Introduction to Autonomous Agents and Multi-Agent Systems
Theoretical lectures: Tuesdays (Tagus), Thursdays (Alameda)

Evaluation:
- Theoretic component: 50% (2 tests).
- Practical component: a project (2-3 people): 50%

Lecturers:
- Prof. Ana Paiva (coordination- Alameda, some theoretical classes)
- Prof. Manuel Lopes, Dr. Pedro Sequeira (some theoretical classes and some practical classes)
- Eng. Filipa Correia (some practical classes)
Bibliography

- Several papers distributed in the site as we talk about them
Practical Issues

- Project: those that want to propose a project, need to contact us as soon as possible.
- 1st Conference of IAD (International Workshop on Distributed Artificial Intelligence) in the US in 1980 (after a preliminary meeting at the MIT in 1979)

- In Europe the MAAMAW happened for the first time in 1989, after the launching of the theme in a pannel in the European Conference on Artificial Intelligence, ECAI-88.

- The first international meeting ICMAS, happened for the first time in 1995 in the US.

- The Workshop on Agent Theories, Architectures, and Languages (ATAL) is launched in the ECAI in 1994

- Finally the Internacional Autonomous Agents Conference (Autonomous Agents- AA), held in 1997 a 1999 in the US, in 2000 is held in Europe.

Motivation
Motivation: The world today

- **Ubiquity** – distributed computational power – mobiles, etc
Motivation: The world today

Connectivity

– Ubiquity – distributed computational power – mobiles, etc
– Connectivity – nowadays we are always connected…
Motivation: The world today

- Ubiquity – distributed computational power – mobiles, etc
- Connectivity – nowadays we are always connected…
- Intelligence – Tasks more and more complex to be done by humans and computers
Motivation: The world today

Delegation

- Ubiquity – distributed computational power – mobiles, etc
- Connectivity – nowadays we are always connected…
- Intelligence – Tasks more and more complex to be done by humans and computers
- Delegation – the need for delegating critical tasks – example: the automatic pilot
Motivation: The world today

- **Ubiquity** – distributed computational power – mobiles, etc
- **Connectivity** – nowadays we are always connected…
- **Intelligence** – Tasks more and more complex to be done by humans and computers
- **Delegation** – the need for delegating critical tasks- example: the automatic pilot
- **Autonomy** – more and tasks are given to machines to be performed “autonomously” without direct control of humans;
Motivation: The world today

Serve the human

- Ubiquity – distributed computational power – mobiles, etc
- Connectivity – nowadays we are always connected…
- Intelligence – Tasks more and more complex to be done by humans and computers
- Delegation – the need for delegating critical tasks - example: the automatic pilot
- Autonomy – more and tasks are given to machines to be performed “autonomously” without direct control of humans;
- Serve the human – more and more we use the human metaphors for interaction, rather than “machine based” one.
But what does this mean in terms of advancements in Computing?
....Programming...
Programming has progressed through:
- machine code;
- assembly language;
- machine-independent programming languages;
- sub-routines;
- procedures & functions;
- abstract data types;
- objects;

to agents (relying on distribution).
Interconnection and Distribution have become core motifs in Computer Science.

But Interconnection and Distribution, coupled with the need for systems to represent our best interests, implies systems that can cooperate and reach agreements (or even compete) with other systems that have different interests (much as we do with other people).
Where does it bring us?

• Delegation and Intelligence imply the need to build computer systems that can act effectively on our behalf

• This implies:
  – The ability of computer systems to act *independently and autonomously*!
  – The ability of computer systems to act in a way that *represents our best interests* while interacting with other humans or systems
So Computer Science expands...

All of these trends have led to the emergence of a new field in Computer Science:

multiagent systems and autonomous machines
Global Computing

What techniques might be needed to deal with systems composed of $10^{10}$ processors?
Agents and Robots in the Rise of AI

OFFBOOK

PBS | digital studios
## The fourth Industrial Revolution

### Navigating the next industrial revolution

<table>
<thead>
<tr>
<th>Revolution</th>
<th>Year</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1784</td>
<td>Steam, water, mechanical production equipment</td>
</tr>
<tr>
<td>2</td>
<td>1870</td>
<td>Division of labour, electricity, mass production</td>
</tr>
<tr>
<td>3</td>
<td>1969</td>
<td>Electronics, IT, automated production</td>
</tr>
<tr>
<td>4</td>
<td>?</td>
<td>Cyber-physical systems</td>
</tr>
</tbody>
</table>
The impressive progress made in AI in recent years, driven by exponential increases in computing power and by the availability of vast amounts of data, has lead to the engineering of systems that can not only discover patterns of behavior, make accurate predictions, but also act “autonomously” in the world.

- Artificial intelligence is now all around us, from self-driving cars and drones to virtual assistants and software that predicts and invests.

AI, and Agents are behind this fourth industrial revolution.
But what are Agents?
Agents: a definition

- “Agente é Aquele que opera”, ou “Tudo o que age”, ou
- “Aquele que é encarregue dos negócios de outrem”.

- There are two sides of the definition:
  - An entity that is able to act
  - A helper that we can delegate tasks on

Yet, authors do have different definitions of what they mean by the term “agent”
Interaction with the environment: "An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" (Russel e Norvig, 1995).
Agents, a definition.....

An agent is a computer system that is capable of *independent* action on behalf of its user or owner (figuring out what needs to be done to satisfy design objectives, rather than constantly being told)
Focus on communication: "Software agents are software components that communicate with their peers by exchanging messages in an expressive agent communication language" (Genesereth e Ketchpel, 1994).
Focus on goals and motivations "An agent is a computational system that inhabits a complex, dynamic environment. An agent can sense, and act on, its environment, and has a set of goals or motivations that it tries to achieve through these actions" (P. Maes, 1994).
Focus on mobility: "Along with mobility agents have the following computational characteristics: autonomous; asynchronous; local interaction; parallel execution and object passing" (IBM Aglets White paper, 1997).
Focus on **delegation**: An agent is a program that a person or organisation vests its authority, that can run unattended for a long time and that can meet and interact with other agents. The person or organisation is the agent’s authority" (White, 1994).
Focus on the combination of properties: An agent is a software based computer system that enjoys the properties of: autonomy, social-ability, reactivity and pro-activeness" (Wooldridge & Jennings, 1995).
From one to many....
Multiagent Systems, a definition….

• A multiagent system is one that consists of a number of agents, which interact with one another.

• To successfully interact, they will require the ability to cooperate, coordinate, and negotiate with each other, much as people do.
Agent Design.... to Society Design

The course covers two key problems:

– How do we build agents capable of independent, autonomous action, so that they can successfully carry out tasks we delegate to them?

– How do we build agents that are capable of interacting (cooperating, coordinating, negotiating) with other agents in order to successfully carry out those delegated tasks, especially when the other agents cannot be assumed to share the same interests/goals?

The first problem is *agent design*, the second is *society design* (micro/macro)
Multiagent Systems: Questions…

• How can cooperation emerge in societies of self-interested agents?
• What kinds of languages can agents use to communicate?
• How can self-interested agents recognize conflict, and how can they (nevertheless) reach agreement?
• How can autonomous agents coordinate their activities so as to cooperatively achieve goals?
While these questions are all addressed in part by other disciplines (notably economics and social sciences), what makes the multiagent systems field unique is that it emphasizes that the agents in question are computational, information processing entities.
Multiagent Systems is Interdisciplinary

- The field of Multiagent Systems is influenced and inspired by many other fields:
  - Economics
  - Philosophy
  - Game Theory
  - Logic
  - Ecology and Ethology
  - Psychology
  - Sociology
  - Cognitive Science

- This can be both a strength (infusing well-founded methodologies into the field) and a weakness (there are many different views as to what the field is about)

- This has analogies with artificial intelligence itself
Agents as a paradigm for software engineering:
Software engineers have derived a progressively better understanding of the characteristics of complexity in software. It is now widely recognized that interaction is probably the most important single characteristic of complex software.
Some Views of the Field

Agents as a tool for understanding human societies
Some Views of the Field

- Multiagent Systems is primarily a search for appropriate theoretical foundations
A vision
Welcome to the Autonomous-agents and Multiagent Systems Course