Role Evolution in Open Multi-Agent Systems as an Information Source for Trust

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Outline

1. Introduction
2. Organisational information
3. Evolution of Roles Taxonomies
   - Basics
   - Clustering algorithm
   - Mechanism flow
4. Experiments
   - OMAS simulation
   - Results
5. Conclusions
Open MAS

In Open MAS:

- Agents may join and leave the system at their will
- Agents’ individual design may be heterogeneous
- Interactions among agents are rarely repeated

So...

- Static prescription to enforce desired behaviours does not work
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- Static prescription to enforce desired behaviours does not work
- Adaptive mechanisms should be endowed to obtain desired results
Organisational structures

- Organisational facilities to structure MAS: roles, hierarchies, norms, ...
- Most of the times are conceived as static design patterns that regulate agent’s behaviour
- Autonomous agents always have some freedom of choice (for next action to do)
- Organisational structures might be used to improve agent’s behaviour
Decision making processes in Open MAS

- How to choose a "good" counterpart to interact with
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Our work → how agents can use organisational structures to determine "good" partners (for them) to interact with
Trust models

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5. To know what is good for you could be useful for others
Our approach

Main assumption:
- Information provided by agents in an Open MAS may be shared to help others
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   - Build organisational structures (role hierarchies) using information about trust among agents (TRUST NETWORK)
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5. When to do that:
   - Depends on system’s policies (out of this talk)
What do we propose?

- A mechanism that makes use of the information managed by agents’ trust models so as to create and evolve role taxonomies
- An appropriate role taxonomy should help agents to select agents with which interact
- evolution = modification (so far extension with new roles)
- New roles: more specialised and better in terms of expected utility
- Taxonomy evolution provides agents with more precise information, helping them to take better decisions
- We propose an adaptive mechanism that evolves role taxonomies by using a multidimensional clustering algorithm to capture behavioural patterns among agents
Our approach

- Open MAS +
Our approach

- Open MAS +
- Rational agents +
Our approach

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- Role as an atomic piece of reasoning +
Our approach

- Open MAS +
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- Role as an atomic piece of reasoning +
- An adaptive mechanism (based on trust measures) that evolves role taxonomies by using a multidimensional clustering algorithm to capture behavioural patterns among agents
Role definition

Let $O$ be an OMAS and $\mathcal{A}g$ the set of agents participating in it. $\mathcal{A}$ is the set of possible actions that the environment allows agents to carry out. Among those, we can distinguish a subset $S \in \mathcal{A}$ representing the set of service type interactions. Let $\mathcal{R}$ be a set of role identifiers. Then, a role in an OMAS is defined as a pair $\langle r, \mathcal{E} \rangle$ where

- $r \in \mathcal{R}$ is the role identifier;
- $\mathcal{E} = \{s_1, ..., s_n\}$, where $s_i \in S$ is a finite set of (service type) interactions.
Semantics of a role \( \langle r, \mathcal{E} \rangle \equiv \) agents playing the role \( r \) are qualified providers of the interactions contained in \( \mathcal{E} \) in the sense that they are ”skilful” for providing the services.

We assume that all agents could provide any service, but only are qualified for a subset of them.
A role specialization taxonomy in an OMAS $O$ is a tuple $\mathcal{RT} = (R, \succ_r)$ consisting of a set $R$ of roles in $O$ and a partial ordering $\succ_r$ on $R$, such that:

1. $\exists r_{\text{root}} = (r_r, \mathcal{E}_r) \in R:\quad \mathcal{E}_r = S \land \forall r \in R : (r = r_{\text{root}} \lor r_{\text{root}} \succ_r r)$

2. $\forall (r_1, \mathcal{E}_{r_1}), (r_2, \mathcal{E}_{r_2}) \in R : (r_1, \mathcal{E}_{r_1}) \succ_r (r_2, \mathcal{E}_{r_2}) \iff \mathcal{E}_{r_2} \subseteq \mathcal{E}_{r_1} \land$

$$\forall s \in \mathcal{E}_{r_2} : \quad \frac{\sum_{a \in Ag} \sum_{b \in ag(r_2)} u_a(b, s)}{|ag(r_2)| \cdot |Ag|} > \frac{\sum_{a \in Ag} \sum_{b \in ag(r_1)} u_a(b, s)}{|ag(r_1)| \cdot |Ag|}$$
Organisational information IV

- $r_1, r_2 \in R$ then $r_1 \succ_r r_2$ iff. there is a subset of services from $r_1$ on which agents playing role $r_2$ perform better, on average, than agents playing role $r_1$

- Special case: a top role - the root of the taxonomy $\langle r_{\text{root}}, E_{\text{root}} \rangle$
  - Defined for all service-type interactions,
  - Does not specialise any other role, and
  - Every agent in an OMAS plays at least the top role

- Role taxonomies are publicly provided by the OMAS
  - Source of information to help agents to reason about what to do
  - Specially interesting for newcomers
Example

Role *Surgeon* could be created to fill the gap existing among the *Physicians* that are "*good*" - and accordingly trusted by others - at operating and those which do not reach a minimum level of quality to operate.
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Evolving role taxonomies

What do we propose?

- An **adaptive** mechanism that (re-)builds the structure of a role taxonomy by capturing behavioural patterns of agents within the OMAS, gathering trust estimations

- Adaptation $\equiv$ creation of new roles that specialise existing ones
Evolving role taxonomies

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Use clustering methods to capture behavioural patterns of agents providing service-type interactions.

Identify groups of agents that perform a set of tasks better than others and reflect such cases in form of a new role.

A trust space ($TS$) over which build clusters can be defined as:

$$TS_{r_k} = \{ \widehat{a} = (t_1, t_2, \ldots, t_n) | a \in A_g \text{ and } a \text{ enacts } r_k \}$$

The evolution of the role taxonomy depends on the group of agents in a given time within the OMAS.
Clustering algorithm

- K-Means
- Each execution is applied to each $TS_{r_i}$ where $r_i \in RT$ (role taxonomy)
- The whole cluster represents a pattern of behaviour
- Cluster filtering:
  1. We do not want to create "bad-behavioured" roles
  2. At least there should be more than $x$ agents
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An example:
The mechanism calculates the trust space for root role
K-means algorithm is then applied
If filters are passed a new role is created.
1. Useful for newcomers

2. Useful for long-term periods (how to realise something is changing in the society!)

3. Useful for contracting combined services (best roles for several interactions)
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OMAS simulation I

1. Agents capabilities for different interactions are built on a normal distribution
   - Mean: average behaviour
   - Standard deviation: changes in the behaviour

2. Heterogeneity on requesters’ utility functions:
   - TYPE A
   - TYPE B → noise

3. Changes on the population:
   - Every $t$ time steps some agents join/leave
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Test configuration

Scenarios:
- Heterogeneity
- Openness
(a) Overall utility (Mech. usage vs. No Mech. usage)

With mech. (75% type A)

Without mech. (75% type A)

With mech. (25% type A)

Without mech. (25% type A)
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(b) Overall utility with 10% changes on users' population

Utility with mech. vs without mech.

Time

0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
10
20
30
40
50
60

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We have presented:

- An adaptive mechanism to evolve role taxonomies
- A "well-formed" taxonomy can help agents to take decisions
- Evolution is supported on how trusted the agents which play the roles are considered
- Clustering algorithm to capture common behavior
- Evolution consists of creating new roles.
Conclusions II

Ongoing work:

- Define when the mechanism should start to run
- Define the possibility of removing roles besides creating new ones
- Modifying existing roles entails:
  1. re-allocating agents that were enacting those roles
  2. defining policies to allocate agents when these join the system for the first time
THAT’S ALL

Thank you for your attention!
Any question?