Master Informatique / Parcours DSC

Multi-Agent Systems

Introduction

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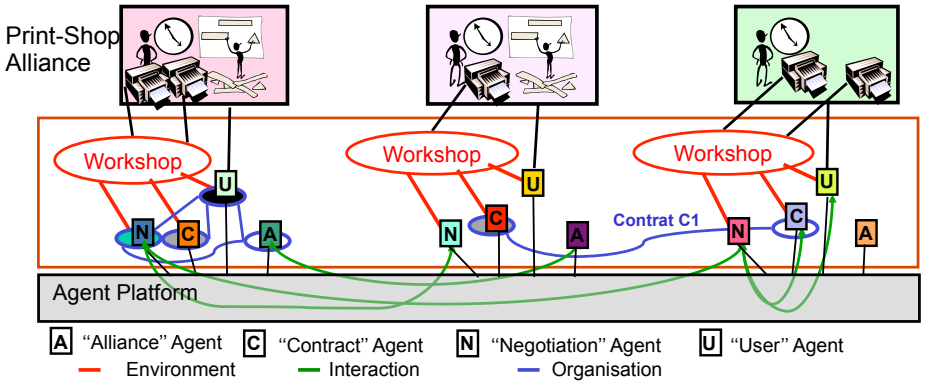
Plan

1. **Definitions**
2. Action Domains
3. Positioning
4. "Vowels" Dimensions
5. Multi-Agent Engineering
6. Perspectives …

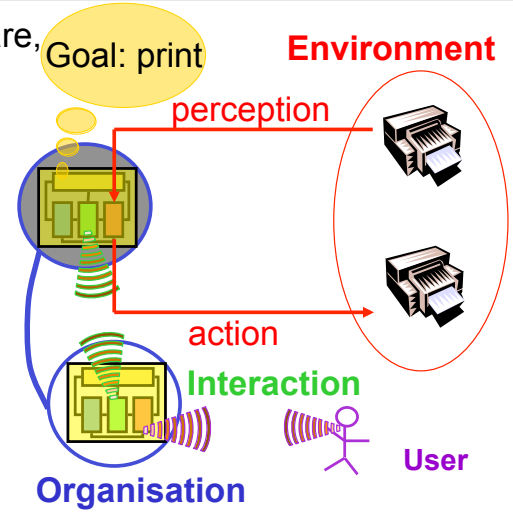
Multi-Agent Systems



Multi-Agent System (MAS) : set of agents, that interact with each other, situated in a common environment, eventually, building or participating to, an organisation

Agent (in a Multi-Agent World)

Agent : physical or software, *autonomous* entity that is pro-active, reactive, social, able to take part to an organised activity, in order to achieve its goals, by interacting with other agents and users.



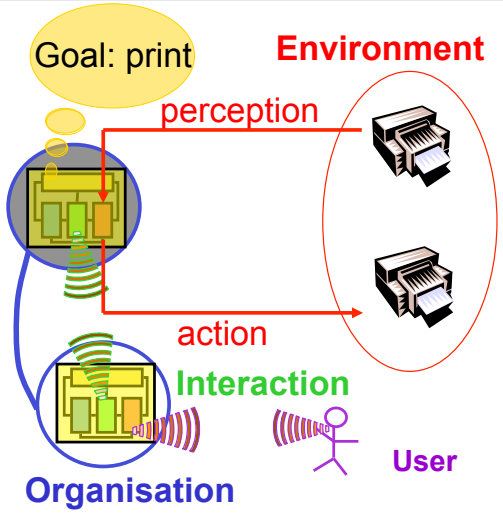
Autonomous Agent (in a Multi-Agent World)

- An agent ***X*** is autonomous with respect to ***Y*** for ***O*** in situation ***S***
  - ***Y*** can be a user, another agent, a group of agents, an organisation, …
  - ***O*** can be a *goal*, a *plan*, an *action*, a *resource*, a *norm*, a *role*, …

It means that:

- agent ***X*** can *decide locally* of the adoption of ***O*** in situation ***S***
- **And** ***Y*** *has no certainty that* ***X*** is going to adopt ***O*** in situation ***S***

→ **Loose** coupling between agents



Multi-Agent Systems Principles

- The ***Agent perspective*** (micro perspective)
  - *Reactive* & *Pro-Active* entities / Encapsulation of control
  - *Autonomy*: agents may exhibit activities that are not the one expected by the other agents in the system
  - *Delegation*: agents may receive some control over their activities
- The ***Multi-Agent System perspective*** (macro perspective)
  - *Distribution* of knowledge, of resources, of reasoning/decision capabilities
  - *Decentralization* (loose coupling) of control, authority
  - Agreement technologies, Coordination models and mechanisms to install coordination between the autonomous agents
  - Emergent / Social order / Normative functioning

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MAS Action domains

- **Socio-technical Systems**
  - Integration of software applications, with humans, organizations and the physical world
  - Making them interoperate, interact, cooperate in a flexible and consistent manner with each other
- **Problem Solving**
  - Modeling and solving problems by cooperation between local solvers
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- **Simulation**
  - Modeling and reproducing complex phenomena of interacting entities in the real world in order to understand or to explain their behavior

Socio-Technical Systems (1)

- Industries, services, IT applications are getting global
  - Placed at the centre of multiple networks
  - Developing Knowledge intensive processes
  - Based on large scale underlying IT platforms such as Internet, Web, Internet of Things
- Industries, services, IT applications are situated in an ever-evolving environment
  - Requiring efficient collaboration processes
  - While keeping flexibility and agility
- Users are more and more at the centre of the cooperation and collaboration taking place in these socio-technical systems

Socio-Technical Systems (2)

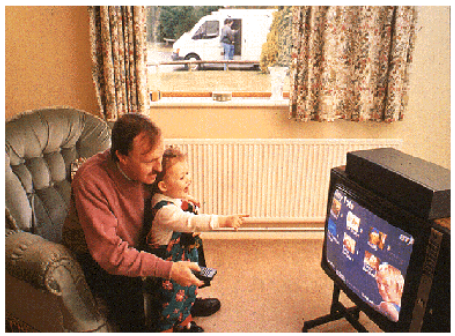
- Properties of the targeted applications:
  - Absence of monolithic vision
  - Incremental development, by different teams
  - Multi-* (sites, expertise, domains, points of view, decisions, goals, motivations, …)
  - Continuous execution and adaptation
  - User-Centred
- Main requirements:
  - Openness, permeability, scalability in size or structure
  - Distribution, no central control, control and interaction are local
  - Autonomous Interacting entities loosely coupled with others or applications
  - Knowledge Intensive processing and sharing
  - Users may delegate their decisions to the application

Example (1/3)

Service Personnalisation

Tonight's Suggested Viewing:

7pm World News Headlines
7:15 Personal Newsround
7:30 Selected highlights of today's golf
7:50-8:00 Intermission (Video-call - it's your brother's birthday)
8:00-10:00 Film choice
Jurassic Park (VR) OR Cyberspace 2
(please select now)



Source CLIMATE Industrial Workshop 26/4/99

Example (1/3)

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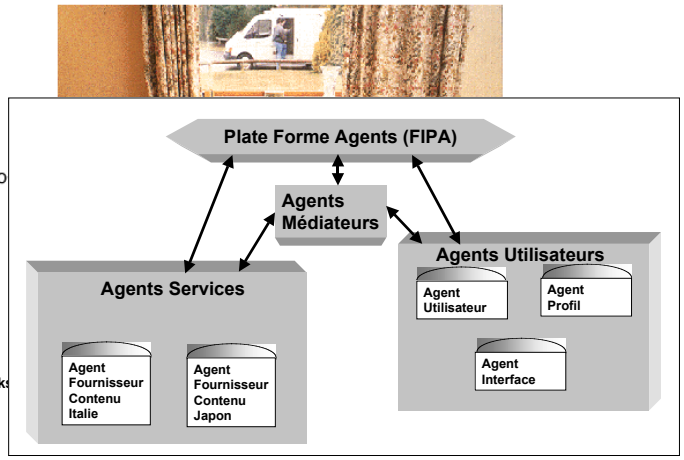
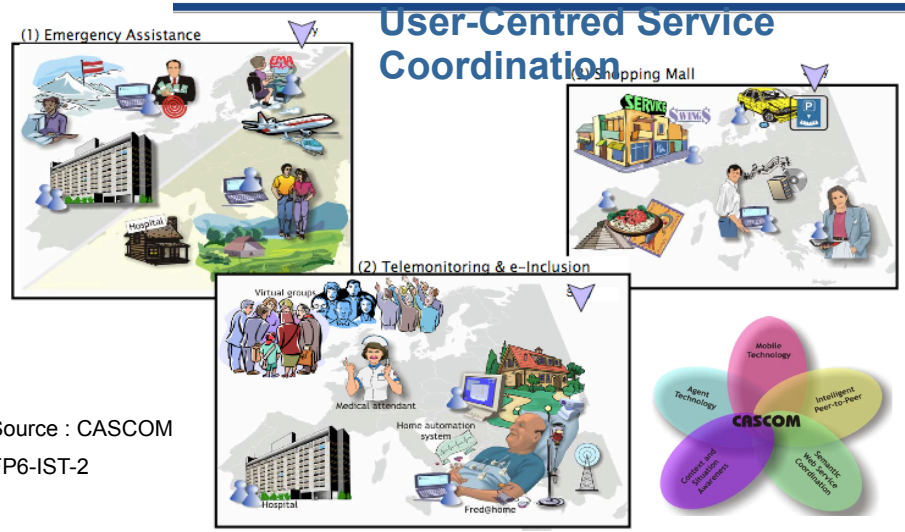
Source CLIMATE Industrial Works



Example (2/3)

User-Centred Service Coordination



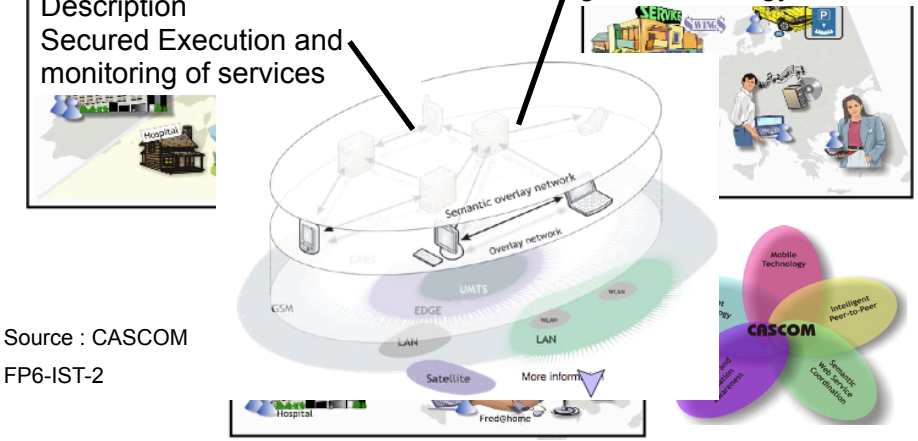
Source : CASCOM

FP6-IST-2

Example (2/3)

Service Composition
Semantic Services Description
Secured Execution and monitoring of services

Semantic Web Agent Technology

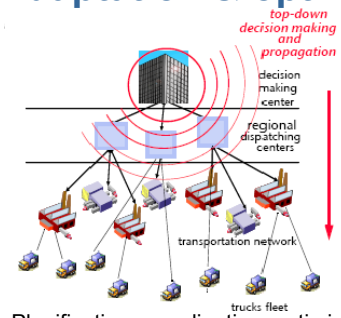


Source : CASCOM

FP6-IST-2

Example (3/3)

Adaptation & optimisation



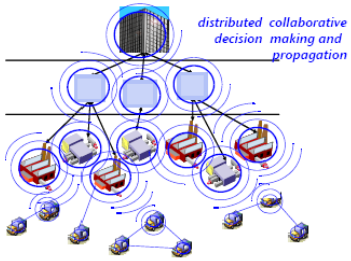
Planification, coordination, optimisation along a top-down approach :

• *Centralised collect and processing of informations and events*
• Propagation of plans & decisions
• No realtime decision.

Source Whitestein Agent Technology Conference 2004

Planification, coordination, optimisation along a bottom-up approach

• Responsibility Delegation
• Communication between the nodes
• Real time detection & reaction to changes
• Adaptation to changes & continuous optimisation



MAS Action domains

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- **Problem Solving**
  - Modeling and solving problems by cooperation between local solvers
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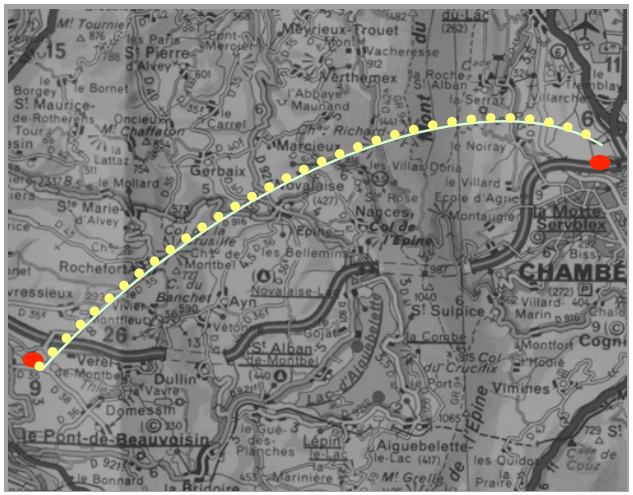
- **Simulation**
  - Modeling and reproducing complex phenomena of interacting entities in the real world in order to understand or to explain their behavior

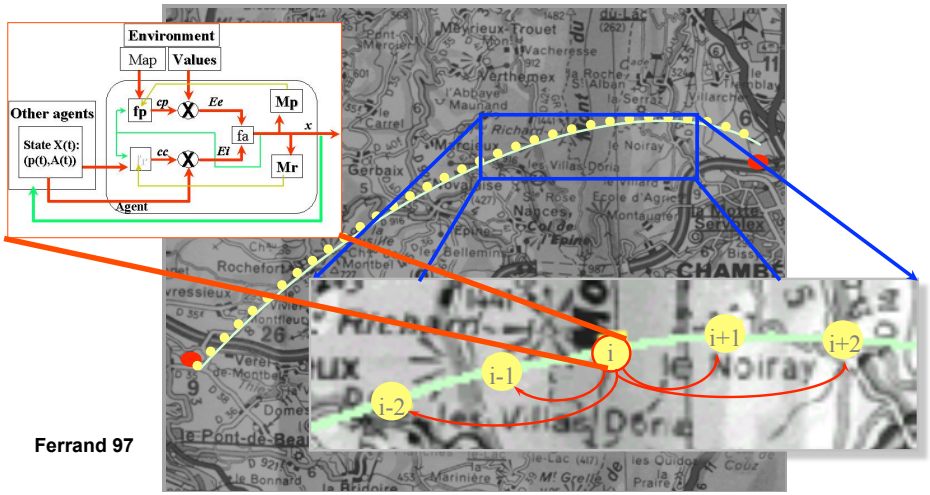
Problem Solving

- Properties of the targeted applications:
  - Absence of global strategies, of global solving method
  - Interaction between local strategies, between local solving methods
  - Solution is the result of the interaction between local processes (points of view, decisions, goals, motivations, …)
  - Continuous functioning and evolution
- Main requirements:
  - Decentralisation, local control, interactions
  - Openness, permeability, scalability in size or structure
  - Shared and dynamic environment
  - Emergence of the solution

Example (1/2)



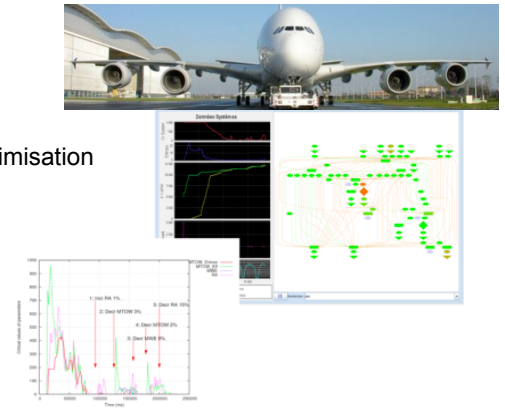
Example (1/2)



Example (2/2)

Design of Complex Systems

- Multi-Disciplinary Simulation & optimisation (ID4CS)
- Design of complex system :
  - Multi-level, Multi-disciplinary
  - Multi-methods
  - Multi-objectives, Multi-attributes
  - Uncertainty
- Cooperation methods between optimisation technics,
- Management of uncertainty
- Multi-* problem solving
- Emergence



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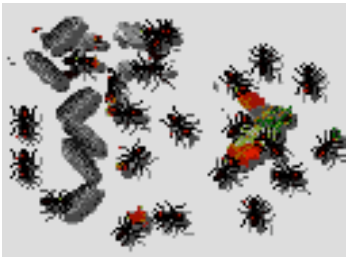
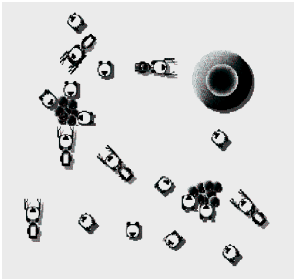
Example (1/2)

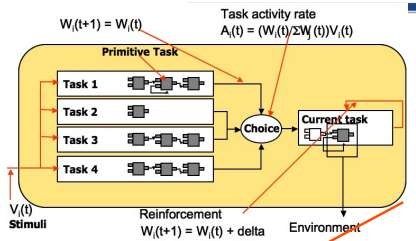
In order to:

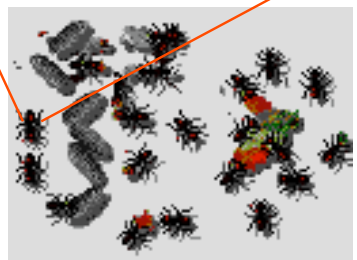


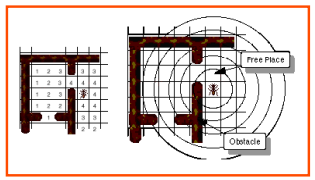


Understand, Explain
Discover, …, Help,

Example (1/2)







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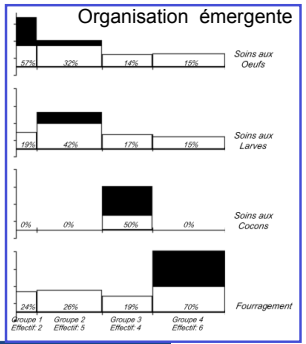
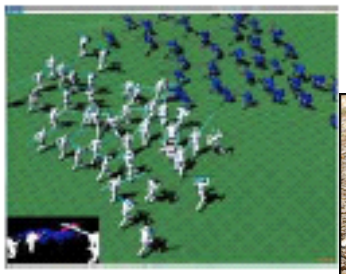


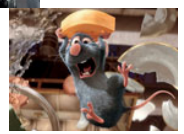
Example (2/2)

http://www.massivesoftware.com/

The Return of the King (2003)
The Two Towers (2002)
The Fellowship of the Ring (2001)



I, Robot (2004)



Ratatouille (2007)

…, Entertainment

Conversational Zeno Robot
http://hansonrobotics.com/

Plan

1. Contexte
2. Definitions
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4. **Positioning**
5. "Vowels" Dimensions
6. Multi-Agent Engineering
7. Perspectives …

History – Major Steps

- 1980 : Agents in the Artificial Intelligence (AI) area
  - From AI to **Distributed** AI …

  … to Multi-Agent Systems
- 1990 : Agents are invading other domains
  - Personal Assistants, avatars,
  - Mobile Agents,
  - Reactive Agents, ….
- 1995 : Agents spread in other domains, Application domains are enlarging
  - Artificial Life, Economic Agents, …,
  - …, Web, Ambient Computing, …

History – Evolutions

- 1973 - 1980:
  - Hearsay II (1973): blackboard architecture for speech recognition
  - Actor Languages (1973): messages as control structures
  - Beings (1975), Society of Minds (1978)
- 1980 - 1990:
  - Contract Net (1980): hierarchical decentralized control
  - DVMT (1984): Distributed Interpretation
  - Subsumption architecture (1986) : Reactive Robots
  - MACE (1987): multi-agent platforms
- 1990 - … :
  - Self-organisation, emergence, Interactions, organisations, reputation, trust, Agent Oriented Software Engineering, …
  - In 1995, first international conference ICMAS,
  - since 2002, Autonomous Agents + MAS -> AAMAS

Inter-Disciplinary Domain…

- Direct Links with:
  - Programming, Objects...
  - Artificial Intelligence,
  - Distributed Systems, Parallelism,
- But also:
  - Complex System (physics, …, ethology, ecology, …)
  - Artificial Life, Neural networks, …
  - Social Psychology, Sociology, Activity Theory, Economy, ...

Direct Inheritance

- Object Oriented Programming:
  - Encapsulation, modularity : an object encapsulate data and methods that manage them (ex : C++, Java, Smalltalk),
  - Distribution : Distributed objects, CORBA, DCOM
  - → Actor Languages Development
- Artificial Intelligence:
  - Symbolic Reasoning Models (Expert systems, Knowledge Representation), logic, …
  - distribution : Blackboard Architectures
- Distributed Systems

Multi-Agent vs Objects

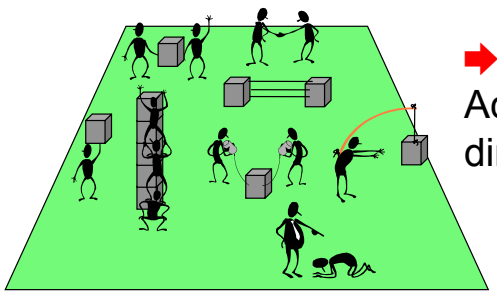
- An agent, as an object, encapsulates a state and behaviors

BUT:

- An agent encapsulates its control over its behaviors; an object has only control over its state
- Interactions among agents have a broader scope than the method calls between objects. Interactions consist in goals, plans, actions, hypothesis exchanges
- An agent may have different control cycles (data-directed, goal-directed, interaction-directed, …)
- A MAS has several control flows. An Object system has, a priori, only one control flow.

Multi-Agent vs Artificial Intelligence (1)

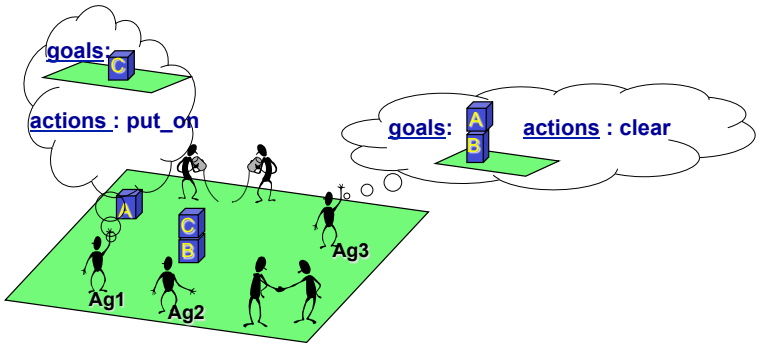
Mono-agent perspective of Artificial Intelligence is pushed away



➡ Knowledge, Goals, Actions gain a **social** dimension

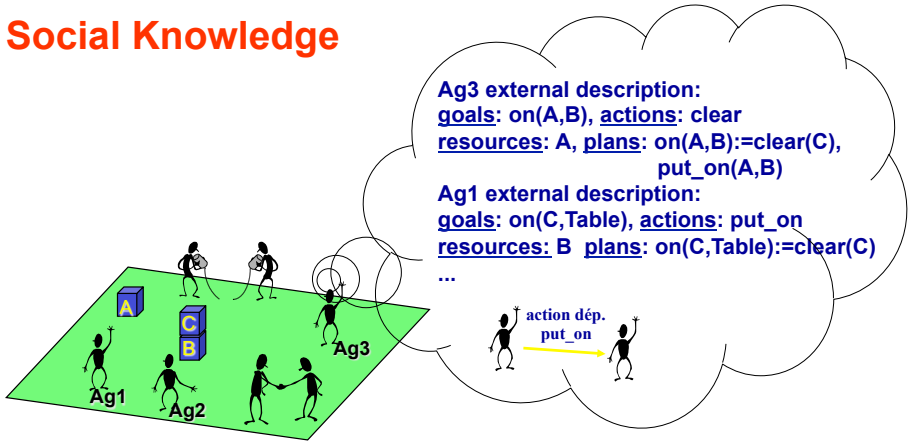
Multi-Agent vs Artificial Intelligence (2)

Ex. dependence networks



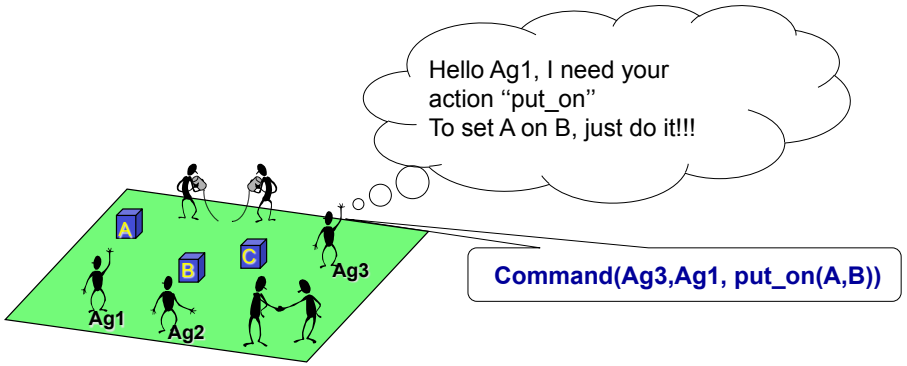
Multi-Agent vs Artificial Intelligence (3)

Social Knowledge



Multi-Agent vs Artificial Intelligence (4)

Social Interaction



Multi-Agent vs Distributed Systems

- Both take into account interconnection and distribution
- In MAS, Interconnection and Distribution are concerned by:
  - The requirement of taking into account the agent autonomy, of developing synchronization and coordination mechanisms to coordinate their activities
  - The requirement to represent and take into account the user interests
  - The requirement to cooperate and to achieve agreements (or even compete) with other systems aiming at achieving their own interests.

A Large Domain!!!

From *Autonomous Agents* to *Multi-Agent Systems*

- Autonomous Robots
- Personal Assistants
- Desktop Agents
- Softbots, Knowbots
- Mobile Agents
- Reactive Agents
- Intelligent Agents, Cooperative Agents, Conversational Agents
- Autonomous Agent in a multi-agent world

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To continue …

- General references
  - Pitfalls of Agent-Oriented Development, M. Wooldridge, N.R. Jennings, Agents ’98, 1998.
  - Foundations of Distributed Artificial Intelligence, G.M.P. Hoare, N.R. Jennings, Wiley & Sons, 1996
  - Les systèmes multi-agents, J. Ferber, InterEditions, 1995
  - Multiagent Systems: A Modern Approach to Distributed Artificial Intelligence, edited by Gerhard Weiss, MIT Press, 1999. ISBN 0-262-23203-0
  - Principes et architectures des Systèmes Multi-Agents, J.P. Briot, Y. Demazeau, IC2, Hermès, 2001
- Some standards
  - Knowledge Sharing Effort http://www.cs.umbc.edu/kse/
  - OMG Agent Working Group http://www.objs.com/isig/agent.html
  - FIPA http://www.fipa.org
  - W3C http://www.w3.org
- Some general adresses
  - Collège SMA de l’AFIA : http://sma.lip6.fr
  - AgentLink : http://www.agentlink.org
  - AgentCities : http://www.agentcities.org

Multi-Agent Modeling

- Multi-model :
  - Articulation of different formalisms
- Multi-viewpoints :
  - Extern/intern, system centred/agent centred
  - Multiple views on a shared world
- Multi-levels
  - Via organisations, via the environment (MAS)
- Multi-scales
  - temporal, spatial, …

Domain Overview (1/2)

- International Conferences
  - International Conference on Multi-Agent System (ICMAS) de 1995 à 2000,
  - International Conference on Autonomous Agents and MultiAgent Systems (AAMAS) depuis 2002. (http://www.aamas-conference.org/)
- French Conferences
  - Journées Francophones SMA (http://www.cerv.fr/jfsma08/)
  - Collège SMA de l’AFIA (http://sma.lip6.fr/)
- European Projects
  - AgentLink (réseau d’excellence www.agentlink.org), Roadmap (www.agentlink.org/roadmap)
- Some “Success Stories”
  - Brahms (agentsolutions http://agentsolutions.com/home.htm) @ NASA Ames Research Center
  - Living Systems (Whitestein technologies http://www.whitestein.com) @ ABX Logistics
  - eSTAR (http://www.estar.org.uk/) intelligent robotic telescope network
  - CalicoJack (http://www.calicojack.co.uk/)
  - Review of Industrial Deployment of Multi-Agent Systems http://agents.felk.cvut.cz/teaching/33ui2/on-aplications.pdf

Domain Overview (2/2)

- Standards
  - FIPA (Foundation for Intelligent Physical Agents) (http://www.fipa.org/)
- Competitions

http://www.robocup.org/

http://www.rescuesystem.org/robocuprescue/

Trading Agent Competition TAC

http://tac.eecs.umich.edu/association.html

http://www.lips.utexas.edu/art-testbed/

Domain Overview (3/3)

- Journals
  - Autonomous Agents and Multi-Agent Systems
  - Artificial Intelligence
  - Knowledge Engineering Review
  - International Journal of Agent-Oriented Software Engineering (IJAOSE)
  - Web Intelligence and Agent Systems *An International Journal*
- News
  - Agent List
    - http://www.cs.umbc.edu/agentslist/
  - Distributed Artificial Intelligence List
    - DAI-List-Request@ece.sc.edu
  - French list
    - sma@loria.fr
    - http://sma.lip6.fr/

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