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Study on behaviour analysis and predictability of self-organizing systems as part of project SAPERE

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Overview

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Objectives

Phases of the study

1) The first part focused on the acquisition of knowledge and documents that provide adequate image of the state of the art with regard to the analysis and prediction of the behavior of multi-agent systems and, in particular, of self-organizing systems

2) The second part focused on the analysis of techniques and methodologies highlighted, to see which could merit further investigation, having proved their worth and/or effectiveness

3) The third part focused on how the results achieved in the previous parts might be applied, with reasonable chances of success, to project SAPERE

Background

Analysis by Model Checking
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- It focuses on (semi-)exhaustive analysis of the states the system will go through, often accompanied by a representation by a LTS (*Labelled Transition System*)
- It allows the verification that the system meets certain properties expressed using various types of logics (LTL, CTL, DLTL, GLTL, etc.)
- It is almost exclusively used for the verification of *safety* or *liveness* properties
- Very effective for targeted problems but the application is generally complex for generic analysis and often prohibitive from the computational point of view

Analysis by Model Checking
(2 di 3)

- LTL is usually preferred to CTL
- From LTL numerous extensions have arisen, including:
  - DLTL (*Dynamic Linear Temporal Logic*): focused on upgrading the *until op*erator to provide better support for expressing pre-and post-conditions
  - GLTL (*General Linear Temporal Logic*): allows the definiton of LTL properties for the entire system, as well as for the individual entities involved

Analysis by Model Checking
(3 di 3)

- Many multi-agent systems consist of BDI agents; BDI specifications can be translated into LTL specifications
- AgentSpeak(L) dominates among BDI structures; AgentSpeak(F) is a subset of AgentSpeak(L), for *finite state systems* only
- A system described by AgentSpeak(F) can be represented by a SLPN (*Simple Logic Petri Net*)

Analysis of Swarm systems

- A detailed model checking of individual entities is unthinkable because of the explosion in the number of states
- Under the hypothesis of a system composed of entities of the same type, it is possible to define a state diagram common to all entities
- Each state is then associated to the number of entities that actually are in that state at a particular moment using probabilistic analysis
- Now it is possible to define a set of expected behaviors associated with chances of effective implementation

Analysis by Data Mining

- Because of the complexity of a multi-agent system, approach is often attempted through posteriori analysis of the behavior
- Applying data mining tools to sets of data obtained through a series of simulations, it has been possible to predict the expected behavior of a system with a relatively low margin of error
- In particular, this approach has been used to predict the strategy developed in the field by the various robot teams of the RoboCup football tournament, to thereby prepare an effective counteroffensive

Initial proposals for project SAPERE

MABLE

(1 di 5)

- Model checking is an undoubtedly effective analysis, less often efficient
- The language used to model the system as well as the tool used for the analysis play a very important role
- The main issue, most of the times, is to be able to check global properties of multi-agent system, as well as properties of the internal state of the individual entities

MABLE

(2 di 5)

- MABLE is a *C-like* imperative language that allows the definition of multi-agent systems and the verification of system properties expressed in LTL, the system modeled using MABLE is then translated into a Promela specification that can be analyzed using compatible tools such as SPIN

- It is being currently developed a translation system to the Java language

- MABLE has two unique features compared to other similar languages: *claims* and *semantic specifications*

MABLE

(3 di 5)

```
shared int a;

claim exists ag : agent <>(believe ag
(intend agent1 (believe ag a == 10)));

agent agent1 {

  for (a = 0; a != 10; a = a + 1)

    print("agent1: a = %d \n", a);

  inform agent2 of (a == 10);

  for (a = 10; a != 15; a = a + 1)

    print("agent1: a = %d \n", a);

}
```

- *Claims* allow the definition of properties to be verified during model checking
- These properties are not limited to individual entities, but they affect the system in its entirety
- Claims also allow an entity to make assumptions about the internal state of other entities

MABLE
(4 di 5)

```
i:inform(j,phi)
(believe i phi)
(believe j (intend i (believe j phi)))


i:inform(j,phi)
1
(believe j (intend i (believe j phi)))
```

- It's possible to add a semantic specification for the communicative actions to the multi-agent system model
- The specification enriches communications with preconditions to be met to allow the execution, and post-conditions to be put into effect after the communicative action has occurred

MABLE
(5 di 5)

If it were to choose a language for modeling a SAPERE infrastructure, choosing MABLE would have some benefits:

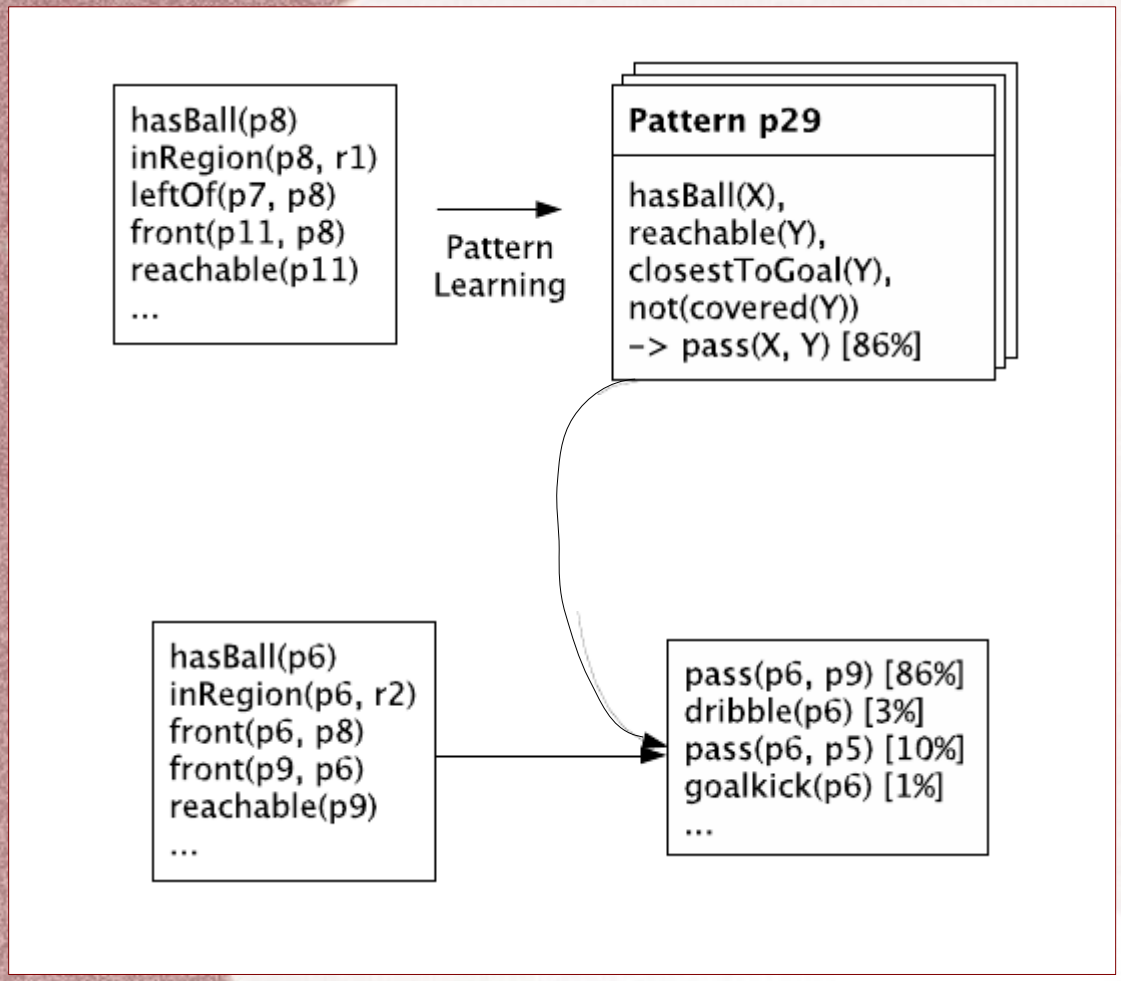
- the mechanism of *claims* would allow to verify global properties which are much more significant for a self-organizing system, compared to properties of state of the individual entities
- the *semantic specifications* supported by MABLE find many similarities to the mechanism of *EcoLaws* used by the SAPERE infrastructures
- Promela is a language widely used so it's possible to find many model checking tools, SPIN first of all; furthermore it's already under development a porting to the Java language

Tuning by Data Mining
(1 di 4)

- At present, there is no analytical method to tune the parameters of the simulations
- Tuning is carried out trying to deduce the effect that changing the value of a parameter will have on the behaviour of the simulation
- Feedback of some kind on the effect that the new value has produced is achieved through observation of various subsequent runs

Tuning by Data Mining

(2 di 4)



- Behavior analysis of the football teams of RoboCup has given encouraging results
- Once identified the variables that characterize the behavior (actions performed by the robot) ...
- … it was possible to obtain predictions about the strategies that the team would put in place with associated probabilities

Tuning by Data Mining
(3 di 4)

- Making necessary changes and adaptations, the same procedure is applicable to the project SAPERE
- A key part will be the identification of significant variables in the simulation
- Once identified these, the data set will be obtained from different runs of the simulation itself
- At this point it will be possible to apply Data Mining analysis to the data sets generated this way

Tuning by Data Mining
(4 di 4)

The analysis should be able to put in evidence:

- the correlations between the values of parameters and the emergent behavior
- any non-intuitive correlations between the parameters of the simulation and the emergent behavior
- ideal policy of assignment of values to these parameters
- any correlations between macro-events of the emergent behavior

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End of presentation