Towards modelling of reactive, goal-oriented and hybrid intelligent agents using P Systems

Thank you!
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Agents and Multi-Agent Systems (MAS)
Formal Modelling of MAS
A MAS Scenario including goal-oriented agents
The main Propopal (agent P Systems)
Agents and Multi-Agent Systems (MAS)
Agents:
- perceive their environment,
- react immediately if it is necessary (reactive behaviour)
- update their beliefs,
- revise their strategies,
- prioritise their goals and
- develop plans to achieve these goals (proactive or goal-oriented behaviour).

MAS are built upon the social behaviour of individual agents that can:
- communicate,
- collaborate and
- negotiate in order to achieve their shared or individual goals.
Reactive Agents
The agents operation is based around a hierarchy of behaviours which resemble simple if-then rules

if situation then action
Belief Desire Intentions (BDI) Agents

- Intentions
- Desires, the
- Beliefs, the

[Belief-Desire-Intention diagram]

which may
Belief-Desire-Intention (BDI) agents are based on:

- **Beliefs**, the information an agent has about the environment, which may be false
- **Desires**, the things that the agent would like to see achieved
- **Intentions**, the goals that the agent is committed to

Practically:
- desires are shrunk down to one, the general raison d'être of the agent.
- plans are not generated but are ready made
- the current goal is the intention that is picked up for deliberation
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Formal Modelling of MAS
State Based Models

State-based methods (e.g. X-Machines) are highly suitable for modelling the internal state of agents.

Problems arose when having to deal with the dynamics of the structure of a system consisting of multiple agents.

MAS are:
- highly interactive,
- highly parallel and
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MAS are:

- highly interactive,
- highly parallel and
- highly dynamic
interactive,

parallel and dynamic

change of organisation
change of roles
change in configuration
change of organisation
change of roles
change in configuration
It is only natural to consider population P systems as a suitable candidate for MAS modelling.
Comparison (see AMCA-POP Workshop)
<table>
<thead>
<tr>
<th>Modelling feature</th>
<th>CXS</th>
<th>tPS</th>
<th>PCol</th>
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<tr>
<td><strong>Individual Agents</strong></td>
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<td>Agent internal state representation</td>
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<td><strong>Communication</strong></td>
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<td>x</td>
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<tr>
<td>Removal of agent instances on the fly</td>
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A MAS Scenario including goal-oriented agents
A disaster area with civilians injured in between obstacles and ruins.

Rescue units are equipped with the necessary first aid kit and could provide help to injured civilians, thus temporarily rescuing victims from immediate danger. They can then broadcast the exact coordinates to the agents in their neighbourhood.

Ambulance vehicles are capable of approaching the temporarily rescued civilians and carry them to a more secure establishment (e.g. emergency room or ER).

- RU would be reactive agents
- AV would be goal-oriented agents which need to form plans to satisfy their goals but also have a reactive layer on top
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- RU would be reactive agents
- AV would be goal-oriented agents which need to form plans to satisfy their goals but also have a reactive layer on top
if there is an obstacle then avoid obstacle
if injured civilian is detected then
    provide first aid to victim and inform nearby agents about location
if empty space then move randomly
if there is an obstacle then avoid obstacle ⏐
if at ER then upload the injured civilians ⏐
if load reached the maximum capacity then move towards the ER ⏐
if injured civilian is detected and not at ER then pick up victim
Keep the seed identical in the same experiments in order to compare accurately models (Deterministic behaviour of models).
The requirements for modelling are:

- modelling of individual separate agents of various types is necessary;
- the agent models should be developed with non-trivial data structures and their accompanying operations;
- there must be a way to code the rules for behaviours within an agent, including the communication behaviour;
- it is essential to set up priorities on these behaviours for the agent to perform the desired overall task;
- describing the change in communication links is desirable according to some "neighbouring" criteria;
- modelling of agents roles, generation and destruction must be possible in order to model the dynamic configuration of the system;
- agents in a MAS could operate in parallel exhibiting an asynchronous behaviour;
The main Proposal (agent P Systems)
\( \mathcal{P} = (V, \Phi, T, \gamma, \alpha, w_E, A_1, A_2, \ldots, A_n, R_b, R_s, O_b, O_r, O_p) \)
Agents as Cells
Each agent can be directly mapped to a cell.

- Four types of cells:
  - a rescue unit (RU)
  - an ambulance vehicle (AV)
  - a civilian victim (CV) and
  - an emergency room (ER).
Data Structures and Objects
Objects within cells should be more than multisets of symbols.

The absolutely necessary subsets of objects required for a goal-oriented agent are:
(a) a set of Beliefs,
(b) a set of Goals and
(c) a set of internal agent States, and
(d) a set of incoming Messages.

In practical modelling, we would need some sort of notation that differentiates objects according to the set they belong
\[ B = \{(\text{victim\_at \ } X \ Y), (\text{er\_at \ } X \ Y), \ldots\} \text{ where } X, Y \in N, \]
\[ G = \{(\text{pickup\_victim \ } X \ Y), (\text{move\_towards \ } X \ Y), (\text{leave\_victim\_at\_er}) \ldots\}, \]
\[ \text{States} = \{\text{doing\_nothing}, \text{rescuing}, \text{moving\_to\_er}, \ldots\}, \]
\[ \text{IncomingMessage} = \{((\text{found\_victim\_at \ } X \ Y), \ldots) \} \text{ etc.} \]

\[ B : (\text{victim\_at \ } 3 \ 8), \ \text{State} : \text{rescuing}, \ \text{Pos} : (4 \ 5), \]
\[ \text{ListOfGoals} : \langle (\text{move\_towards \ } 6 \ 7), (\text{leave\_victim\_at\_er}), \ldots \rangle, \]
\[ \text{IncomingQueue} : \langle ((\text{found\_victim\_at \ } 6 \ 7), (\text{found\_victim\_at \ } 9 \ 1), \ldots) \rangle, \text{ etc.} \]
Behaviours and Rewrite/Communication Rules
• Reactive behaviours can be modelled as a set of transformation rules

• Proactive behaviours, such as updating beliefs, adding goals to the list or executing primitive goals (actions) can be modelled in a similar way.

Communication rules are used:
• to pass messages to cells that are linked through the graph structure.
• to perceive the environment
The performatives:
  • broadcast
  • perceive and
  • output
are equivalent to the commonly used in membrane computing
in
  • enter and
  • exit.
avoid_obstacle : (State : moving_to_er Obstacle : (X Y) Pos : (X_1 Y_1) Direction : D if (next_to X Y X_1 Y_1) → State : moving_to_er Obstacle : (X Y) Pos : (X_1 Y_1) Direction : D' where (random D'))_{AV}

send_victim_position :
(B : (victim_at 4 2); incoming_message : (found_victim_at 4 2), broadcast)_{RU}

perceive_obstacle :
Pos : (X Y); Obstacle : (X_1 Y_1) if (within_range X Y X_1 Y_1), perceive)_{AV}
Priorities of Behaviours
In order to achieve the correct overall agent behaviour, individual behaviours including communication should be ordered.

At a lower level ordering between rules within the same type must exist.

Restrictive effect on the maximal parallelism of the P system, which however for MAS modelling purposes is acceptable.
\[ \text{broadcast rules} \preceq \text{perceive rules} \prec \text{reactive rules} \prec \text{proactive rules} \preceq \text{output rules} \]

\[ \text{avoid_obstacle} \preceq \text{upload_victims} \prec \text{move_towards_evil} \prec \text{pick_up_victim} \]
Communication Links and Bond Making
The graph denotes the communication between cells, e.g. neighbouring RUs and AVs have a direct communication etc.

The graph connecting the cells is by no means fixed.

Depending on the problem, the notion of neighbourhood between cells can be defined.
connect_neighboring_agents : (AV, Pos : (X_{av} Y_{av}); Pos : (X_{ru} Y_{ru}), RU)
if (neighbours X_{av} Y_{av} X_{ru} Y_{ru})
Dynamic Structure and Cell Differentiation/Division/Death
New agents appear into the system
Some agents change role
Eventually some agents disappear.
out_of_order : (fuel : 0)_{RU} \rightarrow \dagger
So ....
Open Issues

A more concrete and precise definition, including the theoretical BDI model as well as the detailed computation steps

We need to identify other practical issues raised by such modelling

The main question is whether the constructs of the aP are adequate to map a MAS

This will lead us to the design and implementation of a tool that animates the models, along the lines of previous work done both textually and visually
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