TD Multi-Agent System

Definitions

Cooperative system

The cooperation is a social attitude. The interaction of some entities in order to solve a problem may require a kind of coordination and mutual assistance. In the context of multi-agent system, this is referred to as cooperation, or cooperative agents, when their behavior results in helping the ones which are struggling the most. Agents act in the wider interest. In order for this kind of system to work, it is necessary that agents trust each other and that there is no ambiguity during inter-agents communications [Camps et al. 1998].

In order to identify which neighbor is struggling the most, agents have the ability to compute a criticality value.

Criticality

The AMAS approach requires that each agent has a local goal that it tries to reach by executing local actions. It also requires that each agent has a cooperative attitude, in other words, the agent has to help its neighbor if this one is more struggling. It is then necessary to be able to evaluate and compare agent's state. That is why the notion of "Criticality" has been introduced (See [Lemouzy 2011]) and can be defined as follow:

The criticality of an agent represents the state of dissatisfaction of it regarding its local goal.

This value is normalized between each entities of the system and can be defined from many criteria. During the decision phase, a cooperative agent evaluates its criticality and the one of its neighbors. Once it is done, this agent selects the action that minimizes the highest criticality at the next cycle.

Non-Cooperative Situations (NCS)

- All perceived signals are understood without ambiguity (¬cper)
  - Incomprehension: The signal can't be understood
  - Ambiguity: The signal has different meaning
- The received information is useful for the agent's reasoning (¬cdec)
  - Incompetence: The agent cannot reach a decision from its knowledges
  - Unproductiveness: The agent decides not to do anything
- Reasoning leads to useful actions towards others (¬cact)
  - Conflicts: Two agents doing opposite actions
  - Concurrency: Two agents doing actions with the same consequences

- Uselessness: Action without any effect on the environment

Cooperation

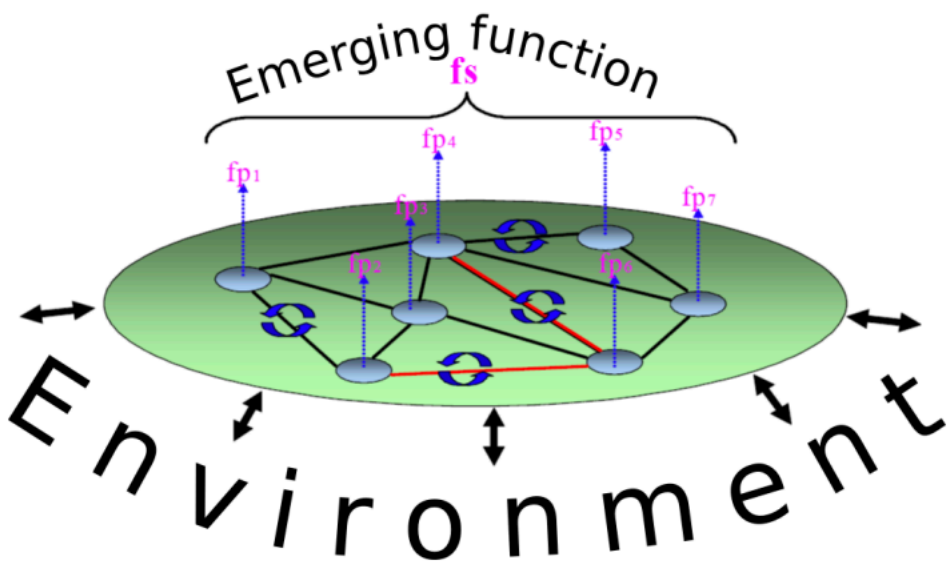
- Avoid NCS: for itself and the others
- Help the most critical

Functional Adequacy Theorem [Glize, 2000]

"For any functionally adequate system in a given environment, there is a system having a cooperative internal medium which realizes an equivalent function"

Emergence and Self-Adaptation

In a multi-agent system, a global function is expected from a set of local specifications. This global level property shouldn't be programmed into agents. Due to the openness characteristic, disruptive elements (environment, users or other agents) force the system to adapt itself and to constantly restructure itself to keep acceptable performances. This self-organizing characteristic can be seen in many domains. It corresponds to spontaneous emergence [Kim and Slors 1997] of a global coherence from local interactions of micro level initially independent components.



The emergence appears from a self-adaptation between agents. Their cooperative behavior allows the appearance of a global function deemed as emerging, that is to say the appearance of a function which is not predictable by simply observing the local behaviors of entities in the system. "[...] On the one hand, the emergence presupposes that there is the appearance of something new - properties, structures, shapes or functions -, and on the other hand, it implies that it is impossible to describe, explain or predict these new phenomena in physical terms from the basic conditions set out below levels." [Van de Vijver 1997] With a dynamic environment, the system must be able to change the way it acts in order to adapt itself. [Georgé 2003] To develop self-adaptive systems able to produce an expected result by emergence, this involves a bottom-up process. To assist this development, the ADELFE methodology has been proposed.

Exercise 1: Carrying heavy boxes

There are two sort of boxes (light and heavy) lying around in a depot and they need to be carried away. A human can only lift a light box and a heavy box is two times the weight of a light one.

(a) How can the problem be solved by cooperation (ok, this one is really easy). Do the humans need to be able to communicate to cooperate ?

(b) We now have robots to carry the boxes but with the same limitations as the humans. On top of that, because of expenses, only basic perception means are installed on the robots (they only perceive the boxes, not the other robots) and no communication device is available. Is it still possible to solve the problem ? What simple tweak to the behavior of the robots would ensure that even the heavy boxes will be carried away given enough time?

Exercise 2: Foraging ants

When ants forage for food, they leave a chemical substance on the ground when returning to their nest carrying food. This substance is called pheromones and is a mark which other ants can detect. Pheromones can accumulate on a given spot or path and evaporate over the course of time. Readers can find plenty of on-line resources explaining how pheromones work in different species and comprehensive descriptions of ant behaviors. Readers can also take a look at the "Methodologies" chapter which uses an artificial ant foraging application as a case study. But a basic understanding is quite enough to tackle this exercise.

(a) Explain how this use of pheromones can be qualified as "cooperative".

(b) Could the behavior of natural ants be enhanced to be even more cooperative? Imagine designing an artificial ant for a simulation or building an ant-like robot using pheromone-like marks and basic perceptions. Describe a few enhancements to their basic behaviors (using pheromones or simple perceptions) which would make them more cooperative and thus produce better results. At least six enhancements can be found.

Exercise 3: To AMAS or not to AMAS

Among the following domains and/or applications, explain whether the use of a self-adaptive SMA approach would be relevant and add value, or not. Justify briefly based on the application's characteristics and potential benefits or drawbacks.

- A video game
- Customer portfolio management software for a large multinational bank
- An aerial drone control system sponsored by DARPA for the US Navy

- The AI for a conversational hologram for personalized greetings at post office counters
- A Decision Support System (DSS) for machine allocation in an electric car production plant

Exercise 4: Colour Cubes Game

Consider the following game: in a house with several rooms connected by doors there are cubes of different colours dispersed among the rooms and several robots. We want all the cubes of the same colour in the same room. A robot can carry up to 4 cubes and has three available actions: pick up cube, drop a cube, go to another room. There are no communication means.

Your client wants to build a simulation which would solve the problem. For this he asks you to design a multi-agent system in which each agent controls a virtual robot which can act once per simulation step.

Describe the algorithm of the agents so that a solution is efficiently reached and does not depend on the number of robots, rooms, cubes or colours.

Exercise 5: AMAS Application

Many application domains could profit from the use of an autonomous self-adapting system approach.

Give 3 domains and/or applications where AMAS are adapted.

Justify with the characteristics of the application and the expected gain.