An Agent-Based Approach for Distributed Resource Allocations

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COST-ADT — Algorithmic Decision Theory: Computational Social Choice

Université Lille 1 - Sciences et Technologies

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Outline

1. Context
2. Contributions
3. Results
4. Conclusion & future works
Resource allocations

Resource Set $\mathcal{R}$

Entity Set $\mathcal{P}$

Resource allocation

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An example

<table>
<thead>
<tr>
<th>Population $\mathcal{P}$</th>
<th>Resource Set $\mathcal{R}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$r_1$</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
</tr>
</tbody>
</table>

Social welfare                      Optimal allocation
---                                   ---
Utilitarian (sum) \[\{r_1, r_3, r_4\}, \{r_2, r_5, r_6\}, \{\}\] \[
Egalitarian (min) \[\{r_1\}, \{r_5\}, \{r_2, r_3, r_4, r_6\}\] \[
Nash (prod) \[\{r_1, r_3\}, \{r_2, r_5\}, \{r_4, r_6\}\] \[
Elitist (max) \[\{r_1, r_2, r_3, r_4, r_5, r_6\}, \{\}, \{\}\] \[

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State of the Art

Studies on resource allocation problems are mainly theoretical.

**In literature**
- [Sandholm, 1998]: Existence of transaction sequences
- [Dunne, 2005]: Complexity
- [Chevaleyre et al., 2006 to 2009]: Identification of characteristics ensuring the existence of a transaction path

**Our assumptions**
- Restrictions on communications
- Private information
  ⇒ Limited view of the system
Research Objectives

My thesis objective is to design a distributed mechanism based on local transactions leading agent negotiations to socially optimal allocations.

I identify four important parameters:

- **Transactions**: what agents can offer during a negotiation?
- **A behavior**: how agents interact to determine acceptable transactions?
- **A criterion**: agents have a local knowledge only
- **A social graph**: agents have a limited neighborhood.
Transactions
- Model based on offers’ cardinality (e.g. \(\langle 1, 0 \rangle = \text{gifts, ...}\))

Agent behaviors
- Rooted / frivolous
- Stubborn / flexible
- Priority on partners / Offers / transaction kinds

Decision-making criteria
- Individual rationality
- Sociability

Contact graphs
- Complete
- Grid
- Erdős-Rényi
- Small world
Utilitarian and elitist negotiations

Elitist negotiations on complete graphs
Elitist negotiation processes based on complete social graphs always converge towards a global optimum using social clusters of maximal size.

Utilitarian negotiations on complete graphs
Utilitarian negotiation processes based on complete social graphs always converges towards a global optimum using only social gifts.

No path on restricted graphs
Negotiations on restricted graphs cannot ensure the achievement of socially optimal allocations, independently of the social notion considered.
Egalitarian and Nash negotiations

Bilateral transaction insufficiency on complete graphs

During egalitarian or Nash negotiations, bilateral transactions cannot ensure the achievement of optimal allocations.

Population \( \mathcal{P} \)  

<table>
<thead>
<tr>
<th>Resource Set ( \mathcal{R} )</th>
<th>( r_1 )</th>
<th>( r_2 )</th>
<th>( r_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
Efficiency of egalitarian negotiations

Simulations are performed on population of 50 agents where 250 resources are available.

<table>
<thead>
<tr>
<th>Social graph kind</th>
<th>Rational $\langle 1, 1 \rangle \leq \langle 2, 2 \rangle$</th>
<th>Social $\langle 1, 0 \rangle \leq \langle 1, 1 \rangle \leq \langle 2, 2 \rangle$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td>19.3 20.8</td>
<td>78.5 24.1 99.9 99.9</td>
</tr>
<tr>
<td>Grid</td>
<td>13.9 14.6</td>
<td>66.2 23.6 80.2 80.6</td>
</tr>
<tr>
<td>Erdős-Rényi</td>
<td>17.4 20.2</td>
<td>77.3 23.8 96.1 96.6</td>
</tr>
<tr>
<td>Small world</td>
<td>13.1 13.9</td>
<td>63.8 23.4 78.1 78.2</td>
</tr>
</tbody>
</table>
## Conclusion

### Social welfare notions

<table>
<thead>
<tr>
<th></th>
<th>Utilitarian (sum)</th>
<th>Egalitarian (min)</th>
<th>Nash (prod)</th>
<th>Elitist (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centralized Algorithm (on complete graph)</td>
<td>Trivial Allocation of each resource to one of the agents who estimates it the most</td>
<td>$\mathcal{NP}$-hard problem Estimation using linear program</td>
<td>$\mathcal{NP}$-hard problem Accurate estimation quite difficult</td>
<td>Trivial Allocation of all resources to the agents who estimates them the most</td>
</tr>
</tbody>
</table>

### Agent features

- **Social criterion**
  - Gifts and swaps
  - Frivolous and flexible
  - Optimal on complete graphs
  - More than 86% for graph with a very weak connectivity
  - Bilateral transactions unsufficiency
  - Requires a high mean connectivity
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### Characteristics

- **Optimal on complete graphs**
  - Very scalable
  - Sensitive to the mean connectivity
  - Sensitive to the intial allocation

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**Generosity is essential in all cases**

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Future Works

Based on my thesis, different facets of social web applications can be investigated.

- Preferences and topologies
- Preferences and externalities
- More expressive preferences
- Dynamic environment
Thanks

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