Introduction to Multi-Agent Systems

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Multiagent Systems: General

Lecture	9x	Mehdi Dastani (M.M.Dastani@uu.nl)
Presentations	7x	Mehdi Dastani
Final Exam	1 February 2012	
Webpage		http://www.cs.uu.nl/docs/vakken/mas

Multiagent Systems: Exam and Marks

- The final mark is determined by the written exam (70%) and the presentations/participation (30%). Active participation will influence the mark for the presentation part.
- The final mark will be in one decimal and should be equal or higher than 5.5.
- Participation to presentations is mandatory.
- For the presentations there are NO second opportunities.

Multiagent Systems: Projects and Marks

- Each presentation should be prepared for max. 30 minutes, including questions (3 presentations per session).
- Presentations can also be performed by a team of two students. The type of papers and the quality of the presentation are critical. Both students should perform a part of the presentation.
- Please have a look at papers and let me know which paper you want to present.
- The first presentation session is on Friday, 25 November 2011. Who?

Multi-agent Systems: Literature

- Book (some sections): Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundation, by Yoav Shoham and Kevin Leyton-Brown, Cambridge University Press, 2009.
- Book (background): An Introduction to Multiagent Systems (second edition): Michael Wooldridge. John Wiley & Sons, LTD, 2001.
- See the home page of the course for other background literature.

The Aim of This Course

- A general introduction to the field of multi-agent system.
- Lectures will cover:
  - game theory
  - social choice
  - mechanism design
  - auctions
  - normative systems
- Presentations will cover:
  - game theoretic approaches
  - organisation en Coordination
  - Cooperation and Negotiation
  - multi-agent system development

A Working Definition

A multi-agent system consists of a set of autonomous entities, called agents, which interact with each other and their surrounding environment to achieve their (joint) objectives.

- computing perspective
- software engineering perspective
- artificial intelligence perspective

Computing Perspective

Multi-agent system is a computational paradigm and an advance in computer science.

- Computational power: powerful computing devices are everywhere
- Interconnection: computing devices need to interact
- Intelligence: more complex tasks can be done by computing devices
- Delegation of control: computing devices makes decisions on behalf of their users/designers
- Human-orientation: interaction with computing devices are in terms of high-level concepts and metaphors

Software engineering perspective

Multi-agent systems is a new software engineering paradigm providing new abstractions for different phases of software development process.

$$\text{Analysis} \Rightarrow \text{Design} \Rightarrow \text{Implementation} \Rightarrow \text{Test}$$

- Structural analysis methodology: divide and conquer approach
- Object-oriented methodology: design patterns
- Agent-oriented methodology: organisation and society patterns

Artificial intelligence perspective

Multi-agent systems and Artificial Intelligence are NOT the same. Understand and model social intelligence and emergent behavior are essential in multi-agent systems.

- Artificial Intelligence
  - Planning
  - Learning
  - Vision
  - Language understanding
- Multi-Agent Systems
  - Interaction and Communication
  - Social concepts: obligation, norms, responsibilities, etc.
  - Optimal solutions can be obtained by co-ordination and co-operation
  - Simulation can verify social and economic theories

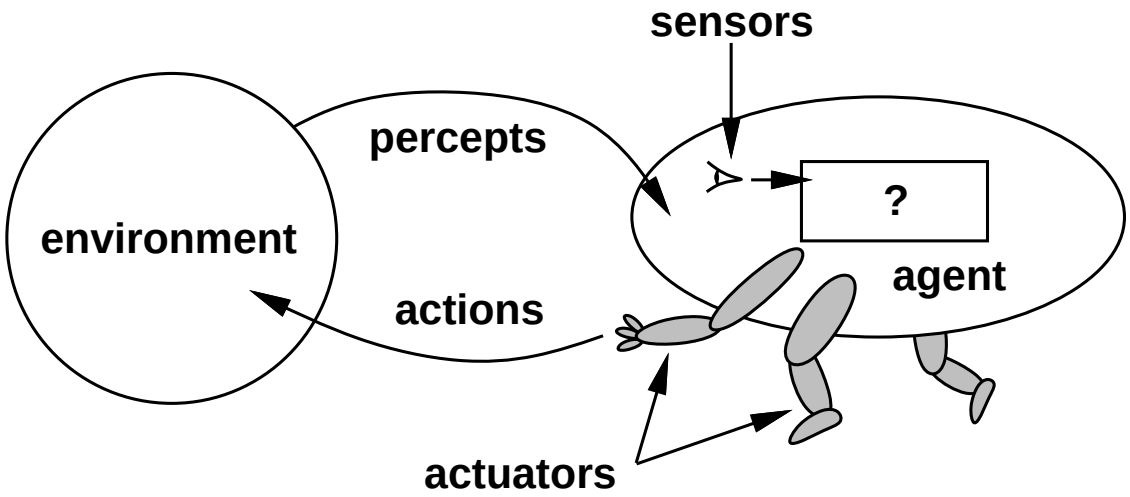
Characteristics of multi-agent systems

- Multi-agent systems consists of a number of *interacting* autonomous agents.
- Multi-agent systems are designed to achieve some *global goal*.
- Agents need abilities to *cooperate*, *coordinate*, and *negotiate* to achieve their objectives.
- Multi-agent systems are specified in terms of high-level abstract concepts such as *role, permission, responsibility*, and *interaction*.
- Applications for multi-agent systems are, for example, power management systems, transportation systems, and auctions.

Autonomous agents

- Autonomous agents are *active*, *social*, and *adaptable* computer systems situated in some *dynamic environment* and capable of *autonomous actions* to achieve their *objectives*.
  - Reactive: respond to changes in its environment.
  - Pro-active (deliberative): goal-directed behavior.
  - Social: interaction and communication.
  - Rational: behave to maximize its achievements.
- Agents *decide* which action to perform based on their *internal state*.
- The internal state of agents can be specified in terms of high-level abstract concepts such as *belief, desire, goal, intention, plan*, and *action*.

Agents and environments



- *Agents* include humans, robots, softbots, thermostats, etc.
- The *agent function* maps from percept histories to actions:

$$f : \mathcal{P}^* \rightarrow \mathcal{A}$$

- The *agent program* runs on the physical *architecture* to produce f

Communication

- Agent exchange information by means of messages.
- There have been many attempts to agree on standards for agent communication.
- A message has often the following ingredients:
  - Information about sender and receivers.
  - Content of the message carrying the information to be exchanged.
  - Speech acts such as *Inform*, *Request*, and *Propose*.
- Semantics of messages are defined either internally in terms of an agent's beliefs and goals, or externally in terms of agents' social commitments.
- Communication between agents are governed by means of protocols. Roughly speaking, a protocol determines which messages in which order can be exchanged.

Cooperation and Negotiation

- Agents can cooperate to solve their problems in two ways:
  - Task sharing: tasks are decomposed and distributed among agents.
  - Result sharing: information and partial results are distributed.
- Agents can negotiate to reach agreements.
  - Auctions: an agent (auctioneer) allocate the negotiating item(s) to the bidding agents.
  - Negotiation: agents make proposals in a series of rounds.
  - Argumentation: agents attempt to convince each other to agree on a certain outcome.

Organisation and Coordination

- Organisation: it aims at arranging and managing the relation between agents to ensure qualities and outcomes not apprehended at the level of individual agents.
  - Normative organisations
  - Electronic institutions
  - Market places
- Coordination: it aims at avoiding extraneous activities by synchronizing and aligning agents' activities.
  - Endogenous coordination: the coordination mechanism is inside the agents, i.e., tuple spaces and blackboard architecture.
  - Exogenous coordination: the coordination mechanism is outside the agents, e.g., Channel based interactions.

Multi-Agent System Development

- Tools and languages to analyse and specify multi-agent systems, e.g., game theoretic concepts and frameworks, logical formalisms, and notations.
- Architectures, frameworks and infrastructures supporting distributed, heterogenous, open multi-agent systems.
- Programming languages and integrated development environments to facilitate the implementation of multi-agent systems.
- Verification and debugging tools to test multi-agent programs and ensure their correctness.

Multi-Agent Systems: Objectives

- How to analyse, specify, design and build individual agents that are capable of independent, autonomous action in order to successfully carry out the tasks that we delegate to them?
- How to analyse, specify, design and build agents that are capable of interacting (cooperating, coordinating, negotiating) with other agents in order to successfully carry out the tasks that we delegate to them, particularly when the other agents cannot be assumed to share the same interests/goals?