et al., 2004]

# Beyond EF and proportionality

Envy-free or proportional allocations are nice, but...

- (...they can be hard to compute)
- ...they do not always exist (what can we do if there are none?)
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Can we enrich the landscape of fairness properties to overcome these problems?

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**Max-min share (MmS)**

An allocation $\overrightarrow{\pi}$ satisfies **Max-min share** if
$\forall a_i,\ u_i(\pi_i) \geq \max_{\overrightarrow{\pi}} \min_{a_j \in \mathcal{A}} u_i(\pi_j)$.

# Max-min share: known facts

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# Max-min share: known facts

- $\overrightarrow{\pi}$ satisfies PROP $\Rightarrow$ $\overrightarrow{\pi}$ satisfies MmS [B. and Lemaître, AAMAS'14]
- Does an MmS allocation always exist? No! [Procaccia and Wang, 2014]
- Since then...
  - A lot of follow-up works on this question
  - Complexity of deciding whether there exists an MmS allocation: still open
  - Best approximation factor so far: $\frac{3}{4} + \frac{3}{3836}$ [Akrami and Garg, 2024]
  - In practice, an MmS allocation exists with very high probability [Kurokawa et al., 2016, Amanatidis et al., 2017]

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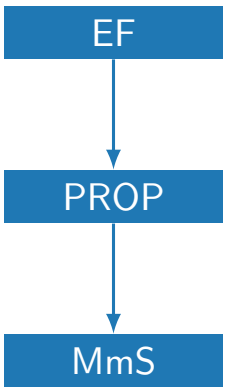

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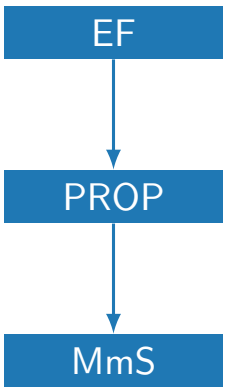


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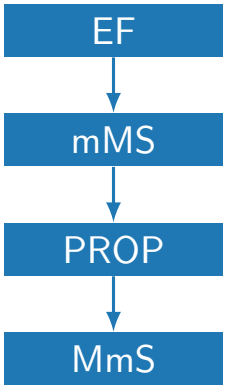


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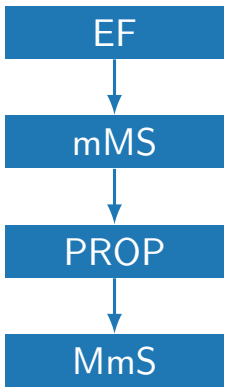


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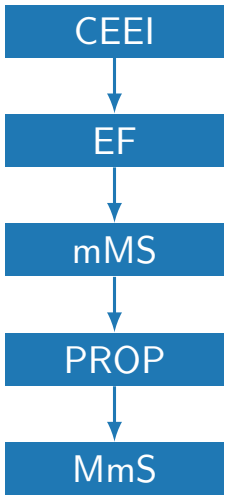


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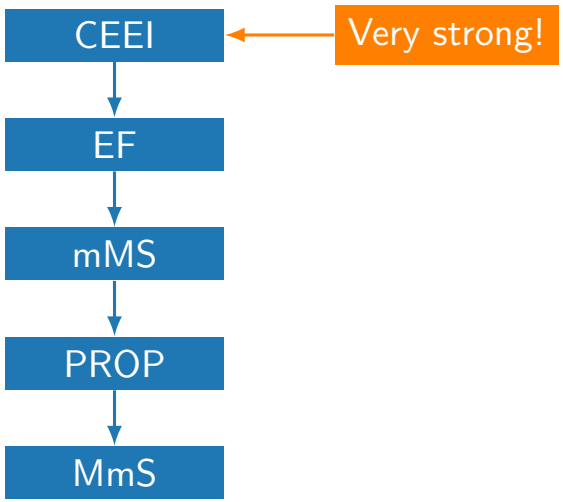


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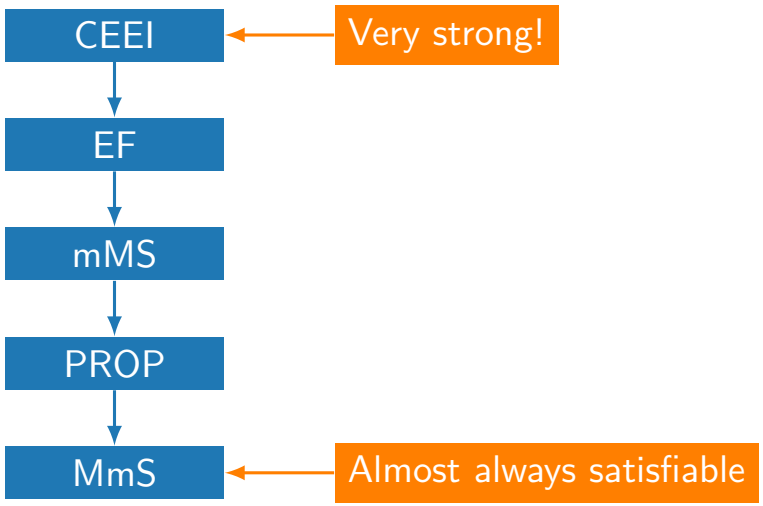


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- **envy-free up to one good** (EF1) [Budish, 2011] and derivatives like EFX [Caragiannis et al., 2016]
  - An EF1 allocation always exists (and is easy to compute)
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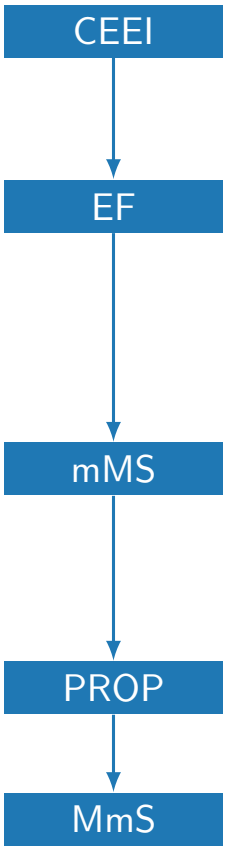

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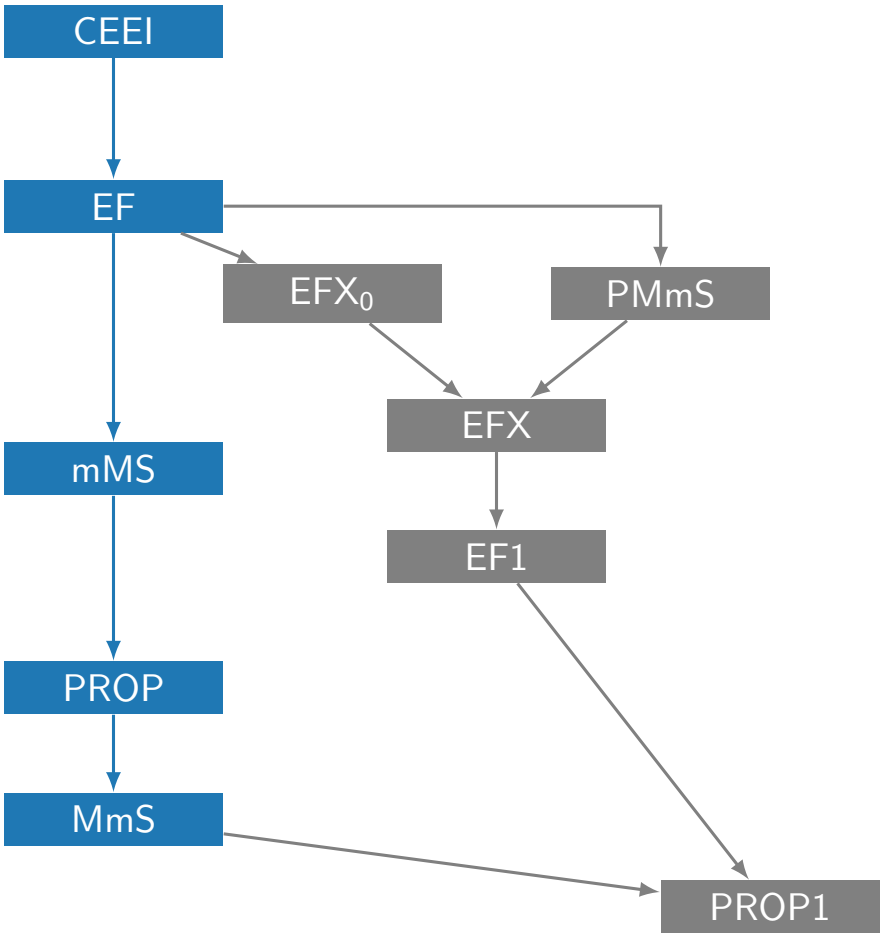

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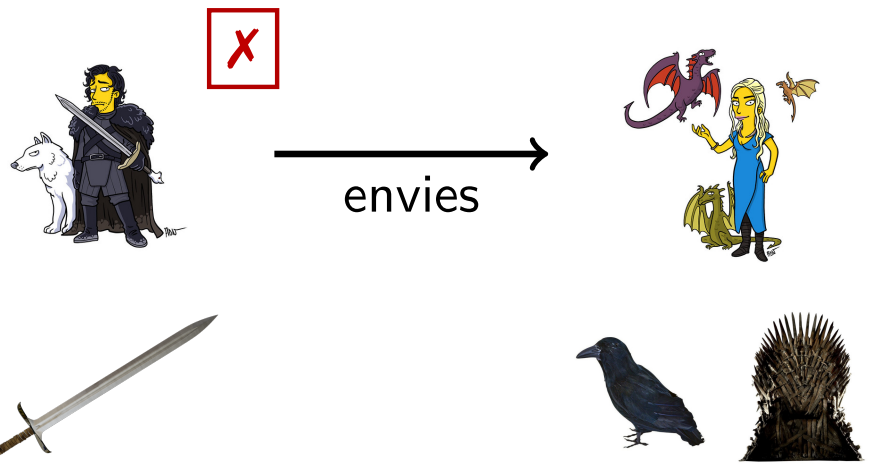

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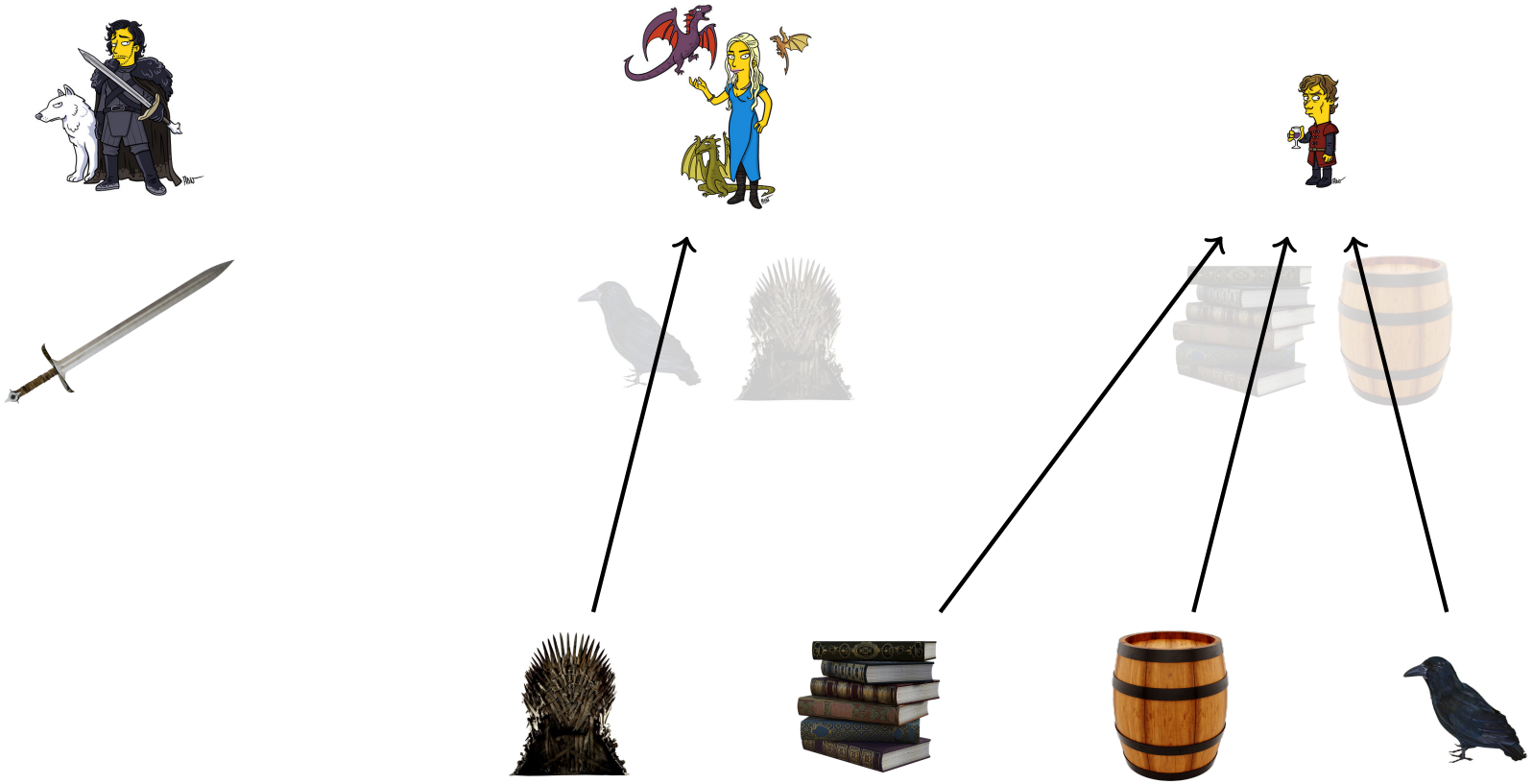

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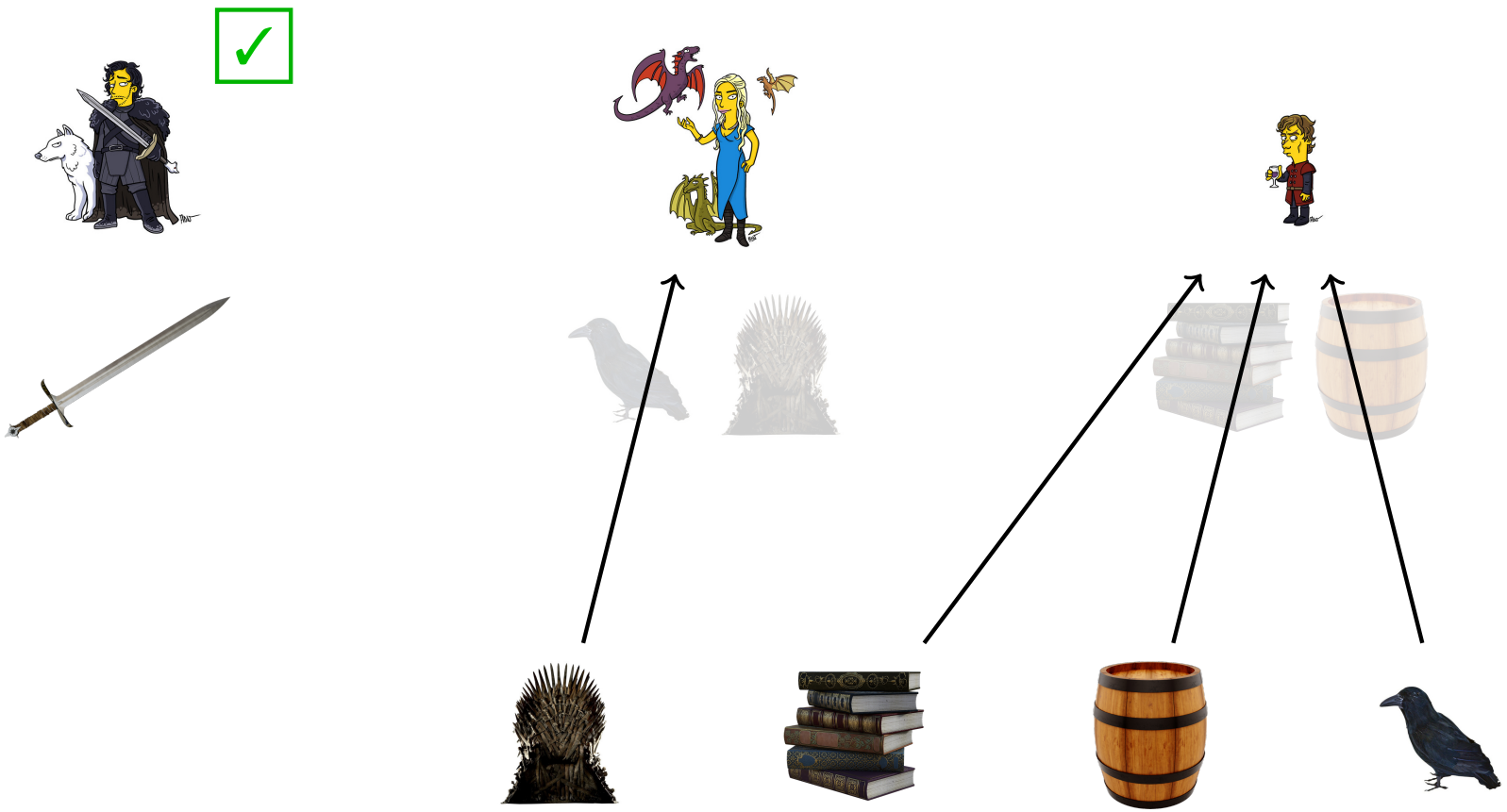

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- **epistemic envy-freeness** (EEF) [Aziz, B., Caragiannis, Giagkousi and Lang, AAAI'18]: they only know their own share
- Intermediate concept: the agents know **some** agents, *via* a social graph $G$ $\rightarrow$ $G$-EEF

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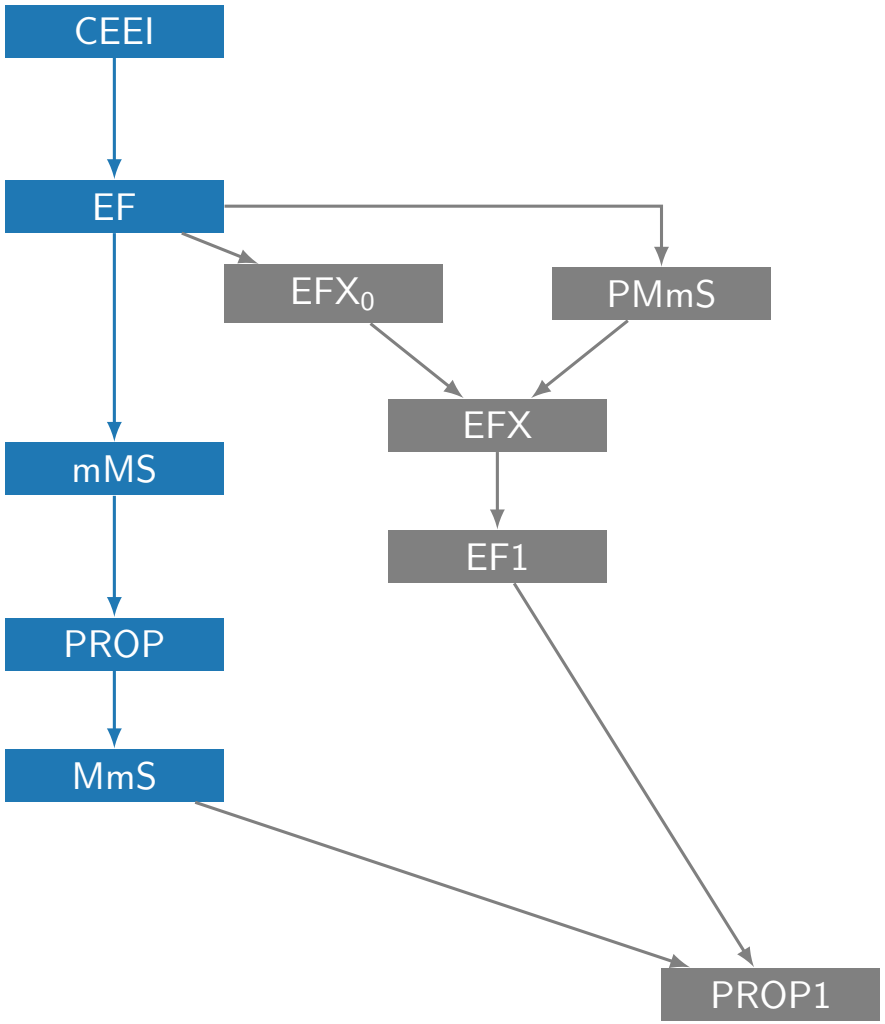

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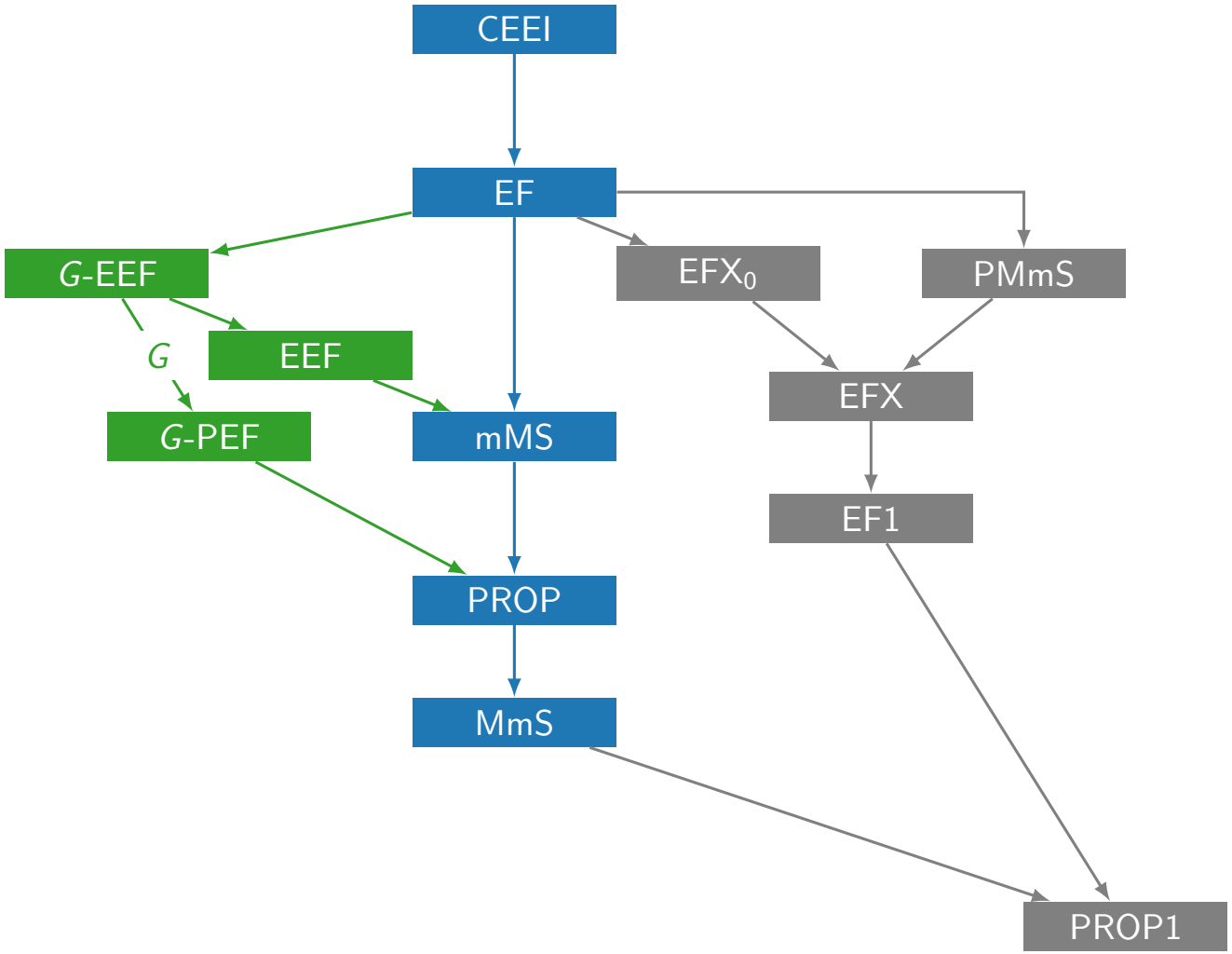

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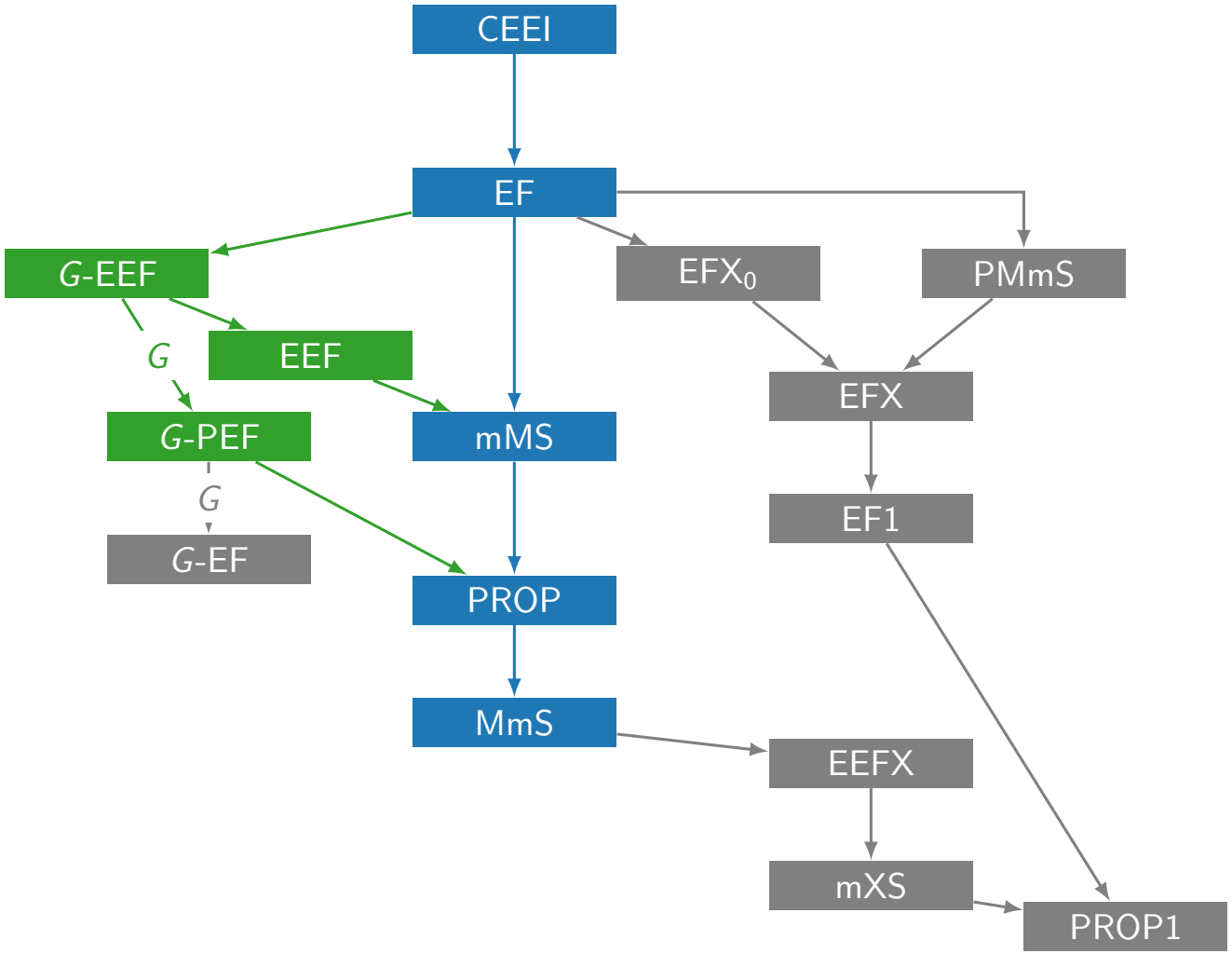

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- If only $K$ agents support this envy $\rightarrow$ $K$-**approval envy** [Shams, Beynier, B. and Maudet, JAIR'22]

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- $\overrightarrow{\pi}$ is ($K$-app envy)-free $\Rightarrow$ $\overrightarrow{\pi}$ is (($K+1$)-app envy)-free
- Finding the minimum $K$ so that $\overrightarrow{\pi}$ is ($K$-app envy)-free is **NP**-complete
- We can extend this concept to **$K$-app non-proportionality**

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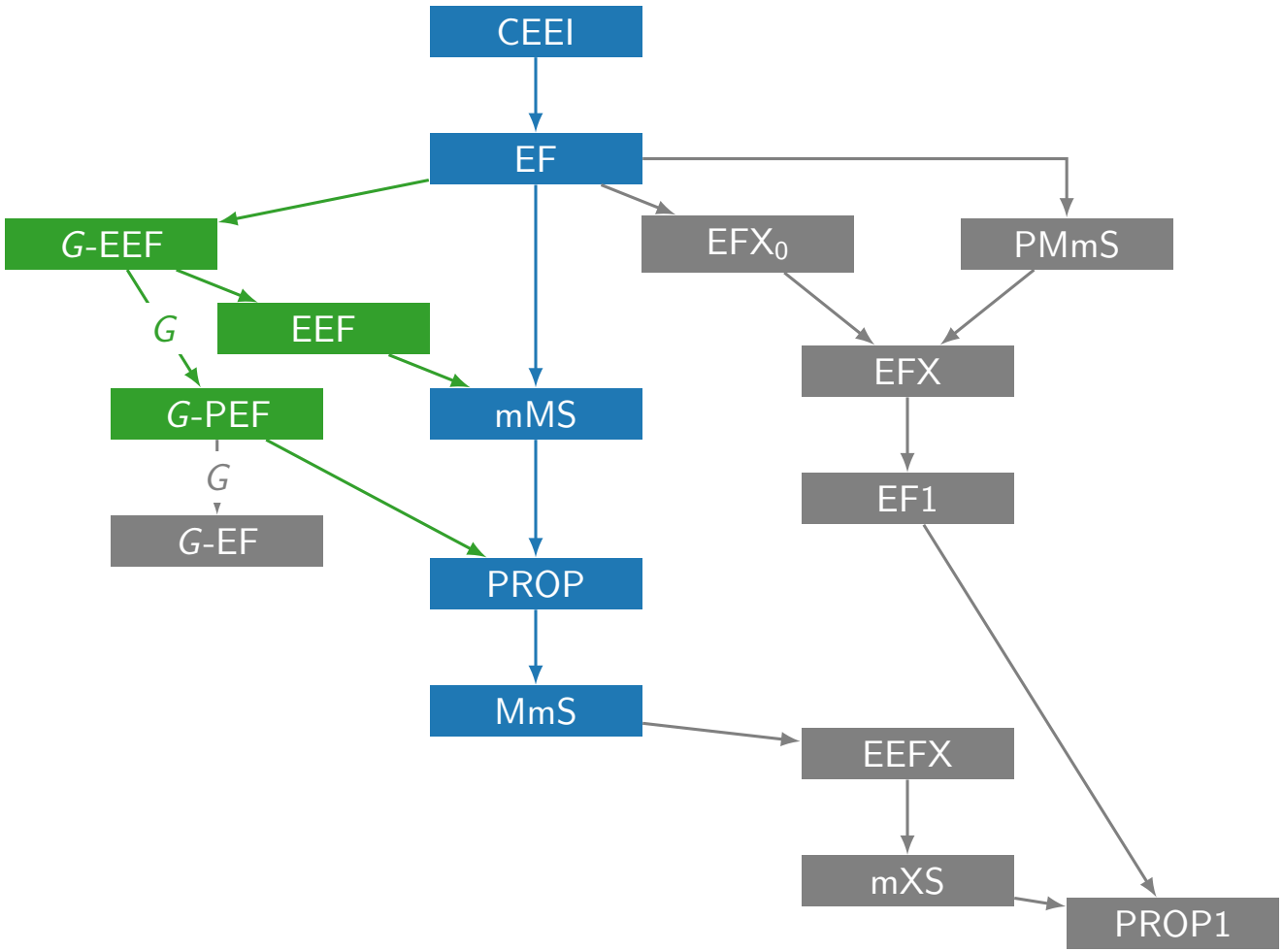

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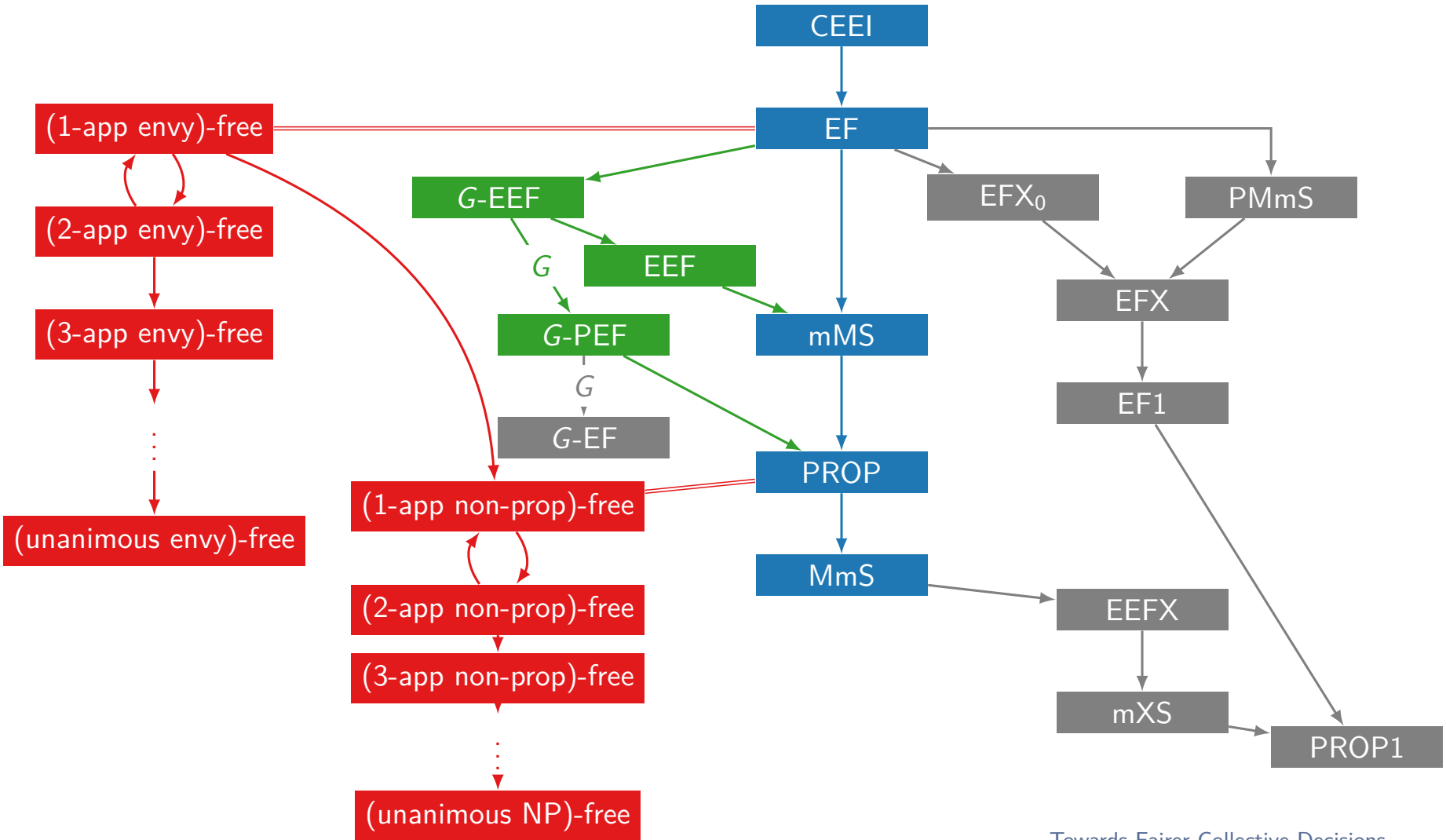

# Fair division

## The unreasonable fairness of picking sequences

# How to compute a fair division...

1. So far, what we have done: (i) ask the agents to give their preferences, then (ii) use a (centralized) collective decision making procedure.

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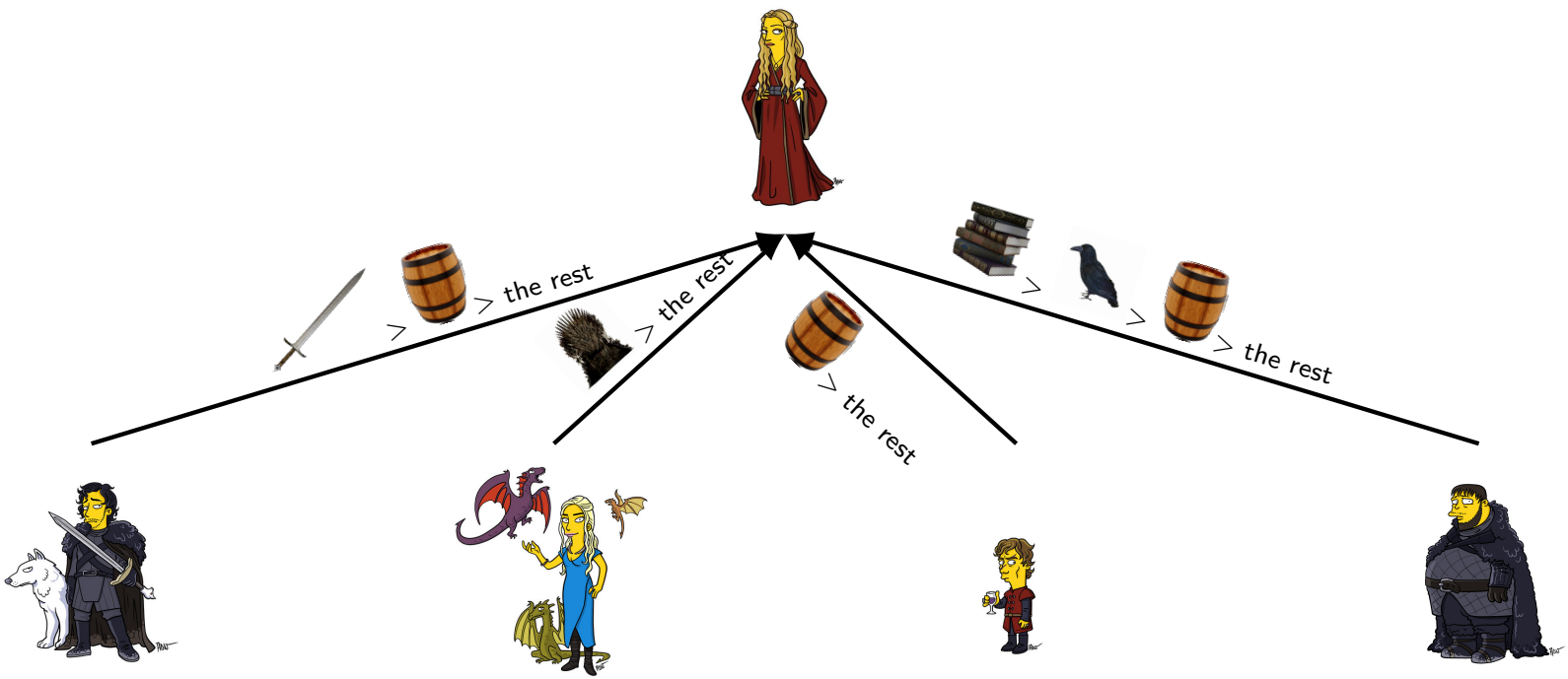

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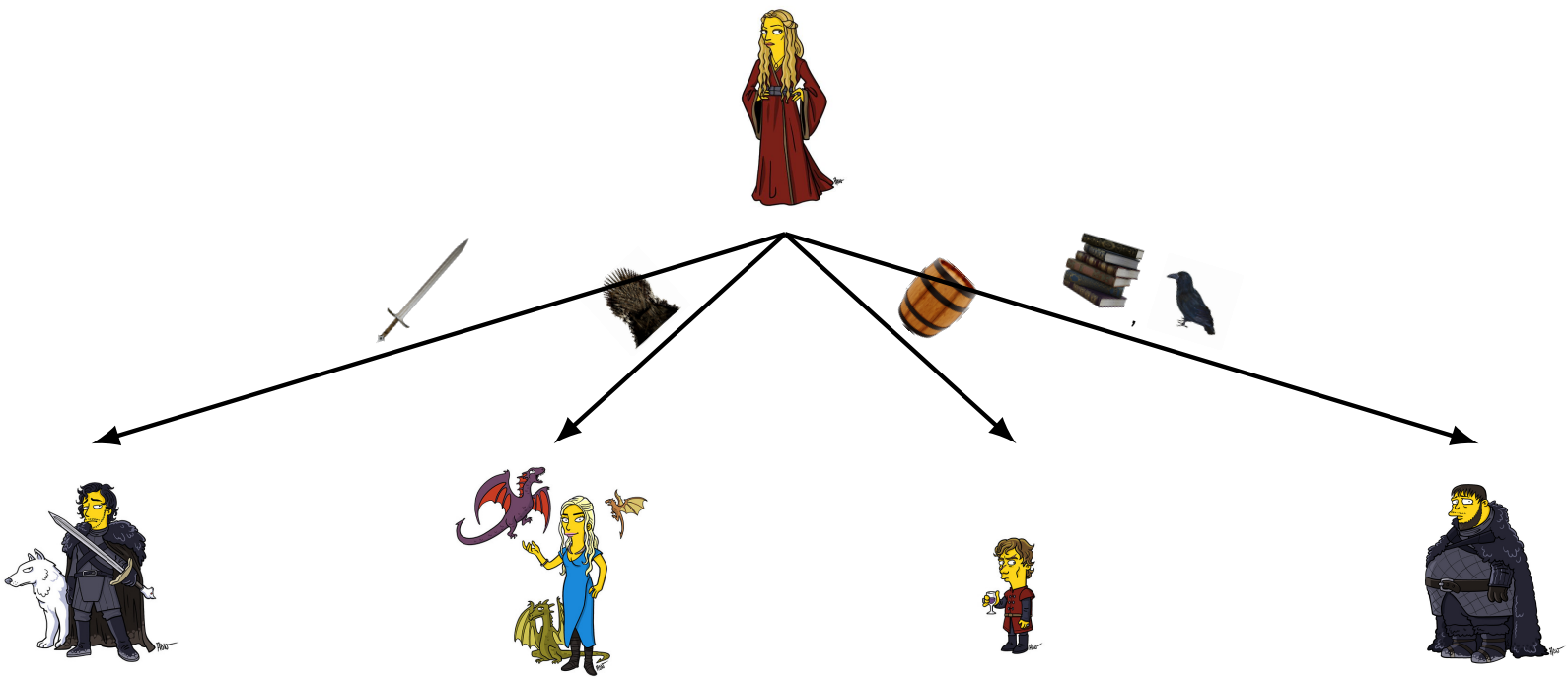

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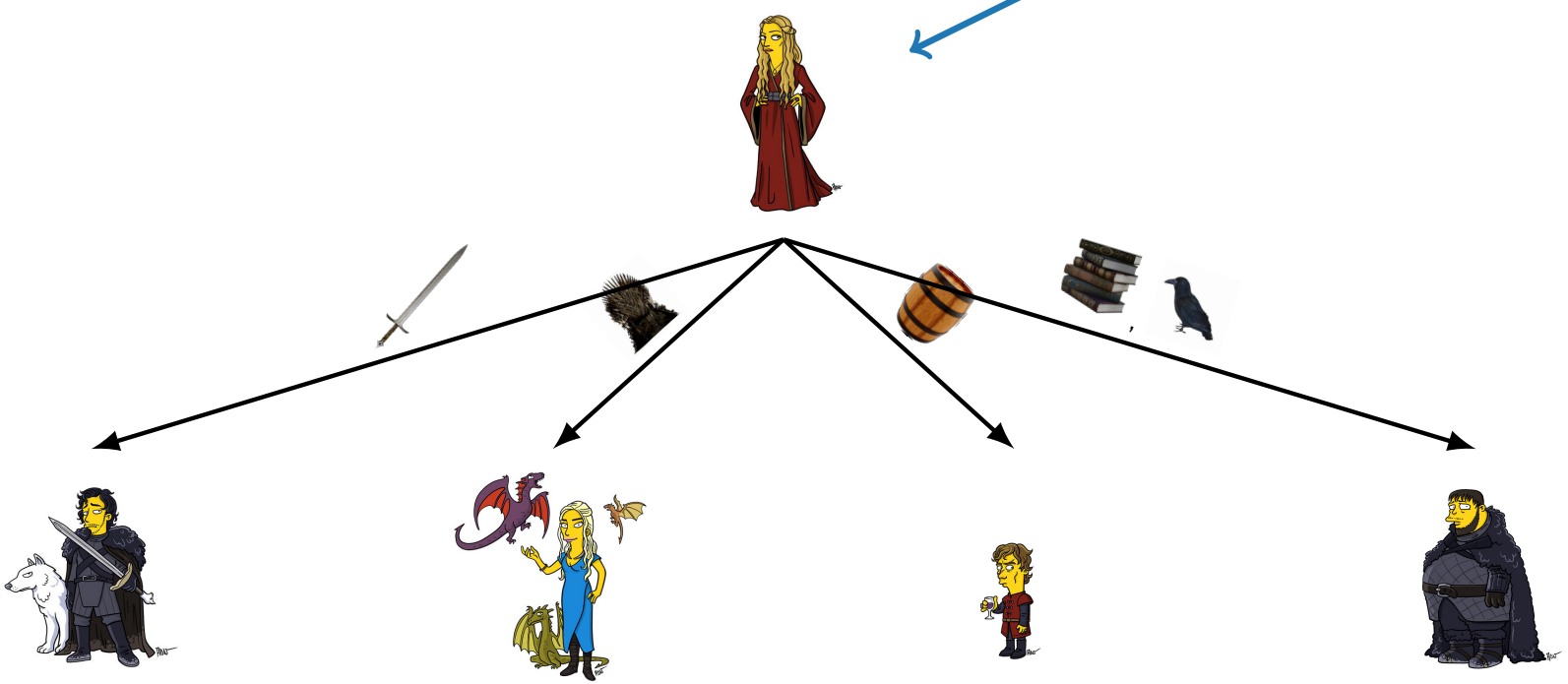

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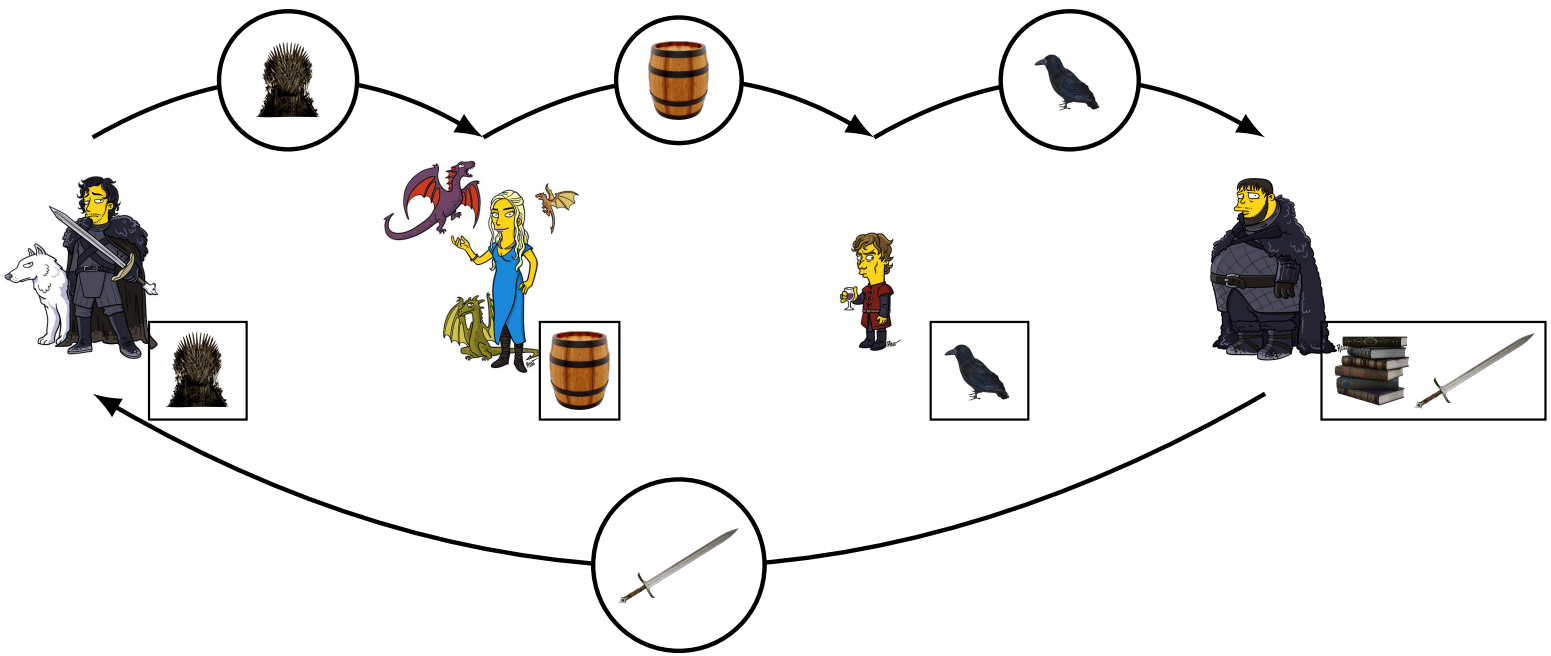

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In this part, we will focus on *picking sequences* (but also talk a little bit about negotiation)

- natural and simple
- used in practice (board games, draft mechanisms, course allocation...)
- preference elicitation-free

# Picking sequences

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3. ...individual utilities are aggregated to collective utilities using a **social welfare function** $sw$, *e.g* egalitarian (min) or utilitarian (sum)

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## Question

What is the *fairest* non-interleaving sequence?

# Results

Good news [B., Gilbert, Lang and Méroué, arXiV'23]...

**Proposition**

For FI, FC, any $sw \in \{ut, eg, Na\}$ and any $g$, we can find an optimal sequence in time $O(m^2 \max(n, m))$ (dynamic programming)

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Examples (full independance, Borda):

| $n$ | $m$ | $sw = eg$ | $sw = ut$ |
|---|---|---|---|
| 3 | 35 | $(9, 10, 16)$ | $(13, 11, 11)$ |
| 5 | 70 | $(12, 12, 12, 13, 21)$ | $(18, 16, 14, 11, 11)$ |
| 8 | 20 | $(2, 2, 2, 2, 2, 3, 3, 4)$ | $(3, 3, 3, 3, 2, 2, 2, 2)$ |
| 8 | 100 | $(11, 11, 11, 11, 11, 12, 13, 20)$ | $(18, 16, 15, 13, 12, 10, 8, 8)$ |

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Discussion:

- Interest beyond picking sequences: under mild conditions, the only deterministic strategyproof mechanisms are within the family of **serial dictatorships** [Pápai, 2000, Pápai, 2001]
- Non-interleaving picking sequences $\approx$ a way to reconcile **strategyproofness**, (ex-ante) **fairness**, and (a form of) **efficiency**

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- Allocations obtained by picking sequences hence have a (weak) form of efficiency

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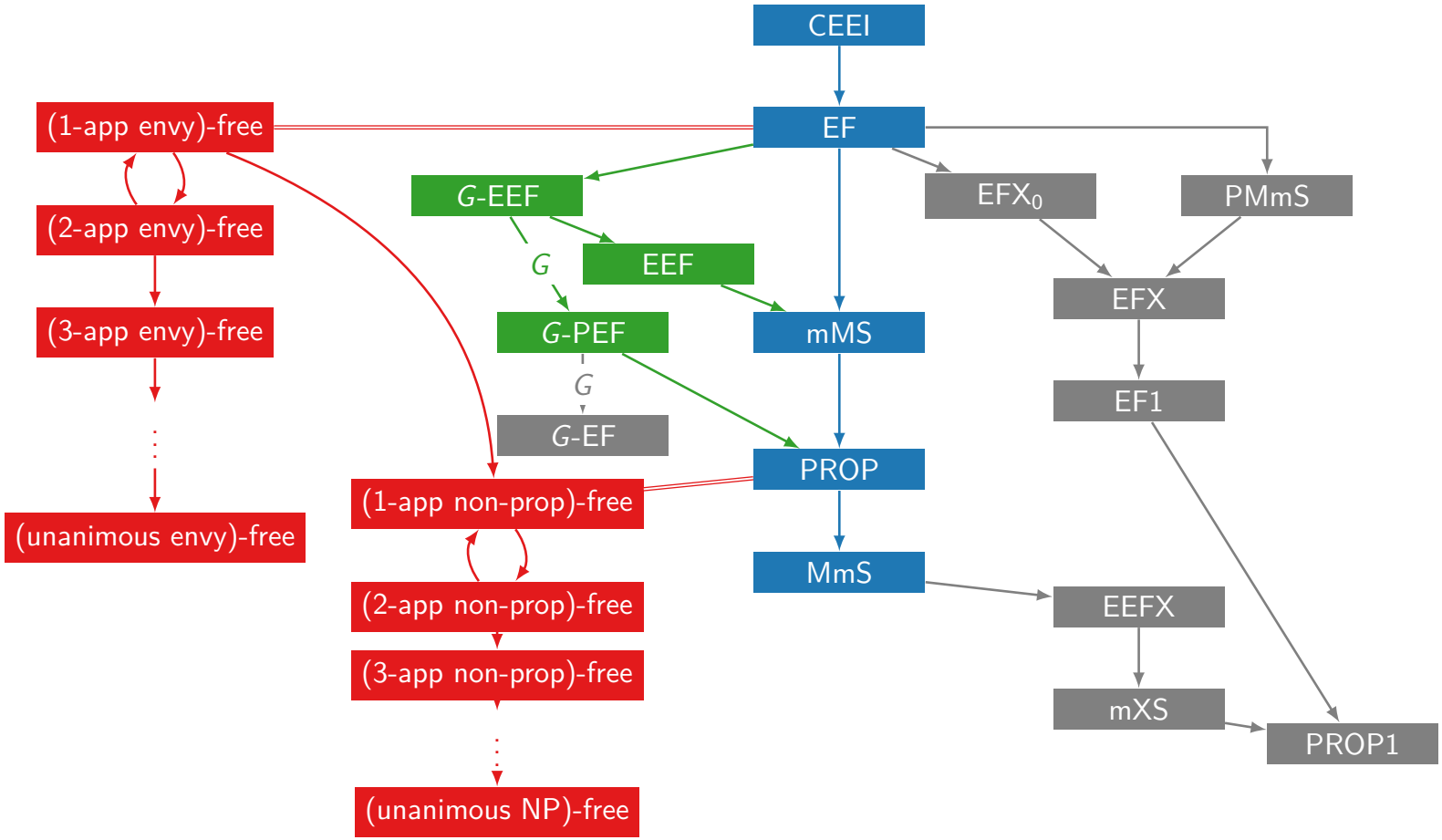
Hence, $N$-cycle deals define:

- a **hierarchy of efficiency properties**
- whose highest level is **sequenceability**

# The full landscape of fairness



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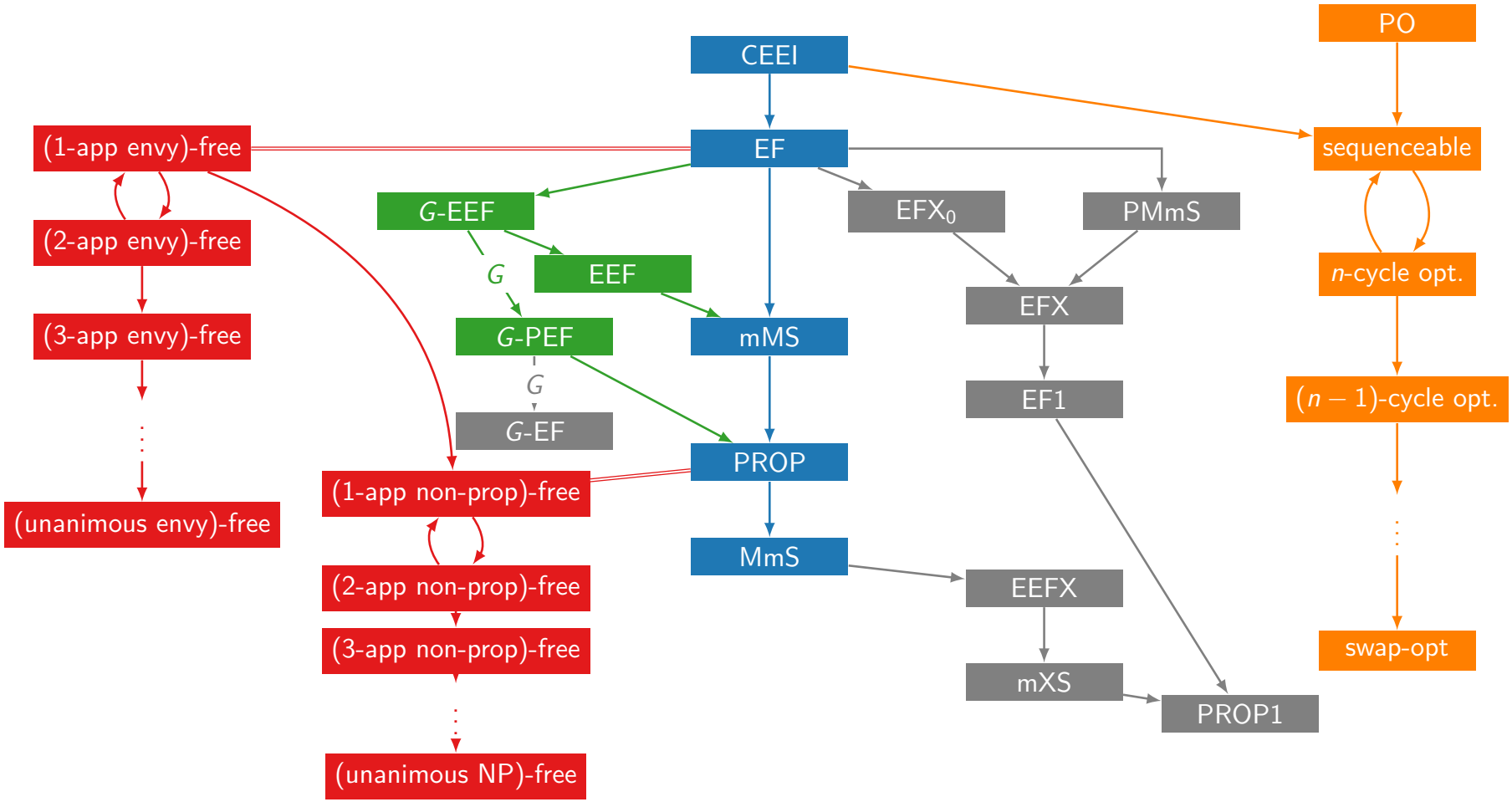

## Voting

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**And the winner is... Alternative (fairer?) voting rules**

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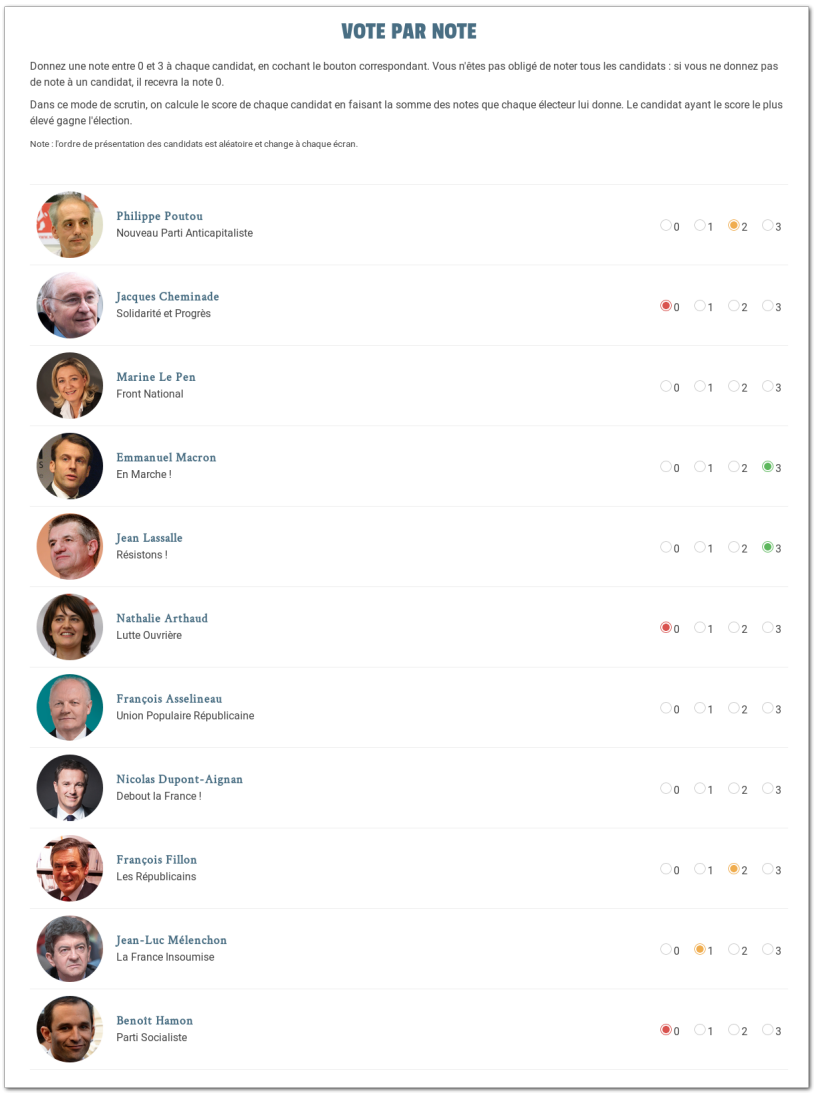
Other similar experiments
[Baujard et al., 2014, Darmann et al., 2017, Darmann and Klamler, 2023]

# More concretely...



**VOTE PAR NOTE**

Donnez une note entre 0 et 3 à chaque candidat, en cochant le bouton correspondant. Vous n'êtes pas obligé de noter tous les candidats : si vous ne donnez pas de note à un candidat, il recevra la note 0.

Dans ce mode de scrutin, on calcule le score de chaque candidat en faisant la somme des notes que chaque électeur lui donne. Le candidat ayant le score le plus élevé gagne l'élection.

Note : l'ordre de présentation des candidats est aléatoire et change à chaque écran.

| | | |
|---|---|---|
| Philippe Poutou | Nouveau Parti Anticapitaliste | ○0 ○1 ●2 ○3 |
| Jacques Cheminade | Solidarité et Progrès | ●0 ○1 ○2 ○3 |
| Marine Le Pen | Front National | ○0 ○1 ○2 ○3 |
| Emmanuel Macron | En Marche ! | ○0 ○1 ○2 ●3 |
| Jean Lassalle | Résistons ! | ○0 ○1 ○2 ●3 |
| Nathalie Arthaud | Lutte Ouvrière | ●0 ○1 ○2 ○3 |
| François Asselineau | Union Populaire Républicaine | ○0 ○1 ○2 ○3 |
| Nicolas Dupont-Aignan | Debout la France ! | ○0 ○1 ○2 ○3 |
| François Fillon | Les Républicains | ○0 ○1 ●2 ○3 |
| Jean-Luc Mélenchon | La France Insoumise | ○0 ●1 ○2 ○3 |
| Benoît Hamon | Parti Socialiste | ●0 ○1 ○2 ○3 |

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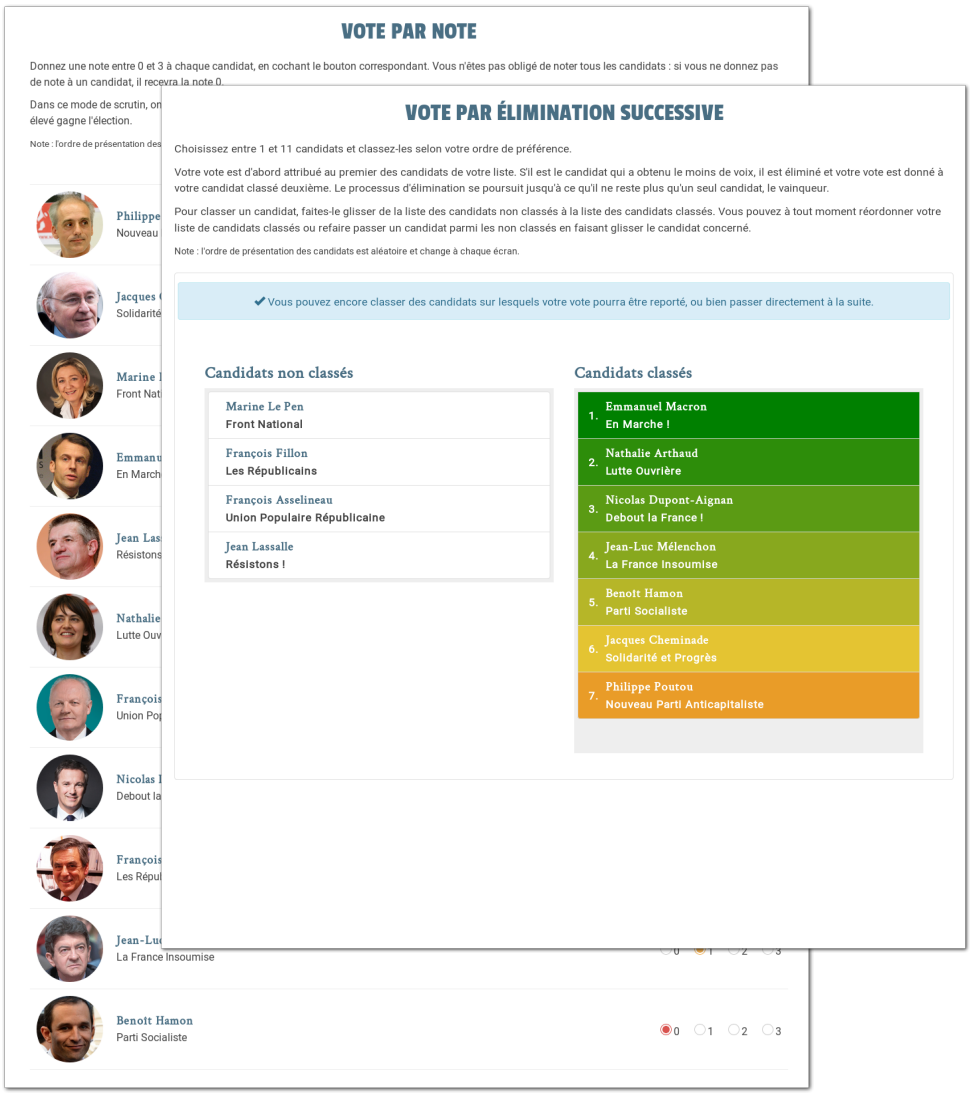

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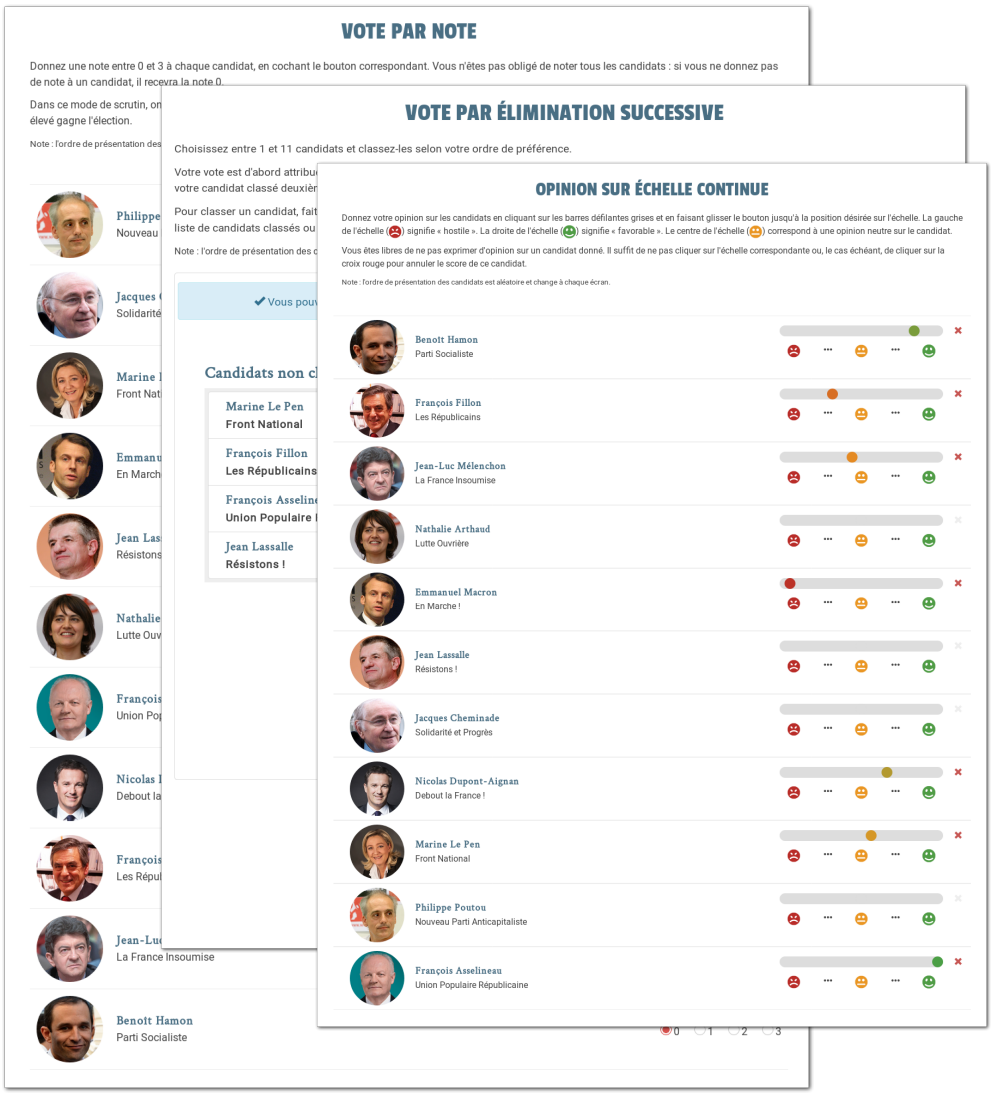

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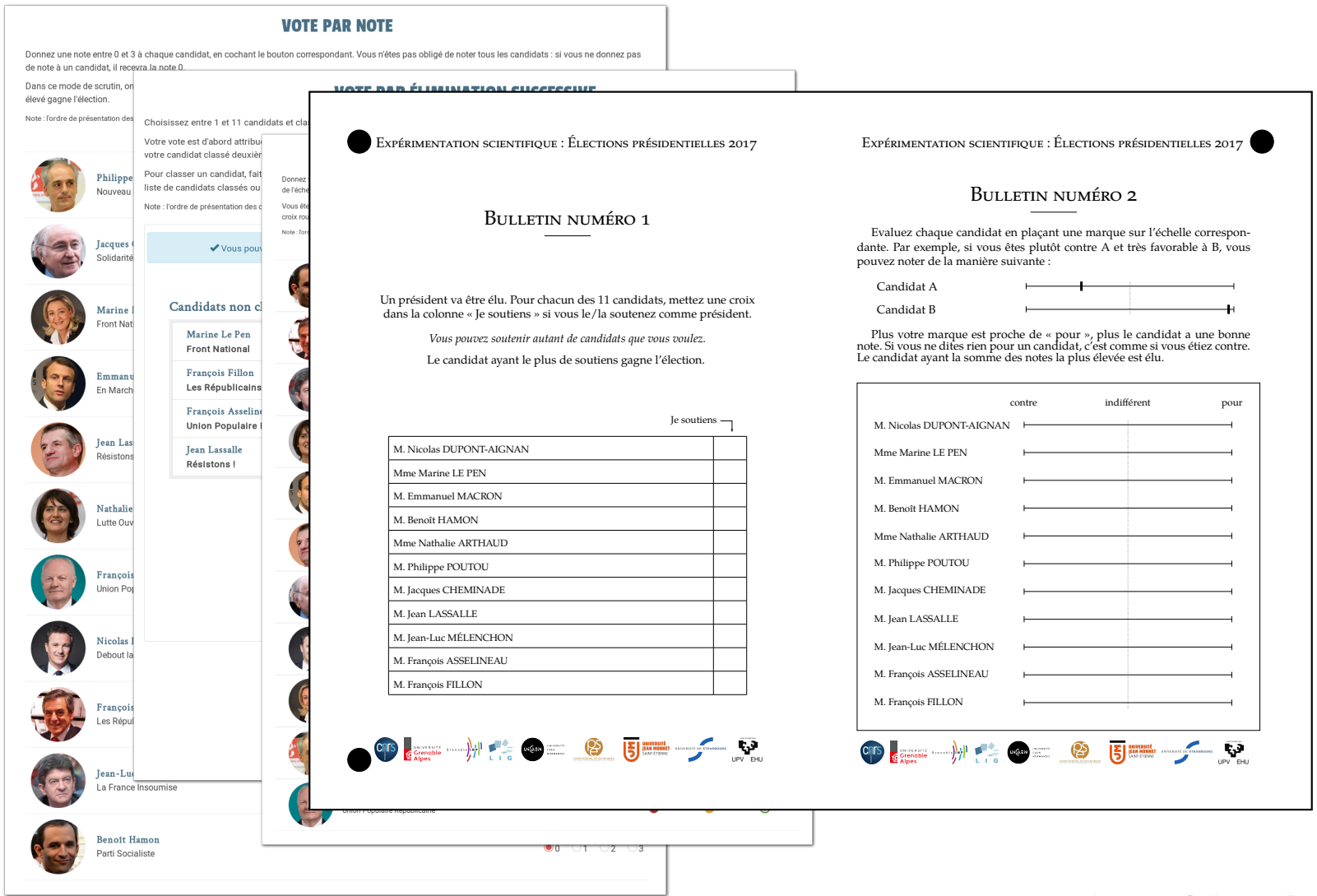
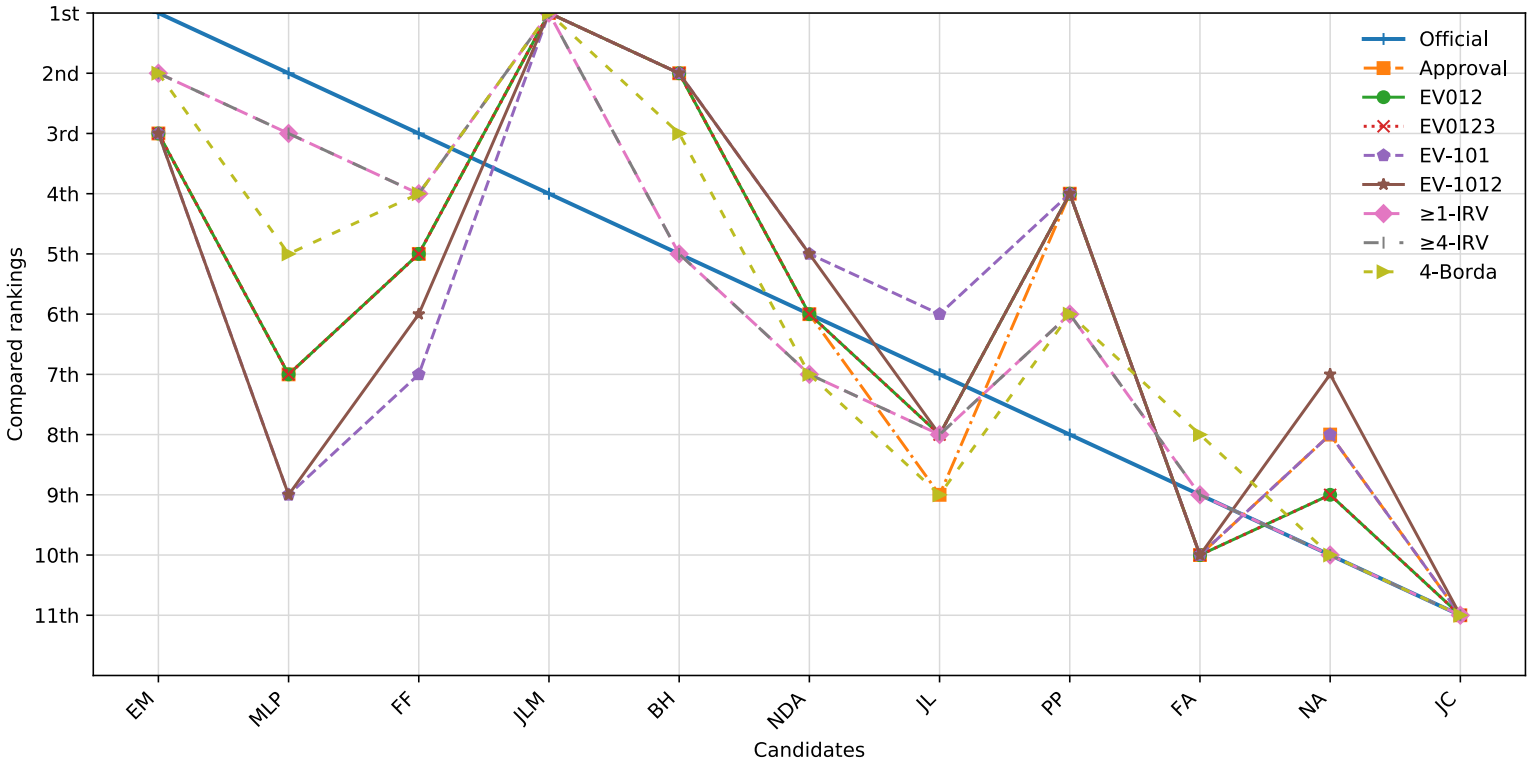


# Results

## Online experiment (corrected results)



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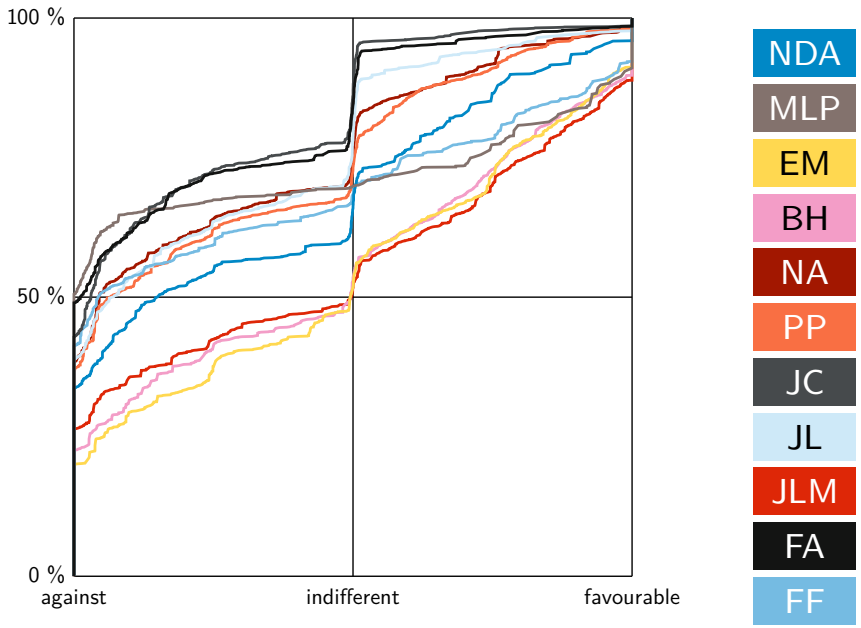

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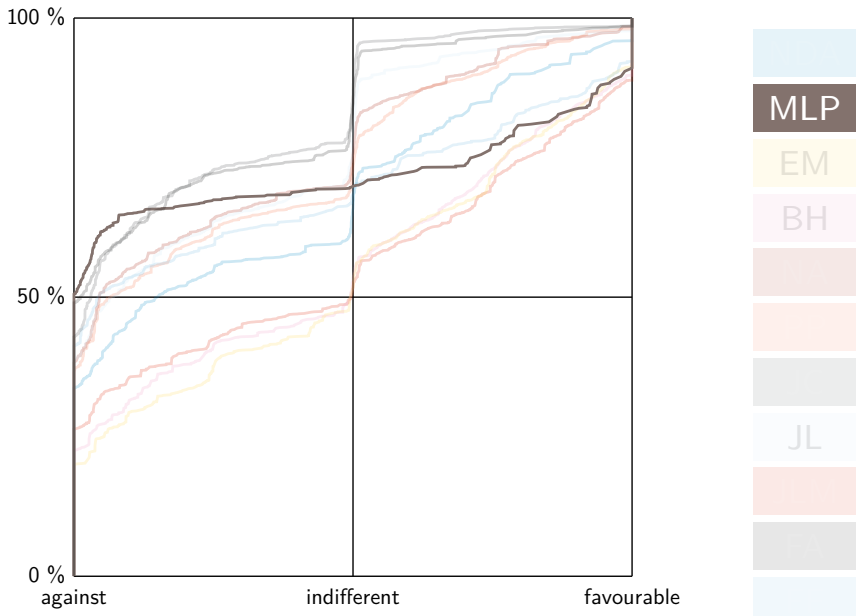

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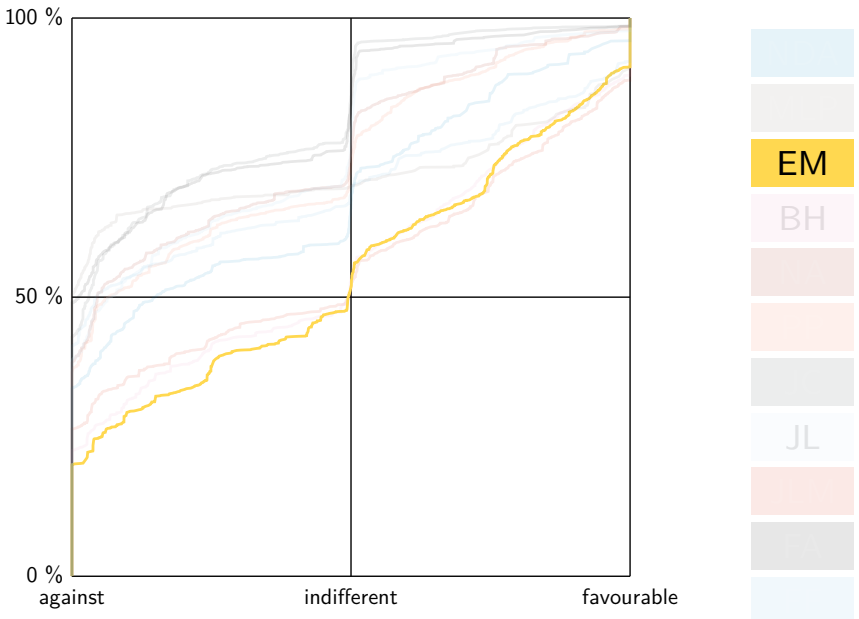

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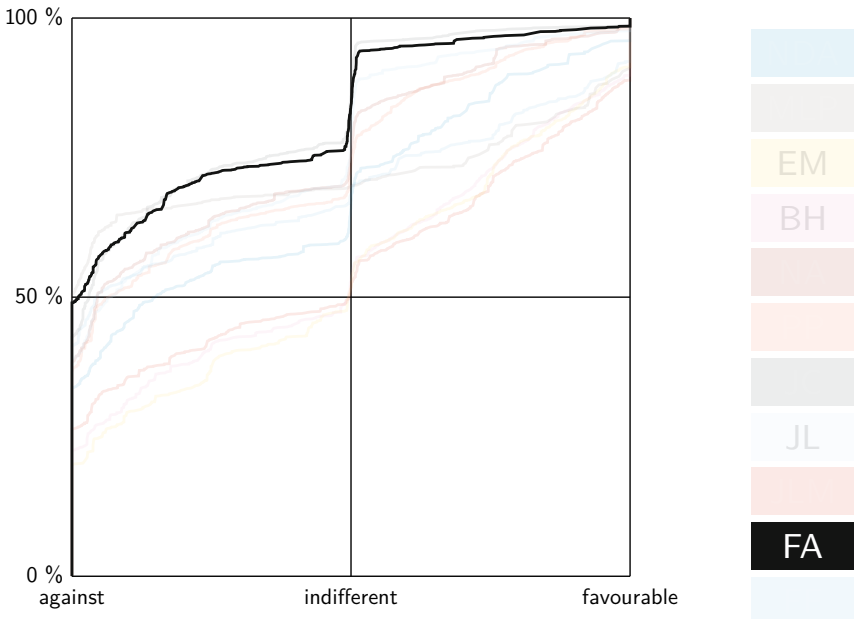



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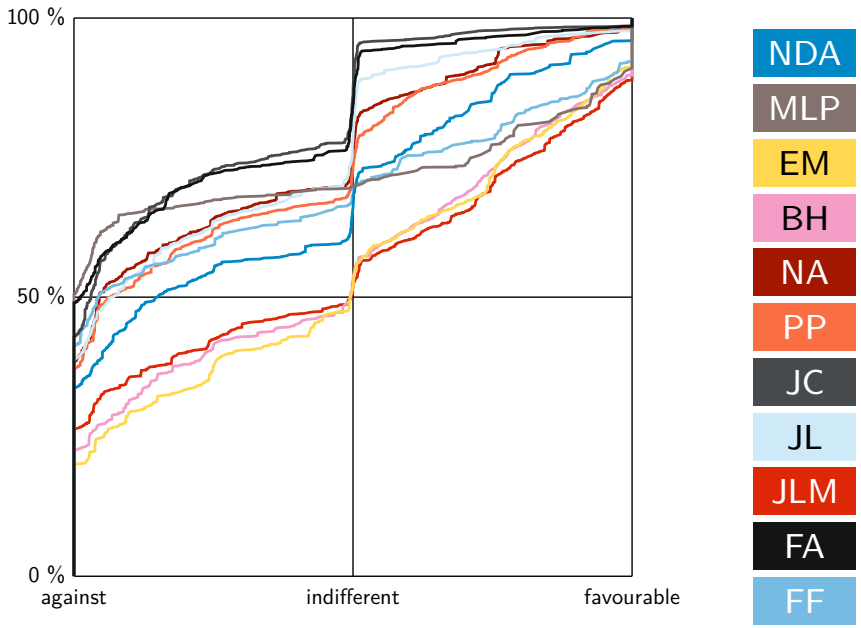

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- Two datasets produced and published [B., Blanch, Baujard, Durand, Igersheim, Lang, Laruelle, Laslier, Lebon and Merlin, Zenodo'18 and 19]
- Part of the experiment run again in 2022

## Perspectives

---

**A fair and safe operating space for humanity...**

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- Actually, these problems are also ubiquitous at the **local** scale.

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- ...But even before that, a **trickier problem**... Make people collaborate and agree upon the carbon emission cut-off implementation

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     - e.g can ICT help an association of farmers manage CPR in a Short Food Supply Chain [Besson, B., Brauner and Brulard, submitted]?
- **More general question**: ICT vs CPR?
  - Role of ICT in the governance and management of CPR?

# Managing the commons

- Dealing with scarcer resources → switching from **private** use to **common** use?
- **Governance** of common pool resources (CPR) [Ostrom, 1990]?
- Underlying questions:
  1. How to make decisions in this context?
     - e.g can a voting application help [B., Trends in COMSOC, 2017]? Can ICT help eliciting the agents preferences and exploring the possible solutions?
  2. How to share the use and operating costs of CPR?
     - e.g can ICT help an association of farmers manage CPR in a Short Food Supply Chain [Besson, B., Brauner and Brulard, submitted]?
- **More general question**: ICT vs CPR?
  - Role of ICT in the governance and management of CPR?
  - Can ICT be sustainable in a world where they are owned (and operated) by a few private actor? → ICT as **commons** for a fairer governance?

# Thank you

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## Want to know more?

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Pictures borrowed from: https://drawthesimpsons.tumblr.com/

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