CMC 11
Jena, August 2010

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

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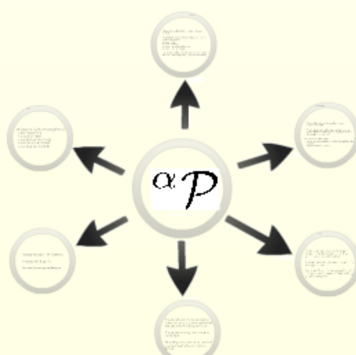
Formal Modelling of MAS

Agents and Multi-Agent Systems (MAS)

A MAS Scenario including goal-oriented agents

The main Proposal (agent P Systems)



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

Thank you!

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Agents and Multi-Agent Systems (MAS)

Agent Properties

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

Belief-Desire-In

- Beliefs, the
  which may
- Desires, the
- Intentions,

Belief Desire Intentions (BDI) Agents

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 shrink down to one, the general raison d'etre 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

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
- highly dynamic

change of organisation
change of roles
change in configuration

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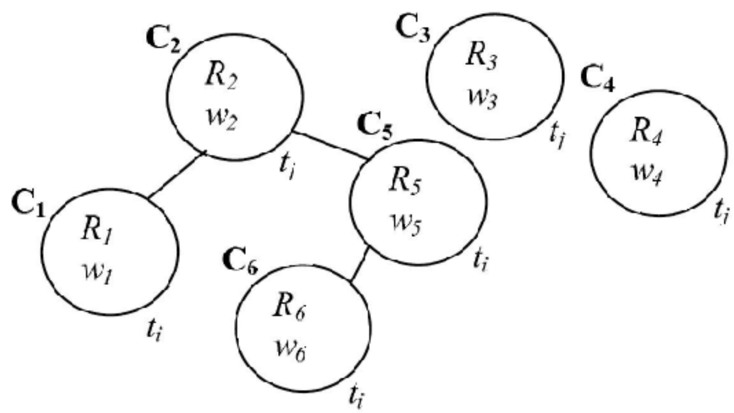
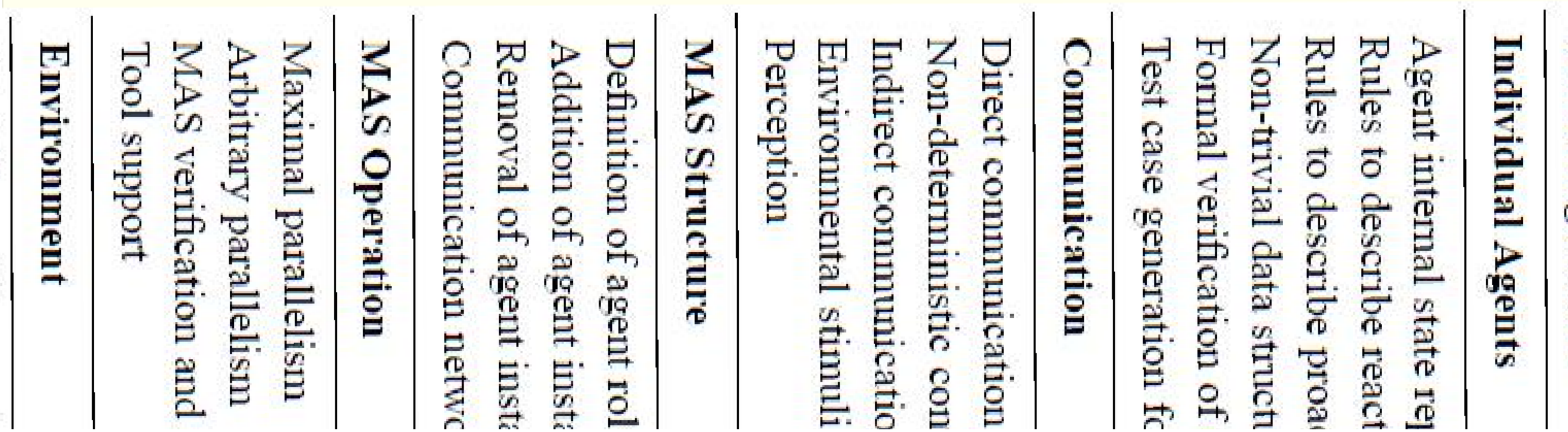
Membrane Models

It is only natural to consider
Population P systems
as a suitable candidate
for MAS modelling.



Comparison (see AMCA-POP Workshop)


Individual Agents
Agent internal state re
Rules to describe react
Rules to describe proa
Non-trivial data struct
Formal verification of
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Communication
Direct communication
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MAS Structure
Definition of agent rol
Addition of agent insta
Removal of agent insta
Communication netwo
MAS Operation
Maximal parallelism
Arbitrary parallelism
MAS verification and
Tool support
Environment

Comparison (see AMCA-POP Workshop)

Modelling feature	CXS	tPS	PCol	PPS
Individual Agents				
Agent internal state representation	√	×	×	×
Rules to describe reactive behaviour	√	×	√	×
Rules to describe proactive behaviour	×	×	×	×
Non-trivial data structures for beliefs, goals, messages, stimuli etc	√	×	×	×
Formal verification of individual agents	√	×	×	×
Test case generation for individual agents	√	×	×	×
Communication				
Direct communication and message exchange	√	√	×	×
Non-deterministic communication	×	√	√	√
Indirect communication through the environment	×	√	√	√
Environmental stimuli (input)	√	√	√	√
Perception	×	×	×	×
MAS Structure				
Definition of agent roles	√	√	×	√
Addition of agent instances on the fly	×	×	×	√
Removal of agent instances on the fly	×	×	×	√
Communication network restructuring	×	×	×	√
MAS Operation				
Maximal parallelism	√	√	√	√
Arbitrary parallelism	√	√	√	√
MAS verification and testing	×	×	×	×
Tool support	√	×	×	√
Environment				
Modelling of the environment	×	√	√	√

A MAS Scenario including goal-oriented agents

A disaster area with civilians injured in between obstacles and ruins.

Rescue Agents

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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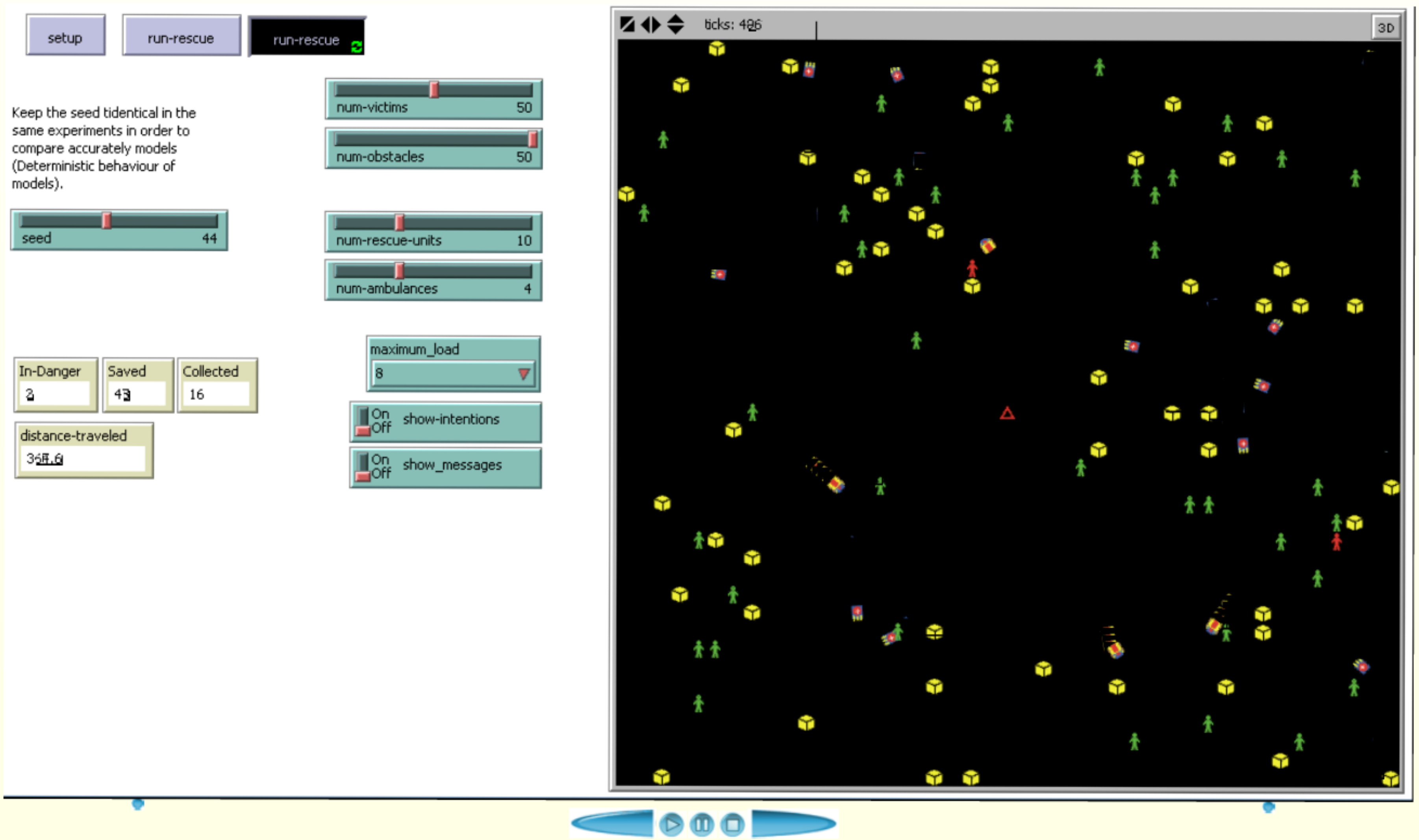
$$
\begin{aligned}
&if\ there\ is\ an\ obstacle\ then\ avoid\ obstacle\ \succ \\
&if\ injured\ civilian\ is\ detected\ then \\
&\quad provide\ first\ aid\ to\ victim\ and\ inform\ nearby\ agents\ about\ location\ \succ \\
&if\ empty\ space\ then\ move\ randomly
\end{aligned}
$$

if there is an obstacle then avoid obstacle $\succ$
if at ER then upload the injured civilians $\succ$
if load reached the maximum capacity then move towards the ER $\succ$
if injured civilian is detected and not at ER then pick up victim


setup
run-rescue
run-rescue
Keep the seed tidentical in the same experiments in order to compare accurately models (Deterministic behaviour of models).
seed 44
num-victims 50
num-obstacles 50
num-rescue-units 10
num-ambulances 4
maximum_load
8
In-Danger
Saved
Collected
16
distance-traveled
On Off show-intentions
On Off show_messages
3D

Requirements for modelling

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 Propopal (agent P Systems)

$\alpha\mathcal{P}$

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).

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

- 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

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.

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.

New agents appear into the system

Some agents change role

Eventually some agents disappear.

$\alpha\mathcal{P}$

$${}^{\alpha}\mathcal{P} = (V, \Phi, T, \gamma, \alpha, v_P, A_1, A_2, \ldots, A_n, R_b, R_c, O_b, O_c, O_y)$$

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Agents as Cells

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- Four types of cells:
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Data Structures and Objects

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$$B = \{(victim\_at\ X\ Y), (er\_at\ X\ Y), \ldots\} \text{ where } X,\ Y \in N,$$
$$G = \{(pickup\_victim\ X\ Y),\ (move\_towards\ X\ Y),\ (leave\_victim\_at\_er) \ldots\},$$
$$States = \{doing\_nothing,\ rescuing,\ moving\_to\_er, \ldots\},$$
$$IncomingMessage = \{(found\_victim\_at\ X\ Y), \ldots\} \text{ etc.}$$

$$B : (victim\_at\ 3\ 8),\ State : rescuing,\ Pos : (4\ 5),$$
$$ListOfGoals :\ \langle (move\_towards\ 6\ 7), (leave\_victim\_at\_er), \ldots \rangle,$$
$$IncomingQueue : \langle (found\_victim\_at\ 6\ 7),\ (found\_victim\_at\ 9\ 1), \ldots \rangle, \text{ etc.}$$

Behaviours and Rewrite/Communication Rules

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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.

$$avoid\_obtacle : (State : moving\_to\_er\ Obstacle : (X\ Y)\ Pos : (X_1\ Y_1)\ Direction : D \text{ if } (next\_to\ X\ Y\ X_1\ Y_1) \rightarrow State : moving\_to\_er\ Obstacle : (X\ Y)\ Pos : (X_1\ Y_1)\ Direction : D' \text{ where } (random\ D'))_{AV}$$

$$send\_victim\_position : (B : (victim\_at\ 4\ 2);\ incoming\_message : (found\_victim\_at\ 4\ 2),\ broadcast)_{RU}$$

$$perceive\_obstacle : Pos : (X\ Y);\ Obstacle : (X_1\ Y_1) \text{ if } (within\_range\ X\ Y\ X_1\ Y_1),\ perceive)_{AV}$$

Priorities of Behaviours

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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.

...ctive rules $\prec$ *reactive* rules $\prec$
...al rules

move towards_cr $\prec$ *pick up victim*

$$\textit{broadbast}\ \text{rules} \preceq \textit{perceive}\ \text{rules} \prec \textit{reactive}\ \text{rules} \prec \textit{proactive}\ \text{rules} \preceq \textit{output}\ \text{rules}$$

$$\textit{avoid\_obstcle} \prec \textit{upload\_victims} \prec \textit{move\_towards\_er} \prec \textit{pick\_up\_victim}$$

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.

$$connect\_neighboring\_agents : (AV,\ Pos : (X_{av}\ Y_{av});\ Pos : (X_{ru}\ Y_{ru}), RU)$$
$$\text{if } (neighbours\ X_{av}\ Y_{av}\ X_{ru}\ Y_{ru})$$

Dynamic Structure and Cell Differentiation/Division/Death

New agents appear into the system

Some agents change role

Eventually some agents disappear.

$$out\_of\_order : (fuel : 0)_{RU} \to \dagger$$

$$\alpha\mathcal{P}$$

$${}^{\alpha}\mathcal{P} = (V, \Phi, T, \gamma, \alpha, v_f, A_1, A_2, \ldots, A_n, R_a, R_e, O_b, O_e, O_g)$$

So ….

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