Hybrid Agent Models for the Regulation of Social Exchange Processes in Open Multiagent Systems

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TX
LA
GA
FL
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Guatemala
Caribbean Sea
Nicaragua
Morocco
Western Sahara
Mauritania
Mali
Burkina Faso
Guinea
Ghana
Venezuela
Guyana
Suriname
Colombia
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South Atlantic Ocean


Gulf of California
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Algeria
Western Sahara
Mauritania
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Burkina Faso
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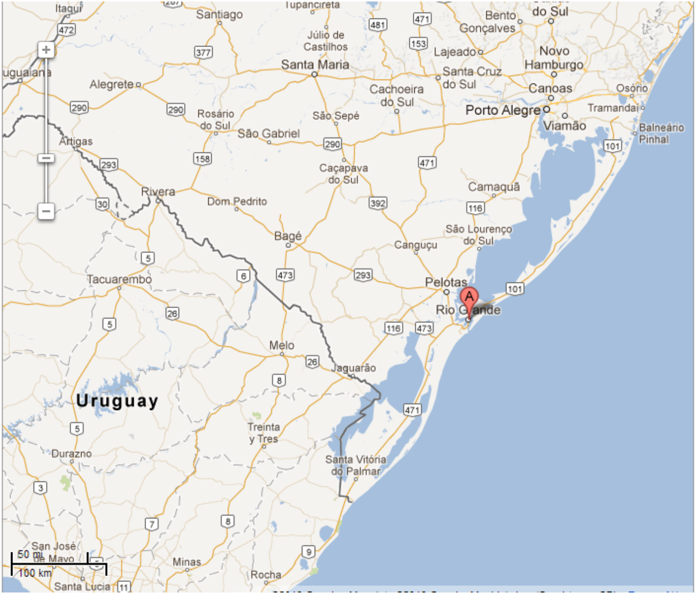
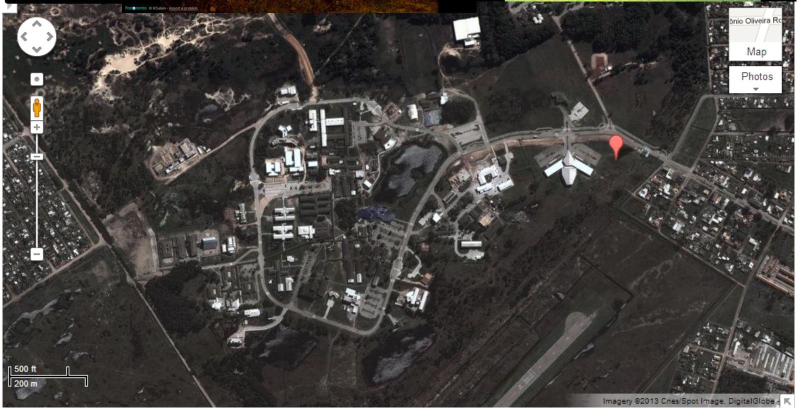


Itaqui
Santiago
Tupanciretã
Júlio de Castilhos
Bento Gonçalves
do Sul
Lajeado
Novo Hamburgo
Santa Maria
Santa Cruz do Sul
Uruguaiana
Alegrete
Cachoeira do Sul
Canoas
Osório
Porto Alegre
Tramandaí
Rosário do Sul
São Sepé
Viamão
Balneário Pinhal
São Gabriel
Artigas
Caçapava do Sul
Camaquã
Rivera
Dom Pedrito
Bagé
São Lourenço do Sul
Canguçu
Tacuarembó
Pelotas
A
Rio Grande
Melo
Jaguarão
Uruguay
Treinta y Tres
Santa Vitória do Palmar
Durazno
San José de Mayo
50 mi
100 km
Minas
Rocha
Santa Lucia

FURG


Map
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500 ft
200 m
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LAMSA - LABORATÓRIO DE MODELAGEM E SIMULAÇÃO SOCIAL E AMBIENTAL

Outline of the Presentation

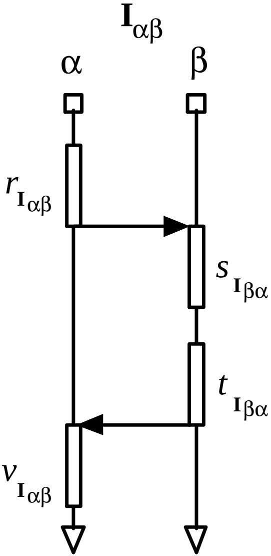
The Social Exchange Regulation Problem in MAS

The Social Exchange Regulation Problem

- Systems of social relationships have often been seen as systems of social exchanges;
- A central problem in such systems of social exchanges is that of **the regulation of the exchanges**, towards producing social equilibrium;
- We have been studying the social exchange problem in the context of MAS:
  - Social exchanges are understood as exchanges of services between pairs of agents, and
  - The agents evaluate qualitatively their exchange results, by the use of qualitative values (e.g, excellent, satisfactory, unsatisfactory, good quality but too slow, etc.).

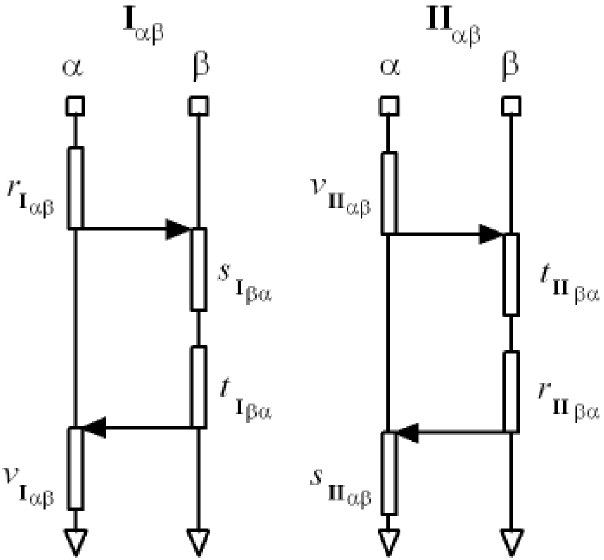
Piaget's theory of social exchanges

Step I



Piaget's theory of social exchanges

Step II



Regulation of social exchanges

- A society is said to be in **social equilibrium** if the balances of exchange values are equilibrated for the successive exchanges occurring along the time;
- **Regulation of social exchanges** refers to controlling social exchanges between agents
  - The balance of exchange values involved in the exchanges are continuously kept - as far as possible - near to equilibrium.

Related and Early Work

- M. Rodrigues and A. Costa (2005-2006):
  - An initial work on an algebra of exchange values;
  - A social-reasoning mechanism and the specification of structures for storing and manipulating exchange values;
  - Application to a political process of lobbying through campaign contributions;
  - However, the approach was not qualitative...
- G. Dimuro and A. Costa (2005):
  - An algebra of qualitative exchange values;
  - Initial approach for manipulating exchange values and reasoning about equilibrated social exchanges;
  - Reinterpretation the politician/voters scenario.
- M. Rodrigues and M. Luck (2006-2010):
  - An approach for the modeling of interactions in open MAS:
  - A system for analysing/evaluating partner selection and cooperative interactions in the Bioinformatics domain, which is characterized by frequent, extensive and dynamic exchanges of services.

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Related and Early Work

- Grimaldo et al. (2007-2008):
  - The coordination of intelligent virtual agents and sociability in a virtual university bar scenario (in a 3D dynamic environment), modeled as a market-based social model, where groups of different types of waiters (e.g., coordinated, social, egalitarian) and customers (e.g., social, lazy) interact with both the objects in the scene and the other virtual agents;
  - A multi-modal agent decision making model, called MADeM, in order to provide virtual agents with socially acceptable decisions, coordinated social behaviors (e.g., task passing or planned meetings), based on the evaluation of the social exchanges.

Related and Early Work

- Franco et al. (2009-2011):
  - Social exchange values are used to support arguments about the assessment of exchanges;
  - Together with the power-to-influence social relationship, those arguments were also used to help the agents to decide about the continuation or the interruption of on-going interactions.
- G. Dimuro and A. Costa (2008-2010):
  - Modeling interactions in the Population-Organization model (PopOrg) - MAS organization model
- R. Barbosa and A. Costa (2009-2011):
  - Social exchanges were model as processes of the CSP formal language for concurrent processes.
- G. Dimuro and A. Costa (2006-2007):
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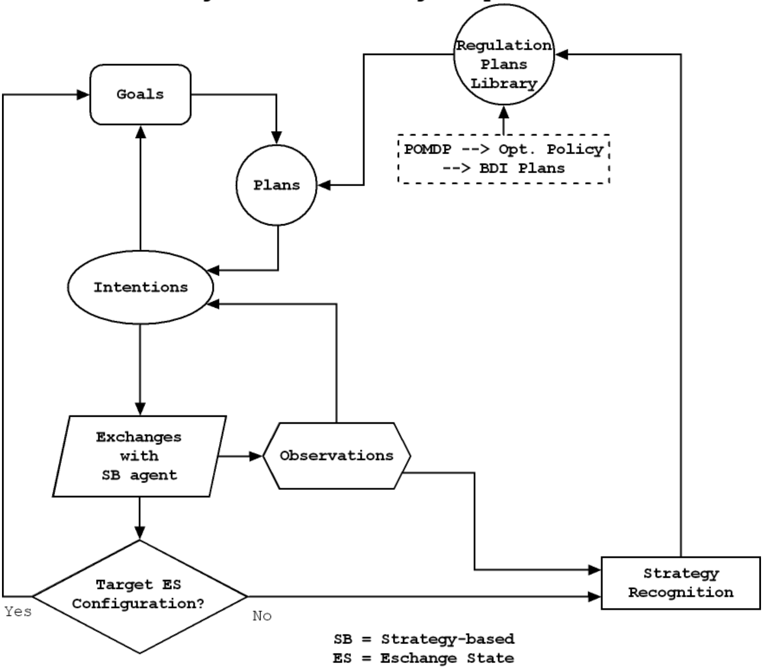
Problem of Self-Regulation of Social Exchanges in Open MAS

The Problem of the Self-Regulation of Social Exchanges in MAS

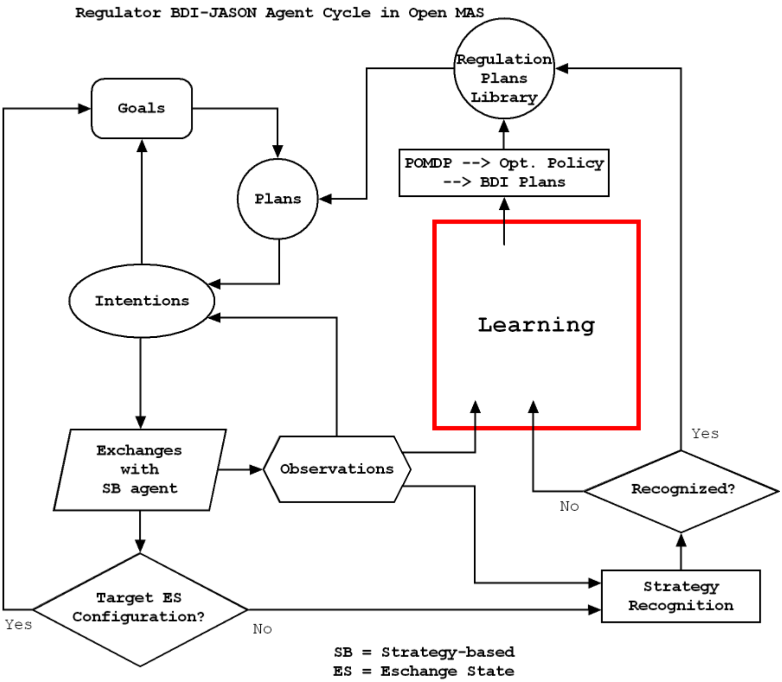
- (D. Pereira et al., 2009-2010);
- We modeled the social exchange regulation problem as POMDPs on the observable agent exchange behaviors, and defined the **policyToBDIplans** algorithm to extract plans for BDI agents from the POMDP optimal policies;
- The derived BDI plans of regulator agents can be applied to “keep in equilibrium” social exchanges performed with BDI agents adopting some known social exchange strategies.

Regulator BDI-JASON Agent Cycle



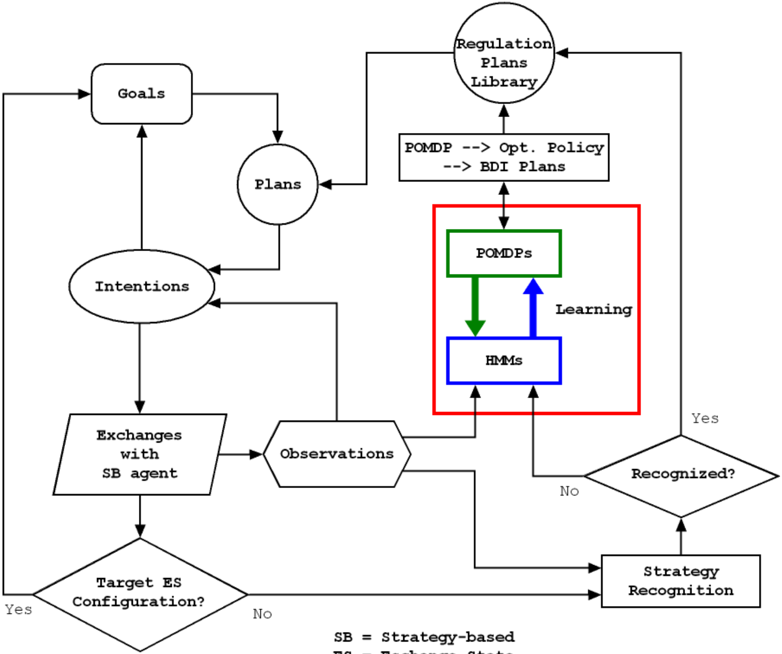
The Social Exchange Regulation Problem in open MAS

- In particular, we are interested in models for recognizing and learning BDI models of social exchange strategies for the regulation of social interactions in open agent societies
  - the agents can enter and leave freely
  - new exchange strategies may appear
  - the agents in the system may modify their strategies
  - the agents may change their roles



Regulator BDI-JASON Agent Cycle in Open MAS
Regulation Plans Library
Goals
Plans
POMDP --> Opt. Policy --> BDI Plans
Intentions
Learning
Exchanges with SB agent
Observations
Yes
Recognized?
No
Target ES Configuration?
Yes
No
Strategy Recognition
SB = Strategy-based
ES = Eschange State

Regulator BDI-JASON Agent Cycle in Open MAS



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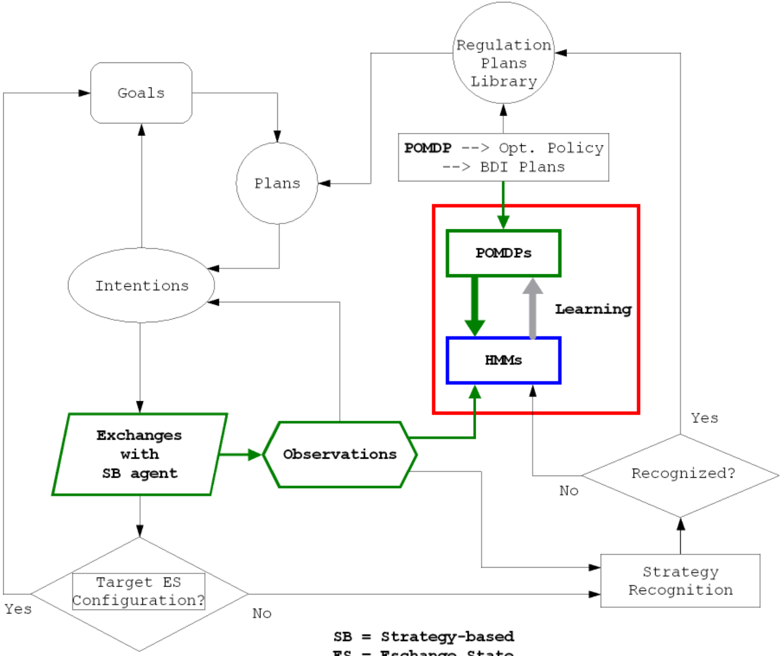

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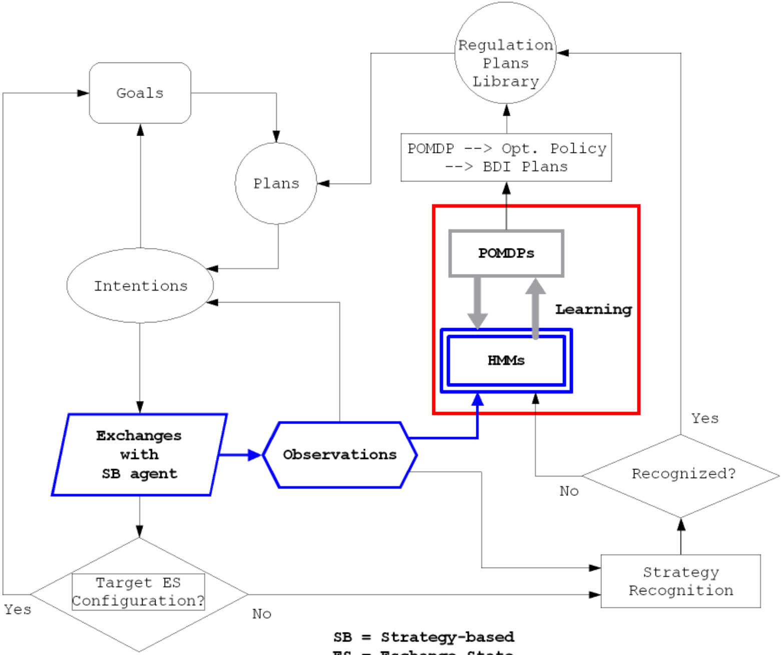

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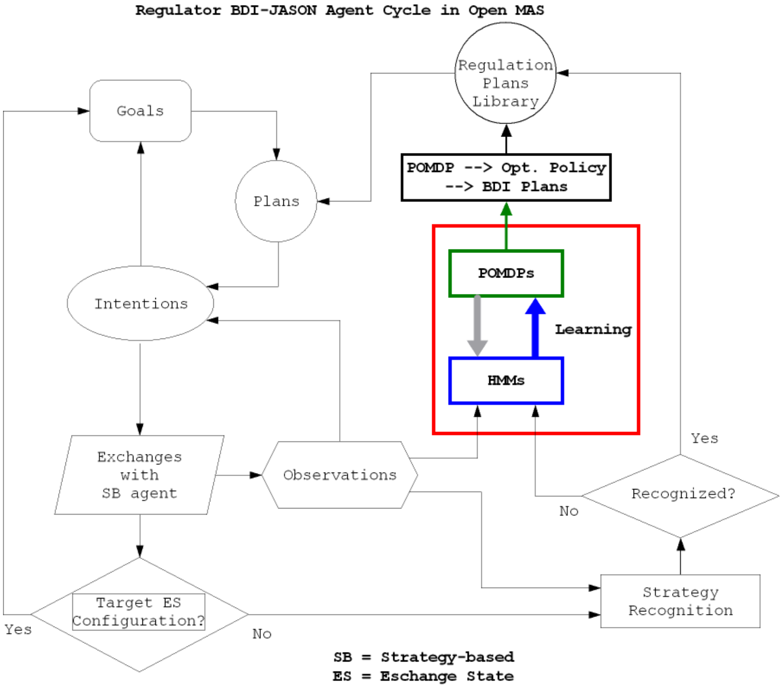
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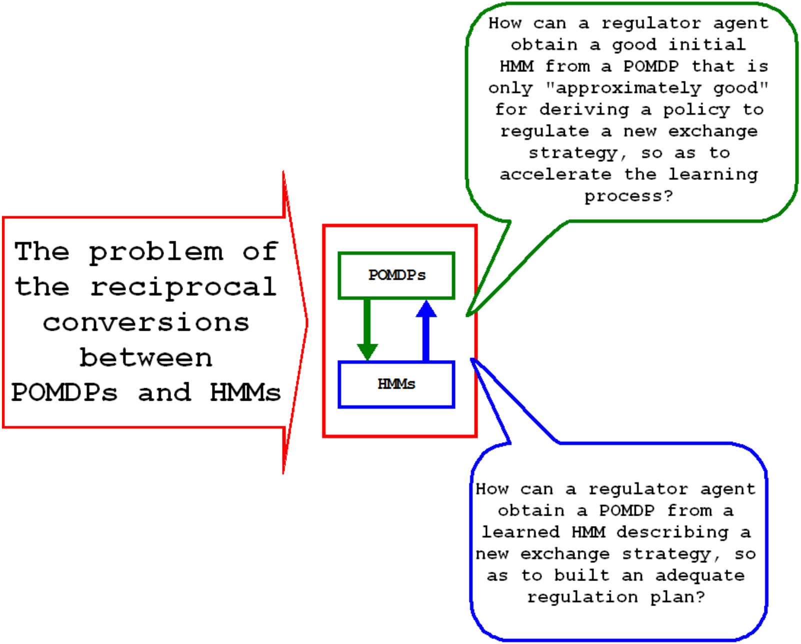
The problem of the reciprocal conversions between POMDPs and HMMs
POMDPs
HMMs
How can a regulator agent obtain a good initial HMM from a POMDP that is only "approximately good" for deriving a policy to regulate a new exchange strategy, so as to accelerate the learning process?
How can a regulator agent obtain a POMDP from a learned HMM describing a new exchange strategy, so as to built an adequate regulation plan?

POMDPs $\leftrightarrows$ HMMs

- The problem arises from the fact that:
  - POMDPs have state transition and observation functions explicitly based on the actions performed by the agents in each state
  - HMMs have state transition and observation functions that are not explicitly related to action performances
- The solution in the **context of the regulation of social exchanges** (L. Gonçalves, 2010-2012):
  - The states of HMMs can be “extended” with the actions, allowing the establishment of an isomorphism between the set of states of the POMDPs and the set of “extended” states of the HMMs
  - Such isomorphism allows the definition of mappings that provide the reciprocal conversions between the models

The POMDP for the Strategy Regulation Problem:

POMDP$_{\alpha\beta}$

The states of the world of the regulation process

- Consider: the regulator agent α, a strategy-based agent β, and the sets of the states of the world, according to the points of view of the each agent:

$$\mathrm{S}_\alpha = \{S_\alpha^1, \ldots, S_\alpha^k\} \text{ and } \mathrm{S}_\beta = \{S_\beta^1, \ldots, S_\beta^l\}$$

- The states of the world for the regulation process are modeled as ordered pairs $(S_\alpha^*, S_\beta^\dagger)$, **denoted by $S_{\alpha\beta}^{*\dagger}$**, with $S_\alpha^* \in \mathrm{S}_\alpha$ and $S_\beta^\dagger \in \mathrm{S}_\beta$, so the set of **the states of the world** is

$$\mathrm{S}_{\alpha\beta} = \mathrm{S}_\alpha \times \mathrm{S}_\beta$$

- α always knows the current state of the world according to its own point of view (S_α^*), but it is not able to determine the current state of the world according to β's ($S_\beta^\dagger$).
  - Thus, α operates in a **partially observable** setting

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Social Exchange Strategy-based Agents

- The agents may have different social exchange strategies that give rise to different **state transition functions**;
- The initial set of social exchange strategies:
  - **Egoistic Strategy**: the agent is mostly seeking his own benefit, with a very high probability to accept exchanges stages in which the other agent performs a service to it;
  - **Altruistic Strategy**: the agent is mostly seeking the benefit of the other, with a very high probability to accept exchanges stages in which it performs a service to the other agent;
  - **Tolerant Strategy**: the agent has a high probability to accept all kinds of exchange proposals.

The state transition and observation functions describing the strategy model of β

- The **set of proposals** that α may make to β:

$$\mathrm{P} = \{p_1, \ldots, p_n\}$$

- β's reactions/responses to α's proposals, in each state, determine probabilistic **state transition functions** of type:

$$T_\beta : \mathrm{S}_\beta \times \mathrm{P} \rightarrow \Pi(\mathrm{S}_\beta)$$

- The **set of observations** that α is able to make on β's reactions/responses to its proposal:

$$\Omega = \{\omega_1, \ldots, \omega_m\}$$

- The probabilistic **observation function** is of type:

$$O_\beta : \mathrm{S}_\beta \times \mathrm{P} \rightarrow \Pi(\Omega),$$

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The POMDP of the Strategy Regulation Problem

- The decision process on the best proposals α can do for an agent β in order to lead both toward the target world state configuration is modeled as a **POMDP**$_{\alpha\beta}$
- Fixing a state S_{α}^{*} among the possible k values in S_{α}, a partitioning of the set of world states $S_{\alpha\beta}$ is possible:

$$S_{\alpha\beta}^{*} = \left\{ S_{\alpha\beta}^{*1}, \ldots, S_{\alpha\beta}^{*l} \right\}, * \in \{1, \ldots, k\}$$

  - k sub-POMDPs, one for each possible state of the world, according to α's point of view: **POMDP**$_{\alpha\beta}^{*}$

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  - *k* sub-POMDPs, one for each possible state of the world, according to α's point of view: **POMDP**$^*_{\alpha\beta}$

The POMDP$^{*}_{\alpha\beta}$ of the Strategy Regulation Problem

$$\text{POMDP}^{*}_{\alpha\beta} = \left(\mathrm{S}^{*}_{\alpha\beta}, \mathrm{P}, T^{*}, \Omega, O^{*}, R^{*}\right), * \in \{1, \ldots, k\}$$

- $\mathrm{S}^{*}_{\alpha\beta}$ is the set of states, P is the set of α's proposals, Ω is the set of observations that may be realized by α, $R^{*} : \mathrm{S}^{*}_{\alpha\beta} \times \mathrm{P} \to \mathbb{R}$ is the reward function for the agent α
- $T^{*} : \mathrm{S}^{*}_{\alpha\beta} \times \mathrm{P} \to \Pi\left(\mathrm{S}_{\alpha\beta}\right)$ is the **state transition function**:

$$T^{*}\left(S^{*\dagger}_{\alpha\beta}, p\right)\left(S^{\star\ddagger}_{\alpha\beta}\right) = \mathbf{T}_{\beta}\left(S^{\dagger}_{\beta}, p\right)\left(S^{\ddagger}_{\beta}\right), \star \in \{1, \ldots, k\},$$

  embedding the **state transition function of β's strategy model**
- $O^{*} : \mathrm{S}^{*}_{\alpha\beta} \times \mathrm{P} \to \Pi(\Omega)$ is the **observation function**:

$$O^{*}\left(S^{*\dagger}_{\alpha\beta}, p\right)(\omega) = \mathbf{O}_{\beta}\left(S^{\dagger}_{\beta}, p\right)(\omega),$$

  embedding **observation function of β's strategy model**

The HMM$^*_{\alpha\beta}$ of the strategy learning problem

- The states of the HMM$_{\alpha\beta}$ are **extended** to specify the kind of proposal that may be performed by α:

$$
\begin{aligned}
\mathrm{SX}_{\alpha\beta} &= \mathrm{S}_\alpha \times \mathrm{S}_\beta \times \mathrm{P} \\
&= \{S^{*\dagger}_{\alpha\beta(\mathbf{p})} \mid * \in \{1, \ldots, k\}, \dagger \in \{1, \ldots, l\}, p \in \mathrm{P}\}
\end{aligned}
$$

- Fixing an extended state S^*_α for α, we obtain k sub-HMMs:

$$\mathrm{HMM}^*_{\alpha\beta} = \left(\mathrm{SX}^*_{\alpha\beta}, \Pi^0_{\mathrm{SX}^*_{\alpha\beta}}, TX^*, \Omega, OX^*\right), * \in \{1, \ldots, k\}$$

  - $\mathrm{SX}^*_{\alpha\beta}$ is the set of extended states
  - $\Pi^0_{\mathrm{SX}^*_{\alpha\beta}}$ is the initial probability distribution of the set of states
  - Ω is the set of observations that may be realized by α about β's reactions/responses
  - $TX^* : \mathrm{SX}^*_{\alpha\beta} \to \Pi(\mathrm{SX}_{\alpha\beta})$ is the state transition function and $OX^* : \mathrm{SX}^*_{\alpha\beta} \to \Pi(\Omega)$ is the observation function, **both patterned on β's strategy model**

The $\text{HMM}^{*}_{\alpha\beta}$ of the strategy learning problem

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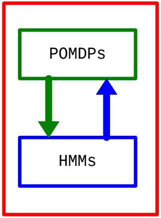
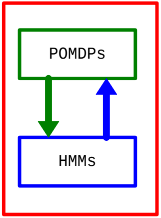
The Conversion Procedures



The fundamental isomorphisms

For all $* \in \{1, \ldots, k\}$: $\mathrm{S}^*_{\alpha\beta} \times \mathrm{P} \equiv \mathrm{SX}^*_{\alpha\beta}$ and $\Pi\left(\mathrm{S}^*_{\alpha\beta}\right) \equiv \Pi\left(\mathrm{SX}^*_{\alpha\beta}\right)$

The commutative diagram and the conversion theorems of state transition functions

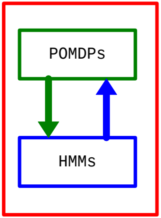


$$
\begin{tikzcd}
\mathrm{S}^*_{\alpha\beta} \times \mathrm{P} \arrow[r, "T^*"] \arrow[d, shift right, "f"'] & \Pi\left(\mathrm{S}^*_{\alpha\beta}\right) \arrow[d, shift right, "g_{\mathrm{P}}"'] \\
\mathrm{SX}^*_{\alpha\beta} \arrow[r, "TX^*"'] \arrow[u, shift right, "f^{(-1)}"'] & \Pi\left(\mathrm{SX}^*_{\alpha\beta}\right) \arrow[u, shift right, "(g_{\mathrm{P}})^{(-1)}"']
\end{tikzcd}
$$

$$
TX^*\left(S^{*\dagger}_{\alpha\beta(p)}\right)\left(S^{\star\dagger'}_{\alpha\beta(p')}\right) = \pi_{(p')} \cdot T^*\left(S^{*\dagger}_{\alpha\beta}, p\right)\left(S^{\star\dagger'}_{\alpha\beta}\right)
$$

The commutative diagram and the conversion theorem of observation functions

$$OX^* = O^* \circ (f^*)^{(-1)}$$



$$\begin{tikzcd}
\Pi(\Omega) & & \mathrm{S}^*_{\alpha\beta} \times \mathrm{P} \arrow[ll, "O^*"'] \arrow[d, shift right, "f"'] \\
& & \mathrm{SX}^*_{\alpha\beta} \arrow[ull, "OX^*"] \arrow[u, shift right, "f^{(-1)}"']
\end{tikzcd}$$

$$OX^*\left(S^{*\dagger}_{\alpha\beta(p)}\right)(\omega) = O^*\left(S^{*\dagger}_{\alpha\beta}, p\right)(\omega)$$

Regulation of Social Exchanges in Open Mas: Simplified model of non-economic social exchanges between two agents α and β

Social exchanges between two agents α and β: the POMDP$^*_{\alpha\beta}$ regulation model

- Set of service proposals that may be done by α:

$$\mathrm{P} = \{\textit{offer\_service}, \textit{request\_service}\}$$

- If β **accepts** the proposal, then a **service exchange stage happens**, and both agents evaluate the results of the exchange
- The accumulated exchange evaluations are classified into ranges: S^θ (**equilibrated**), S^- (**unfavorable**) or S^+ (**favorable**) results, determining the states of the world according to each agent point of view

$$\mathrm{S}_\alpha = \left\{S^-_\alpha, S^\theta_\alpha, S^+_\alpha\right\} \text{ and } \mathrm{S}_\beta = \left\{S^-_\beta, S^\theta_\beta, S^+_\beta\right\}$$

- Set of states of the POMDP$^*_{\alpha\beta}$ regulation model, for each $* \in \{-, \theta, +\}$:

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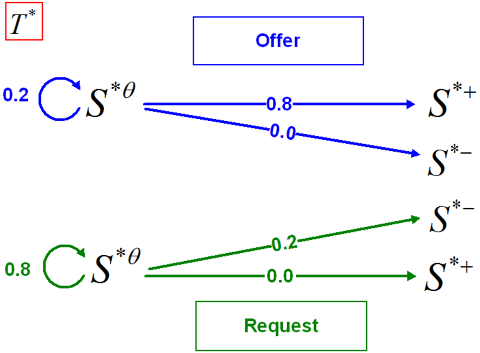
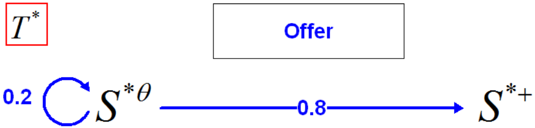
The POMDP$^{*}_{\alpha\beta}$ regulation model

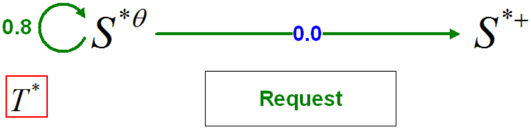
- State transition and observation functions embed the exchange strategy adopted by β:

  Example: the *egoism-80* strategy model – Probability of **accepting service offerings** and **refusing service requests** around 80%



POMDP$^*_{\alpha\beta}$ $\Rightarrow$ HMM$^*_{\alpha\beta}$
The conversion process from T^* to TX^*





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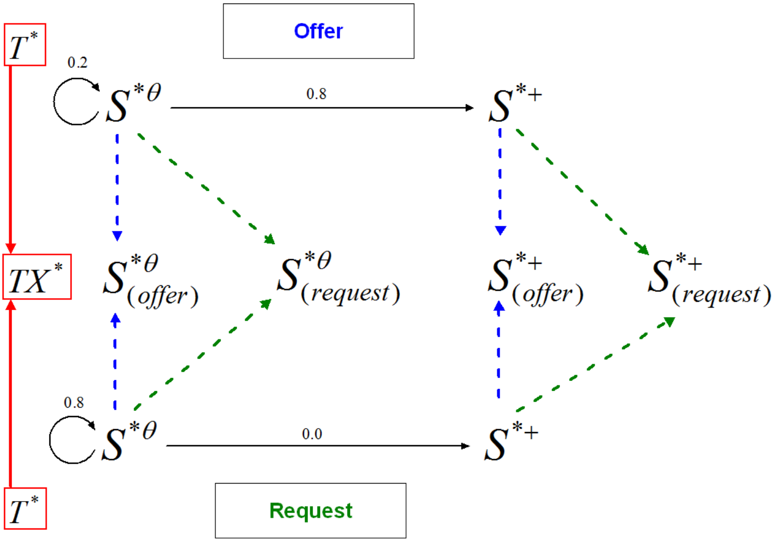

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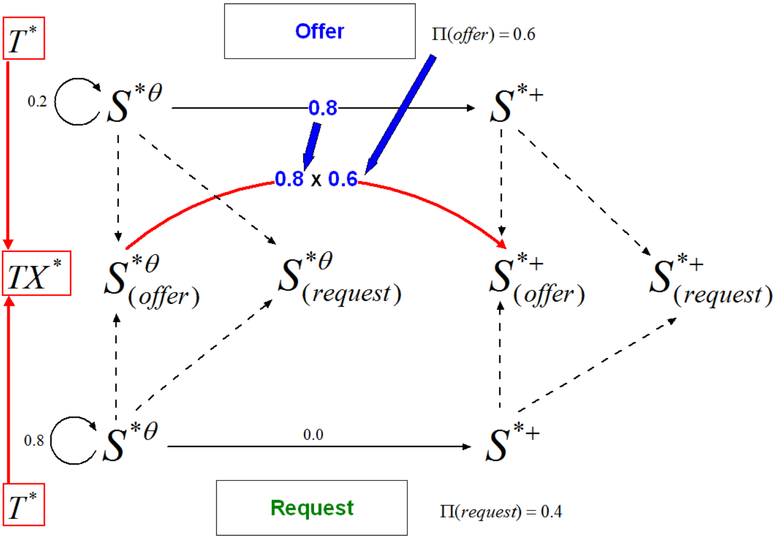

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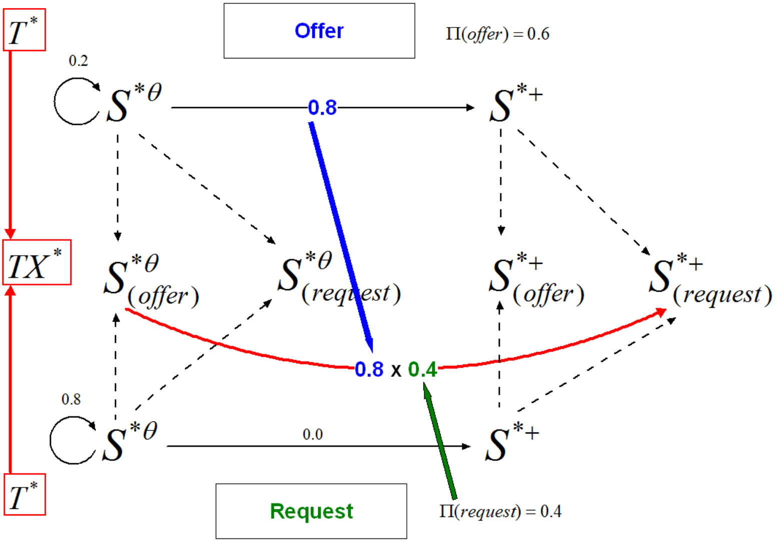

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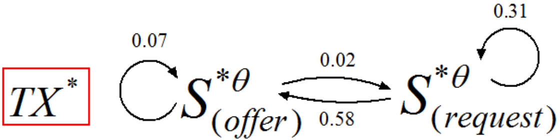

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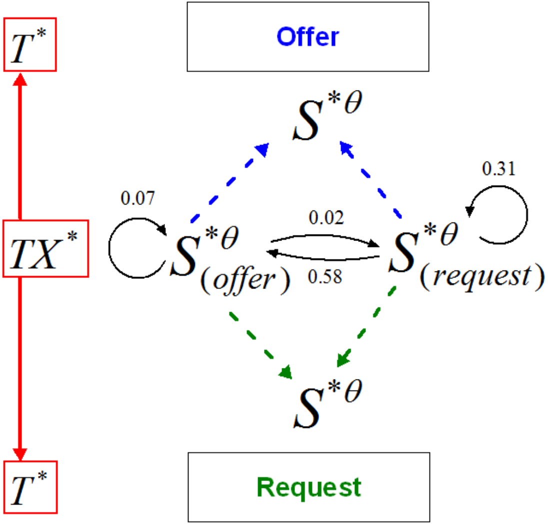

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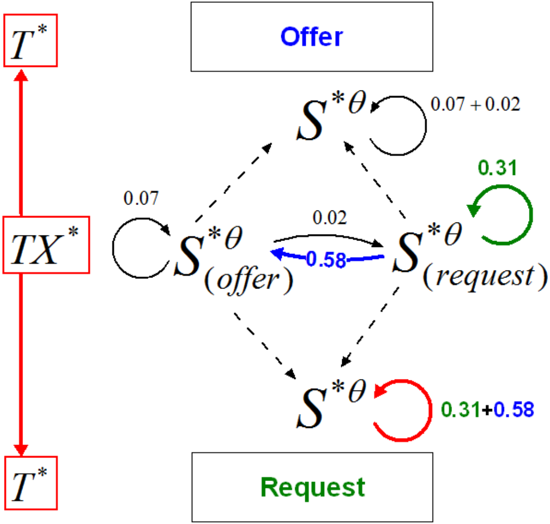

$\text{HMM}^*_{\alpha\beta} \Rightarrow \text{POMDP}^*_{\alpha\beta}$
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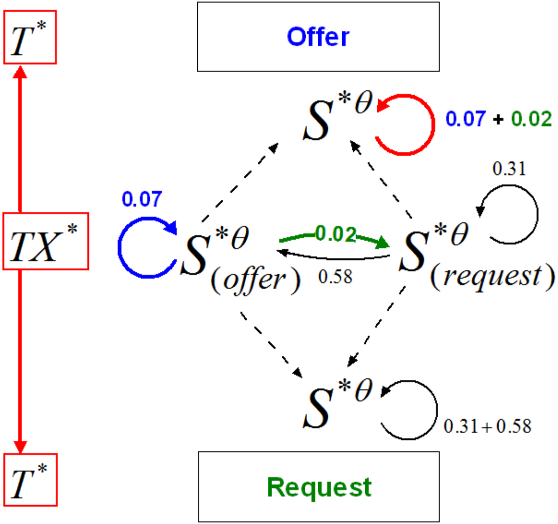
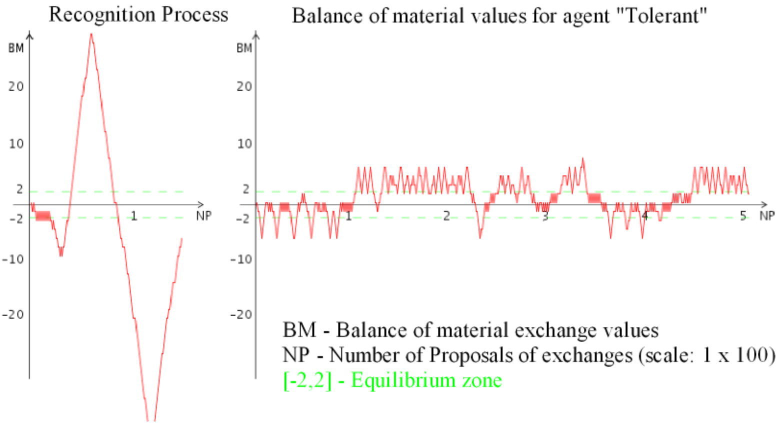
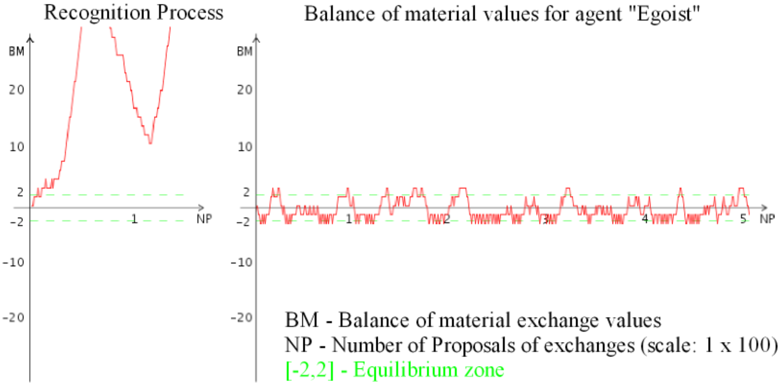


Some Simulations

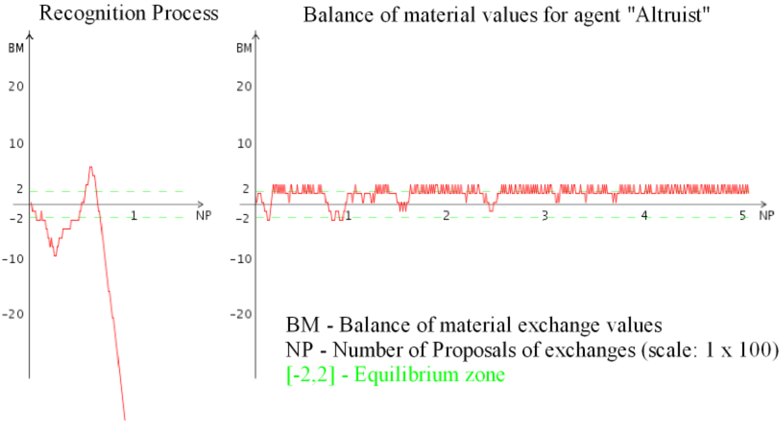
Recognizing and regulating a Tolerant strategy



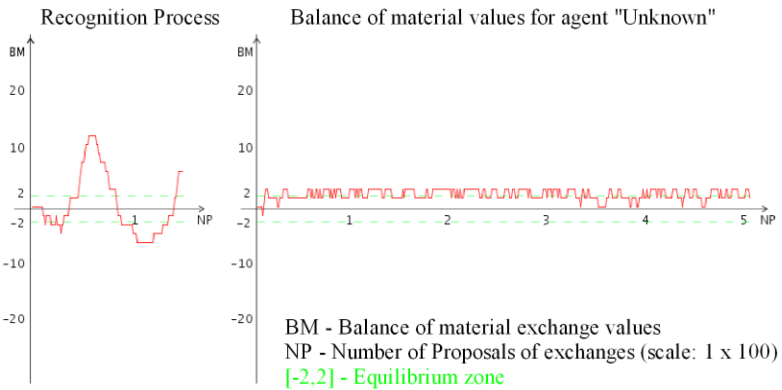
Recognizing and regulating an Egoistic strategy



Recognizing and regulating an Altruistic strategy



Learning and regulating an unknown strategy



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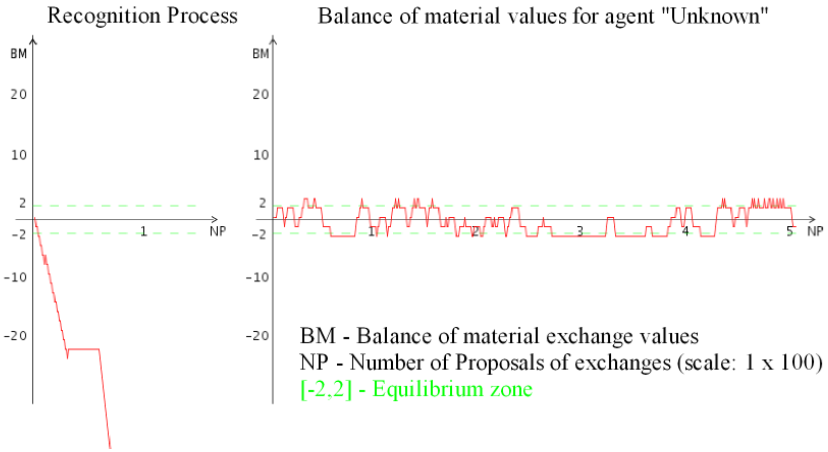

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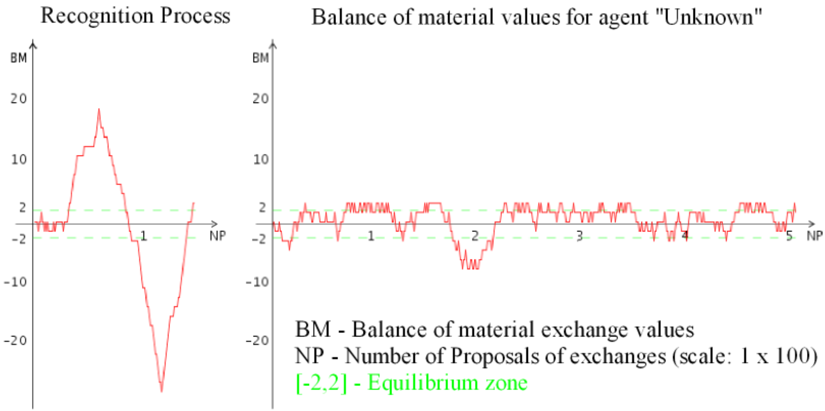

Final Remarks and Ongoing Work

- Joint with F. Macedo, M. Aguiar and Helder Coelho: Self-regulation of exchange processes - an evolutionary and spatial approach based on game theory (preliminary version in BWSS 2012);
- Joint with G. Farias: fuzzy BDI agents for exchange processes (to appear);
- Joint with A. Laer and M. Aguiar: cultural and evolutionary BDI MAS for the self-regulation of exchange processes (to appear);
- Joint with F. Santos, and D. Adamatti and Glenda Dimuro (Universidad of Sevilla): modeling and simulation of social production and management processes in an urban vegetable garden of Sevilla (ESSA 2013)
  - JaCaMo framework (Moise+, Jason, Cartago)

Thank you for your attention!

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Diego Pereira and Luciano Gonçalves!

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