An Agent-Based Approach for Distributed Resource Allocations

Antoine Nongaillard

COST-ADT — Algorithmic Decision Theory: Computational Social Choice

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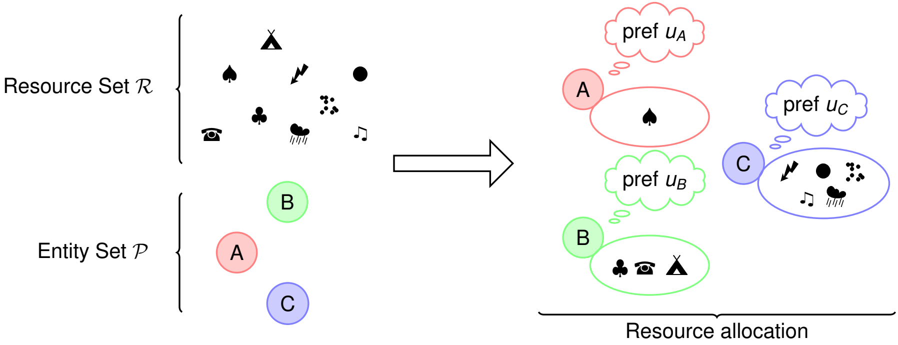
Outline

Resource allocations



An example

Population $\mathcal{P}$	Resource Set $\mathcal{R}$					
	r_1	r_2	r_3	r_4	r_5	r_6
A	10	7	10	9	2	1
B	6	10	3	4	8	6
C	1	2	1	2	1	3

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)	$[\{r_1, r_2, r_3, r_4, r_5, r_6\}, \{\}, \{\}]$

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

$\Rightarrow$ 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. $\langle 1, 0 \rangle$ = 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.

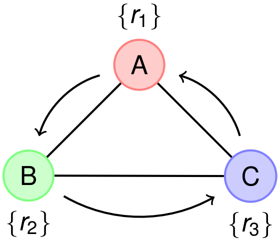
No path on restricted graphs

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 $\mathcal{P}$	Resource Set $\mathcal{R}$		
	r_1	r_2	r_3
A	2	1	5
B	5	2	1
C	1	5	2

Efficiency of egalitarian negotiations

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

Efficiency (%) of negotiation processes

Social graph kind	Rational		Social			
	$\langle 1, 1\rangle$	$\leq \langle 2, 2\rangle$	$\langle 1, 0\rangle$	$\langle 1, 1\rangle$	$\leq \langle 1, 1\rangle$	$\leq \langle 2, 2\rangle$
Complete	19.3	20.8	78.5	24.1	**99.9**	99.9
Grid	13.9	14.6	66.2	23.6	**80.2**	80.6
Erdős-Rényi	17.4	20.2	77.3	23.8	**96.1**	96.6
Small world	13.1	13.9	63.8	23.4	**78.1**	78.2

Conclusion

		Social welfare notions			
		Utilitarian (sum)	Egalitarian (min)	Nash (prod)	Elitist (max)
	Centralized Algorithm (on complete graph)	Trivial Allocation of each resource to one of the agents who estimates it the most	$\mathcal{NP}$-hard problem Estimation using linear program	$\mathcal{NP}$-hard problem Accurate estimation quite difficult	Trivial Allocation of all resources to the agents who estimates them the most
Distributed Approach	**Agent features**	**Social criterion** **Gifts** Frivolous and flexible	**Social criterion** **Gifts** and swaps Frivolous and flexible	**Social criterion** **Gifts** and swaps Frivolous and flexible	**Social criterion** **Clusters** Frivolous
Distributed Approach	**Characteristics**	**Optimal on complete graphs** More than 86% for graph with a very weak connectivity	**Bilateral transactions unsufficiency** Sensitive to bottlenecks Requires a high mean connectivity	**Bilateral transactions unsufficiency** Requires a hight mean connectivity Sensitive to graph bottlenecks	**Optimal on complete graphs** Very scalable Sensitive to the mean connectivity Sensitive to the intial allocation

Generosity is essential in all cases

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

Contact

`antoine.nongaillard@lifl.fr`

Research Team

SMAC:	`http://www.lifl.fr/SMAC/`
Publications:	`http://www.lifl.fr/SMAC/publications/`
Boss:	`philippe.mathieu@lifl.fr`