Voices of Justice

Finding Consensus in the Multitude of Claims

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Motivation

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- Obtaining feedback from distributed systems can be challenging
    - Ongoing assynchronous activities can't stop
    - Processing burden for large systems
- In a resource allocation scenario how to evaluate the fairness of a distribution?
    - Whose feedback should be trusted?
    - How to deal with divergence on the feedback?

Distributive justice: recent problem in computer systems and networks (e.g. operating systems, TCP networks, smart-grids), but longstanding problem in social relations.

Towards a **Computational Justice** Framework: social inspired intelligence applied to technical problems

> "Not only must justice be done; it must also be seen to be done"

- Network setup:
  - n agents, connected in a graph G, performing independent activities and requiring resources to fulfil its tasks
- Availability and demand of resources:
  - At a specific time t (turn), an amount of resources $P(t)$ is made available to all agents and should be shared.
  - Each agent demand $d_i(t)$ ($i \in 1, \ldots, n$)
  - *Economy of scarcity*: $P(t) < \sum_i d_i(t)$
- Resource allocation:
  - Following an allocation policy, agents receive attributions r_i ($0 \leq r_i(t) \leq d_i(t)$)
  - No leftovers: $\sum_i r_i(t) = P(t)$

- Each turn, agents elaborate a metric of *perceived fairness* $\phi_i(t)$, influenced both by **individual** and **local perceptions** of how resources are being allocated
- The sum of all individual perceptions ($\Phi(t) = \sum_i \phi_i(t)$) becomes a metric for **general satisfaction**.

Given a cluster engaged in repeated rounds of resource distribution and agents' personal opinions and interactions, how can we ensure that an allocation is "fair"?

Strategy of Solution

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- Use individual subjective assessments
    - Decentralisated and independent feedback
    - Convergence of opinions can increase reliability (wisdom of the crowds)
    - Gives voice to “regular” individuals
- Questions to be considered:
    - How to deal with malicious agents, trying to misguide the general opinion?
    - How opinions should be weighted, in case of discordance?

Strategy of Solution

1. **Opinion Formation** - agent opinions are formulated, based on individual experience;
2. **Trust** - agents observe their environment and, through comparison, define its trusts;
3. **Influence** - agents communicate and diffuse opinions through their social influence.

Each individual, in light of the amount of resources received over time and the amount of resources demanded, can elaborate a personal opinion of the fairness of an allocation method.

Different possible metrics:

- Average attended demand

$$\phi_i(t) = \frac{\sum_{s=1}^{t} 1\{r_i(s) = d_i(s)\}}{t}$$

- Temporal satisfaction

$$\phi_i(t) = \begin{cases} (1-\alpha) \cdot \phi_i(t-1) + \alpha & \text{if } r_i(t) = d_i(t) \\ (1-\beta) \cdot \phi_i(t-1) & \text{if } r_i(t) < d_i(t) \end{cases}$$

Having formulated its personal opinion, agents then start to observe each other opinions, in order to compare their assessments.

Guiding principles

1. **Affinity**: trust more those who say coherent things (according to yourself!)
2. **Reinforcement**: It takes time to change an impression

1. Accordance index

$$\tau_{ij}(t) = 1 - (1 + \exp^{-\boldsymbol{k}(|\bar{\phi}_{N_i}(t) - \phi_j(t)| - \boldsymbol{\epsilon_0})})^{-\mathbf{1}}$$

where:

$$\bar{\phi}_{N_i}(t) = \frac{1}{|N(i)| + 1} \sum_{n \in N(i) - \{j\} + \{i\}} \phi_n(t)$$

2. Trust:

$$T_{ij}(t) = (1 - \gamma) \cdot T_{ij}\,(t-1) + \gamma \cdot \tau_{ij}(t)$$

($T_{ij}(0) = 1$ and $T_{ij}(t) = 0$ if $j \notin N(i)$)

Influence

Having the personal opinions ϕ and the trust assessments we can model the evolution of opinions under social influence.

$$T = \begin{bmatrix} T'_{11} & T'_{12} & \cdots & T'_{1n} \\ T'_{21} & T'_{22} & \cdots & T'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T'_{n1} & T'_{n2} & \cdots & T'_{nn} \end{bmatrix}; \qquad T'_{ij} = \frac{T_{ij}}{\sum_j T_{ij}}$$

- Iterative process of opinion propagation (DeGroot):

$$\phi^{'}(t) = T^K \phi \qquad (\phi(t) = [\phi_1(t), \dots, \phi_n(t)]^T)$$

- Final opinion:

$$\Phi(t) = \frac{1}{n} \sum_i \phi'_i(t)$$

Algorithm summary

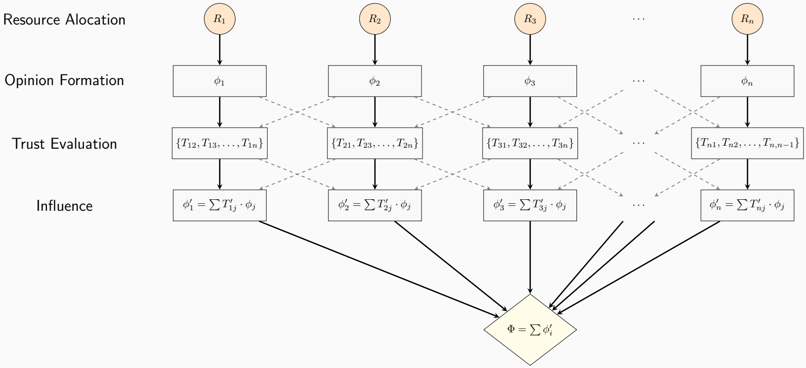


Figure 1: Complete algorithm

Experiments and Analysis

Can the solution identify and distinguish fair and unfair allocation schemes?

- Four allocation methods:
  - *Rotation*
  - *Clique first*
  - *Random order*
  - *Ration*

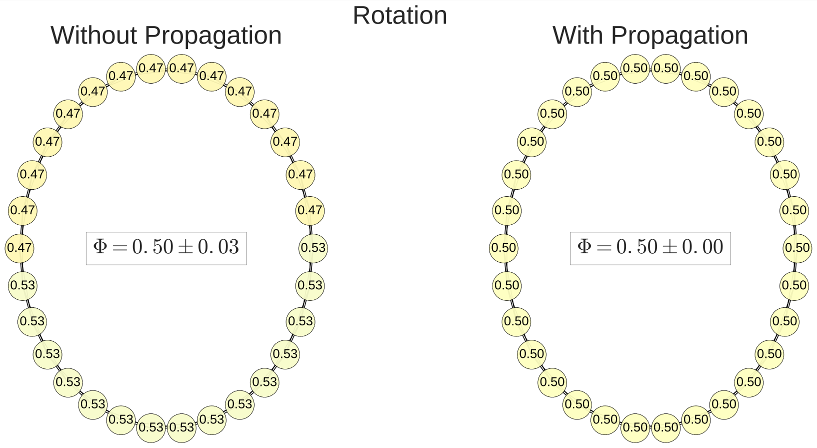


Figure 2: Opinions before and after influence for rotation allocation

Exp 1 - Coherence: Clique First

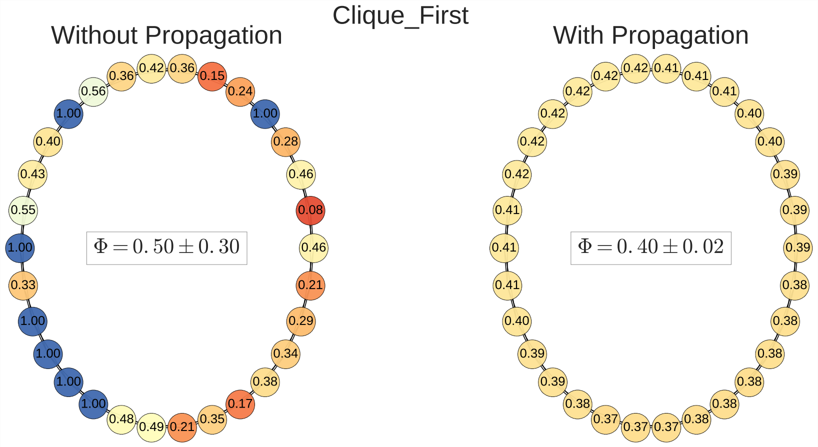


Figure 3: Opinions before and after influence for clique first allocation

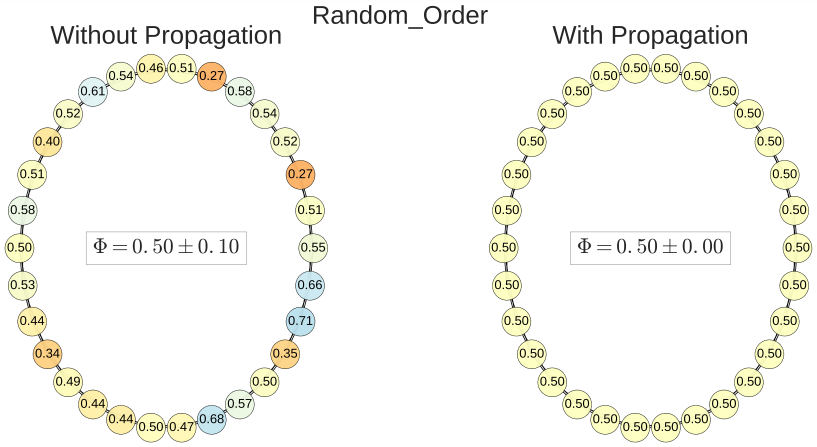


Figure 4: Opinions before and after influence for clique first allocation

Exp 1 - Coherence: Ration

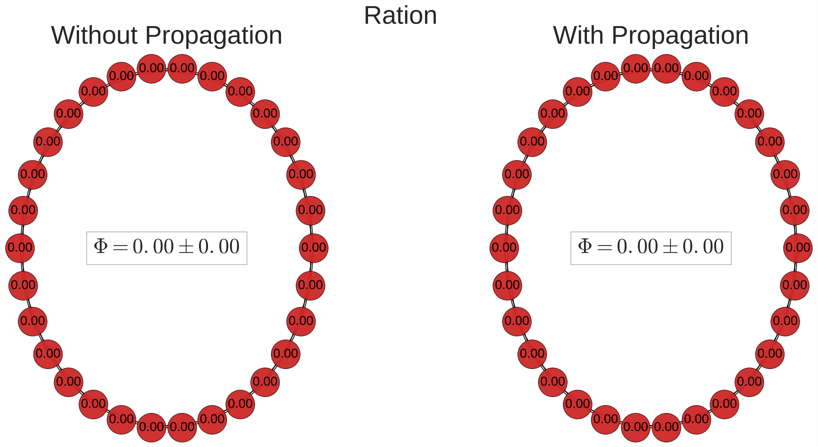
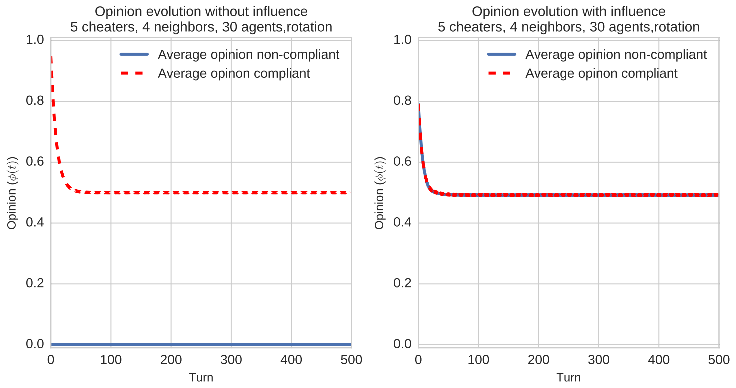


Figure 5: Opinions before and after influence for ration allocation

Are there mechanisms able to avoid the influence of malicious agents trying to propagate false information?

- Fair allocation (rotation);
- A group of agents always give negative feedback, regardless their situation.

Exp 2 - Robustness



Exp 3 - Resilience

Does it work properly in different topologies and with topology changes?

- Two new topologies tested: small world and random graph
- In each case, a fair (rotation) and unfair (clique first) allocation is tested

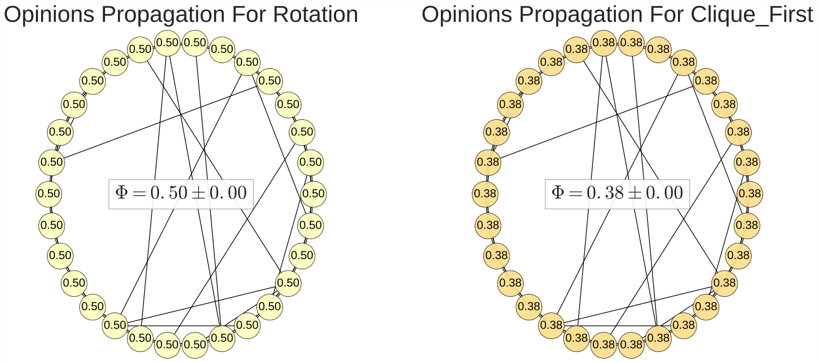


Figure 6: Small World Network

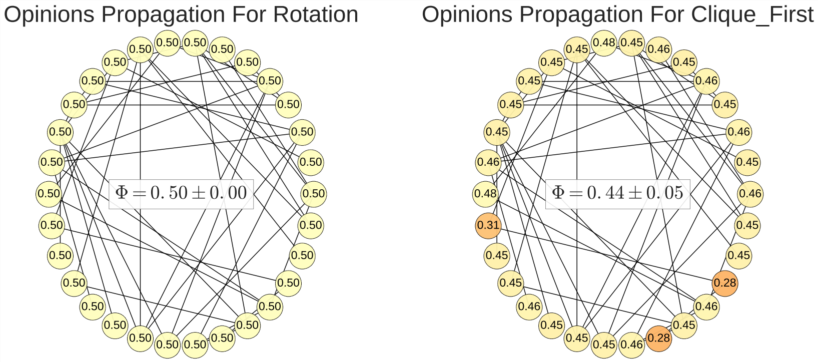


Figure 7: Random (Erdos Renyi) Network

Conclusion

Conclusions

- Practical method of evaluating the fairness of a resource allocation, using subjective assessments, information diffusion and influence methods.
- Main features:
    - Decentralised and independent computation of the fairness of an allocation process;
    - Rapid reaction in case of unfairness – even when there is initial divergence of opinions;
    - Identifying and excluding faulty behaviour (cheating);
    - Robustness to different scenarios and applications.

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