Distributed Decision Making and Multi-Agent Systems

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CentraleSupélec

January 9 , 2018
Gif sur Yvette

Contents

Who knows ?

Who knows ?

Who knows ?

Who knows ?


PIENSE
THINK
DENKE
PENSER
$2,000
Ken
$5,000
WATSON
$5,000
BRAD
YouTube

Who knows ?

Motivations

Artificial Intelligence (AI)

"Designing and building machines that do things that would require intelligence if performed by humans" [Marvin Minsky].

Source : https://humanoides.fr/robot-appris-jouer-echecs-tout-seul/

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➙ the concept of “Intelligent agent” at the base of AI

Motivations

There is not "the" definition of an agent

[Russel and Norvig,1995]

"An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors."

Motivations

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[Russel and Norvig,1995]

"An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors."

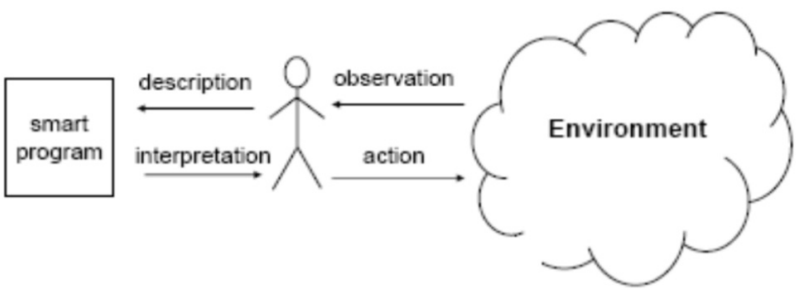
[Wooldridge & Jennings, 1995]

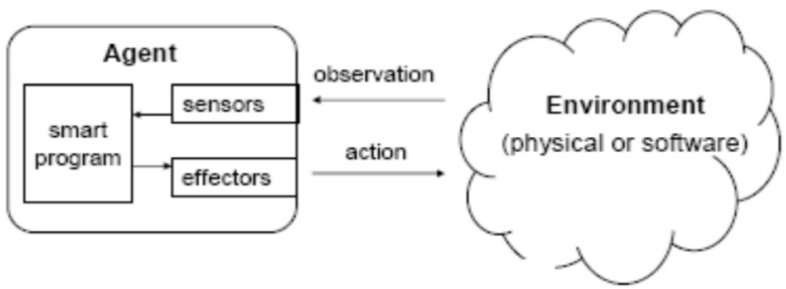
"An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives"

Motivations

Intelligent Agents vs Expert Systems

- In expert systems there is a human present between the program and the environment
- Agent reside in the environment and interacts with it directly (no interface is required)





Motivations

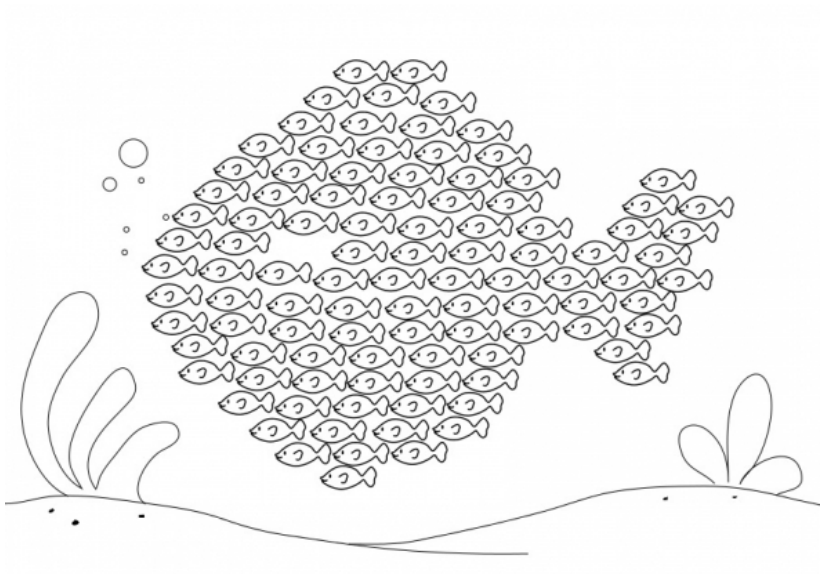
Individual intelligence

- Cognitive capacities :
  - representation, reasoning, thinking, ...
  - decision, planning, ...
  - language, communication, ...
- related to perceptions, action capacities, emotions, ...
- adaptability to an environment : learning, understanding, intuition, ...

Motivations

Collective intelligence

- Intelligence does not come only from individual
- emerges from the collaboration, collective efforts, and competition of many individuals to solve difficult problems and very effectively
  - insects society : ants, temites, ...
  - group of fishes, group of birds, ...
  - ...
  - Of course, group of humans



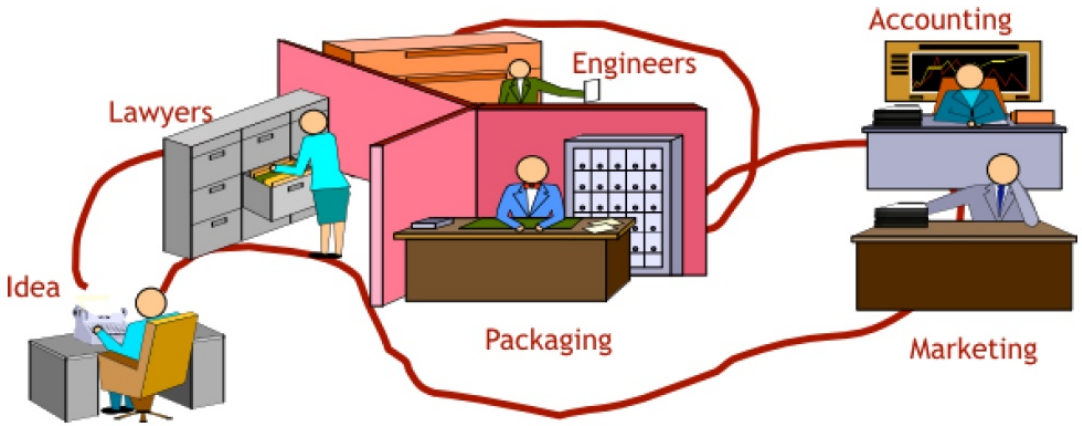
From AI to Distributed AI

- Distributed AI : interested by systems in which artificial agents operate collectively and in a decentralized way to accomplish a task.
- Distributed AI (DAI) is the subfiled of AI concerned with coordinated, concurrent actions and problem solving [Bond and Grasser, 1988].
- AI : modeling the "smart" behavior of an agent + Distributed : modeling the interactions (social organization)

From AI to Distributed AI

Why distributed AI ?

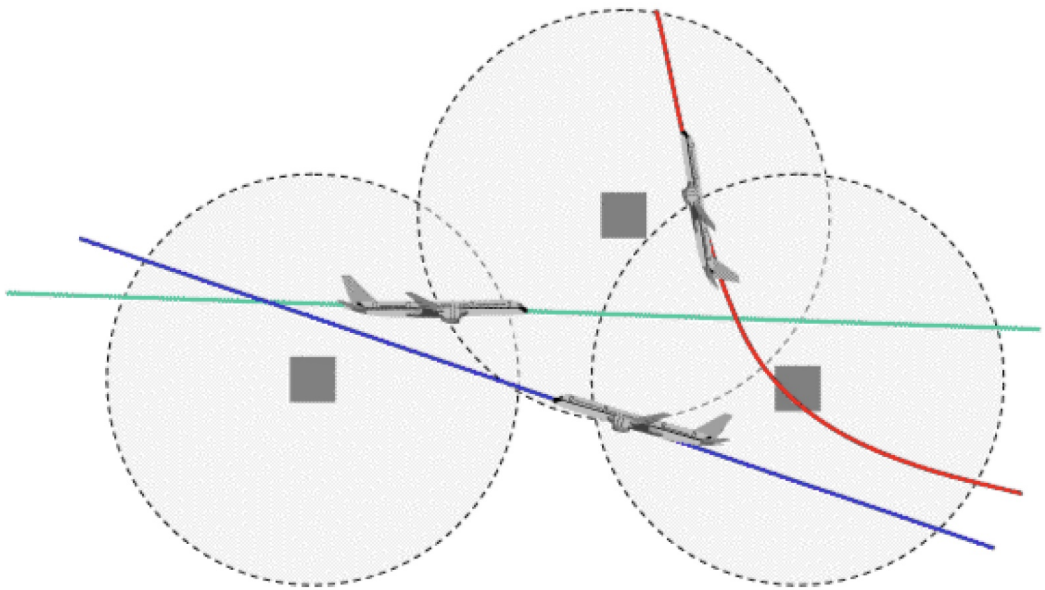
- Functional distribution of human activities (e.g. product design),
- Solving the problem requires the intervention of different experts with different skills
- Different points of views and languages.



From AI to Distributed AI

Why distributed AI?

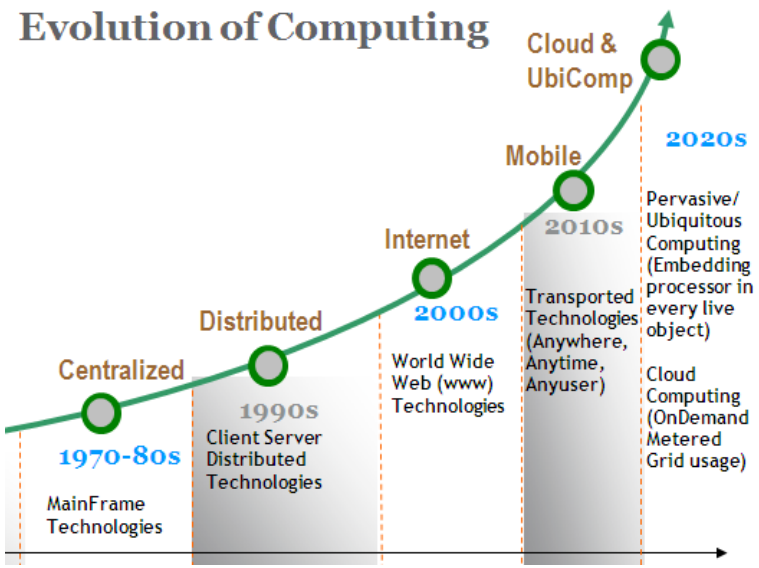
- Physical distribution of actors, sources, ...
- solving the problem requires integrating data from geographically distincts sources (sites)
- Most of real applications involve physically and functionally distributed systems (air control, robotics, network,...)



From AI to Distributed AI

Why distributed AI?

- Evolution of computing
- Towards "pervasive computing" (Ubiquitous computing)



Source https://medium.com/@vivekmadurai/ubiquitous-computing-6dd3685f18e7

From AI to Distributed AI

Why distributed AI ?

- The "everyday" objects (home appliances, tools, clothing, glasses, etc.) will be "augmented" with sensors, actuators, microprocessors and their embedded softwares (communicating by Wifi, bluetooth, (semi-) autonomous, advanced user interface (voice, gesture, etc.)).

Source https://medium.com/@vivekmadurai/ubiquitous-computing-6dd3685f18e7

From AI to Distributed AI

Benefits from distribution...

- **Cooperation** : cooperative systems are capable of solving larger problems than individual systems and with an improved efficiency
- **Cost** : multiple low cost computers are better than a centralized intelligent system with high cost.
- **Parallel development** : a distributed system can be separated into parts that are developed separately by experts in each knowledge domain
- **Efficiency** : if well synchronized, parallel tasks are faster to compute than sequential tasks.
- **Reliability** : the most important parts of the system may be redundant.
- ...

Mainstream problems in DAI

A particular complex problem may not be solvable by any single agent, but possibly by several agents together.

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Distributed Problem Solving/Planning (DPS)

- Problem decomposition : Decompose the original problem into smaller subproblems, that can each be handled by a single agent.
- Solving each subproblem : Each agent solves the problems assigned to them. Agents may share information during this stage.
- Solution synthesis : Integrate the solutions to the subproblems to arrive at a solution of the overall problem.

In this strand of work people generally assume that agents are cooperative and benevolent . . .

R. Davies and R.G. Smith. Negotiation as a Metaphor for Distributed Problem Solving. Artificial Intelligence, 20(1) :63-109, 1983.

Mainstream problems in DAI

DPS – Examples

- designing and manufacturing an artifact (such as a car) by allowing specialized agents to individually formulate components and processes, and combining these into a collective solution.
- supervisory systems for air-traffic control, or crisis management can involve an interplay between separate pieces for event monitoring, situation assessment, diagnosis, and response generation.
- ...

Mainstream problems in DAI

Multi-agent Systems

- is concerned with coordinating intelligent behavior among a collection of autonomous intelligent "agents"
- $\neq$ DPS
  - the agents have their own interests and they might cooperate or compete, agree or disagree, etc.
  - how agents with individual preferences will interact in particular environments such that each will consent to act in a way that leads to desired global goal.

Mainstream problems in DAI

Multi-agent Systems

- is concerned with coordinating intelligent behavior among a collection of autonomous intelligent "agents"
- $\neq$ DPS *(but complementary)*
  - the agents have their own interests and they might cooperate or compete, agree or disagree, etc.
  - how agents with individual preferences will interact in particular environments such that each will consent to act in a way that leads to desired global goal.

Multi-agent system ?

[Maes, 1994]

"Autonomous agents are computational systems that inhabit some complex dynamic environment and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed."

[Wooldrige, 2000]

- A multi-agent system is one that consists of a number of agents, which interact with one another
- Generally, agents will be acting on behalf of users of different goals and motivations ;
- To successfully interact, they will require the ability to cooperate, coordinate, and negotiate with each other.

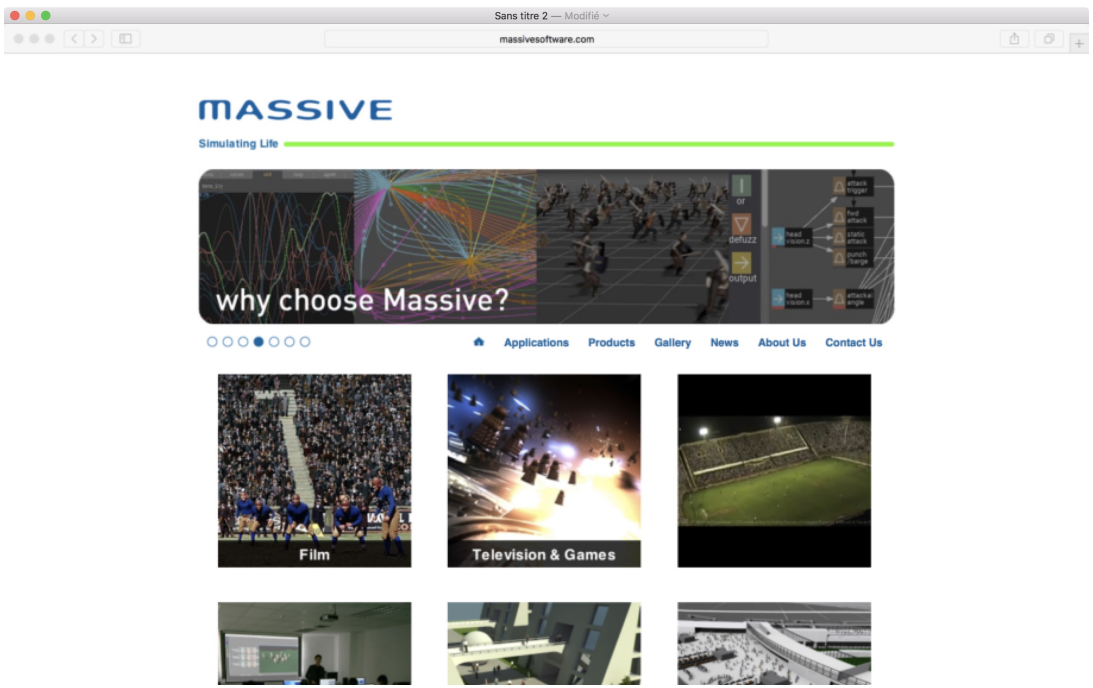
Agent and Multi-agent Systems Application

- → Manufacturing and production
- → Traffic and logistics
- → Robotics, autonomous systems
- → Air traffic and space
- → Security application
- → Energy and smart grids

(e.g. autonomous robots, personal assistant, drones, smart cockpit, video games …)

Agent and Multi-agent Systems Application

MASSIVE (Multiple Agent Simulation System in Virtual Environment) is a high-end computer animation and artificial intelligence software package used for generating crowd-related visual effects for film and television.



Originally developed for “Lord of the Rings” films (2001-2003).

Agent and Multi-agent Systems Application

MetaTrader 4, also known as MT4, is an electronic trading platform widely used by online retail foreign exchange speculative traders.

Source : `https://www.metatrader4.com/fr/trading-platform`

Next Sessions...

We will study formally

- What is an agent ?
- What is a multi-agent system (architecture) ?

Multi-agent Design Problem?

The Two Key Problems

Agent design

How do we build agents that are capable of independent, autonomous action in order to successfully carry out the tasks that we delegate to them?

Society Design

How do we 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?

→ These are the micro and macro perspectives.

Society Design ?

agents need to :

- coordinate their actions
- resolve conflicts of interests, opinions,
- make joint decisions,
- reach agreements,
- engage in dialogues,
- ...

$\rightsquigarrow$ They need to reason and communicate !

Society Design ?

Think about this...

1	☆☆	🍴	🚌	$
h_A	4⋆	no	35 min	120 $
h_B	4⋆	yes	50 min	160 $
h_C	2⋆	yes	20 min	50 $
h_D	2⋆	no	30 min	40 $

2	☆☆	🍴	🚌	$
h_A	4⋆	no	35 min	120 $
h_B	3⋆	yes	50 min	160 $
h_C	2⋆	yes	20 min	50 $
h_D	2⋆	no	30 min	40 $

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h_D	2⋆	no	30 min	40 $

$1 : \quad a \succ_1 b \succ_1 f \succ_1 e \succ_1 c \succ_1 d$

$2 : \quad e \succ_2 b \succ_2 c \succ_2 d \succ_2 a \succ_2 f$

$3 : \quad f \succ_3 a \succ_3 b \succ_3 d \succ_3 e \succ_3 c$

$4 : \quad d \succ_4 a \succ_4 c \succ_4 e \succ_4 f \succ_4 b$

$5 : \quad c \succ_5 e \succ_5 b \succ_5 f \succ_5 d \succ_5 a$

Distributed vs Centralized approach

- In the centralized case, a center entity decides on the final action (decision), possibly after having elicited the preferences of the other agents.

Distributed vs Centralized approach

- In the centralized case, a center entity decides on the final action (decision), possibly after having elicited the preferences of the other agents.
- In the distributed case, the decision is made by the group. There is no central controlling agent, but each agent is to a certain extent 'responsible' for its own decisions.

Disadvantages of the Centralized Approach

The centralized approach promises high accuracy since a center entity has a global view of the whole system,

but

- Can we trust the center entity ?
- Does the centre entity have the computational resources required ?
  - low response speed especially when the system scale is large
  - huge computation and communication to the center entity
- ...

Distributed Decision making

A distinguishing feature of a multi-agent system $\rightarrow$ decision making of the agents can be distributed, where :

- each agent takes decisions autonomously ;
- agents evolves in the same dynamic environment $\rightarrow$ possible interactions between agents actions (not always possible to anticipate during the design of the system) ;
- agents may need to share limited resources.

Distributed Decision making

Advantages

- efficiency : due to the asynchronous computation,
- robustness : the functionality of the whole system does not rely on a single agent.

Distributed Decision making

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- efficiency : due to the asynchronous computation,
- robustness : the functionality of the whole system does not rely on a single agent.

Several challenging questions !

- How to enable agents to communicate ? What communication languages and protocols to use ? What, when, and with whom should an agent communicate ?
- How to represent knowledge ?
- How to enable agents to reason about the actions, plans, and knowledge of other agents ?
- How to enable agents to coordinate and resolve conflicts ?
- ...

Distributed Decision making

Related to this course ... but not in it!

- The collective choices made in a multi-agent system will be driven by the interests of individual agents.
- Agents must be able to communicate preferences (directly through full revelation, or indirectly via "move" in a dialogue game).
- Agents should be able to make joint decisions, thus, we need to aggregate, merge individual decisions.
- Agents may follow different strategies to make decisions.
- ...

Distributed Decision Making

Related to this course ... but not in it!

- Preference, knowledge representation languages.
- Preference elicitation (acquisition) mechanisms.
- Methods of collective reasoning (computational social choice, Multiple Criteria Decison Analysis, Judgement aggregation ...)
- Strategic interactions modeling (Game theory, ...)
- ...

Relations with other disciplines

Distributed Decision Making : a first ingredient

Distributed approach → appropriate coordination mechanisms must be additionally developed.

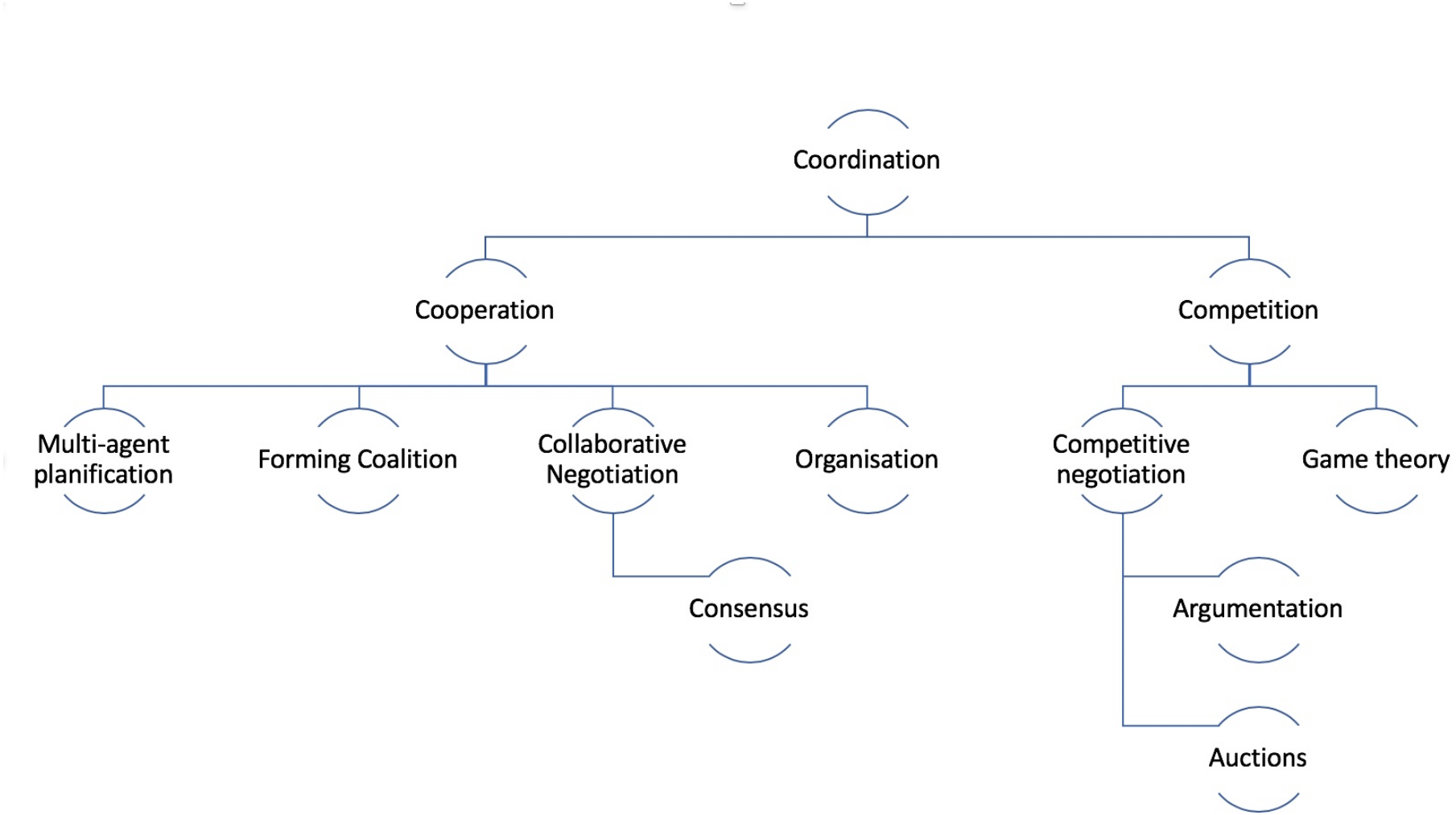
Distributed Decision Making : a first ingredient

Distributed approach ⟶ appropriate coordination mechanisms must be additionally developed.

Coordination

can be regarded as the process by which the individual decisions of the agents result in "good" joint decisions for the group.

Coordination Mechanisms



Source : borrowed from...

Coordinated agents

Arguing

Pervasive human ability

"The function of reasoning is argumentative. It is to devise and evaluate arguments intended to persuade [1]."

1. Hugo Mercier, Dan Sperber. *Behavioral and Brain Science* (2011)

Argumentation theory

Computational Argumentation (Argumentation in AI)

Designing and building machines that argues

Argumentation theory

- Argumentation is the process of attempting to agree about what to believe or what to do.
- Only a question when information, beliefs, actions, ...are contradictory
  If everything is consistent, just merge information from multiple agents.
- Argumentation provides principled techniques for resolving inconsistency (conflicts).
- Or at least, sensible rules for deciding what to believe or what to do in the face of inconsistency.

Argumentation theory

Example

John : Newspapers have no right to publish information I

Argumentation theory

Example

John : Newspapers have no right to publish information I
Mary : why ?

Argumentation theory

Example

John : Newspapers have no right to publish information I
Mary : why ?
John : Because it is about X's private life (a)

Argumentation theory

Example

John : Newspapers have no right to publish information I
Mary : why ?
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Mary : The information I is not private because X is a minister and all information concerning ministers is public (b)

Argumentation theory

Example

John : Newspapers have no right to publish information I
Mary : why ?
John : Because it is about X's private life (a)
Mary : The information I is not private because X is a minister and all information concerning ministers is public (b)
John : But X is not a minister since he resigned last month (c).

Argumentation theory

Example

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Mary : why ?
John : Because it is about X's private life (a)
Mary : The information I is not private because X is a minister and all information concerning ministers is public (b)
John : But X is not a minister since he resigned last month (c).

$$c \rightarrow b \rightarrow a$$

Question : Do newspapers have right to publish information I ?

In this course...

Distributed decision making via argumentation in a multi-agent system

- an agent ?
- a multi-agent system (architecture) ?
- models of interaction ?
  $\rightarrow$ how agent manage to "talk" to each other ?
- an argument ?
- an argumentation system /process ?
- interaction by means of arguments ?
  $\rightarrow$ resolving conflicts, making decision ?

Practical course : implementing an argumentation based negotiation for a MAS

Course Plan

- 09/01- Session 1 :
  - 13h45–15h15 : Introduction
  - 15h15–16h45 : Agent and Multi-agent Systems : some defintions
- 16/01 - Session 2 :
  - 13h45–15h15 : Multi-agent interactions
  - 15h15–16h45 : Practical work : start JADE
- 23/01 - Session 3 (13h45–16h45) : Practical work
- 14/02 - Session 4 :
  - 13h45–15h15 : Arguments and Argumentation System ?
  - 15h15–16h45 : Practical work : Building arguments
- 21/01 - Session 5 :
  - 13h45–15h15 : Argumentation in MAS
  - 15h15–16h45 : Practical work : Relations and status of aguments
- 28/14 - Session 6 (13h45–16h45) : Practical work : Negotiating with arguments
- 07/03 - Session 7 (13h45–16h45) : Practical work
- 21/03 - Session 8 (13h45–16h45) : Evaluation

Course Evaluation

- No exam
- implementing an augmentation-based Negotiation based for a multi-agent system with JADE
- Submit your work (code +comments) on EDUNAO on February 18.

Some References

- Ferber, J. (1995), Les Systèmes Multi-Agents, Inter Editions. (French version)
- Ferber, J. (1999) : Multi-agent systems : An introduction to distributed artificial intelligence (english version)
- Michael Wooldridge (2002), An Introduction to MultiAgent Systems, John Wiley & Sons Ltd
- Jade : http ://jade.tilab.com/
- To practice coding : https ://www.codecademy.com/fr