

Introduction to the Course

Autonomous Software Agents

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Autonomous Software

- A software that can **operate autonomously** (without any human or other software control):

- Wait a minute ! ... any software is like that, right?

Yes, knowing in advance that `cond_1` and `battery_NotOK` are the only variables that can change the execution

What about `obstacle_in_front`, should we change the software?

Also, are you sure that under `cond_1`, `move_right` and `pick_up` are always the best actions to perform?

```
while(run){  
    if(cond_1) {  
        move_right()  
        pick_up()  
    } else {  
        move_left()  
        mov_on()  
    }  
    if(battery_NotOK) {  
        run = False  
    }  
}
```

Amazon warehouse (Video)

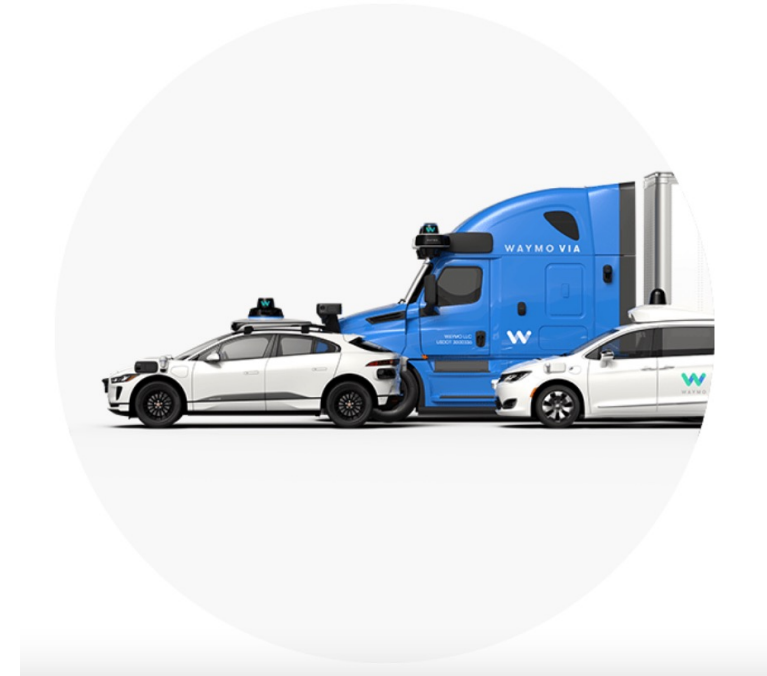
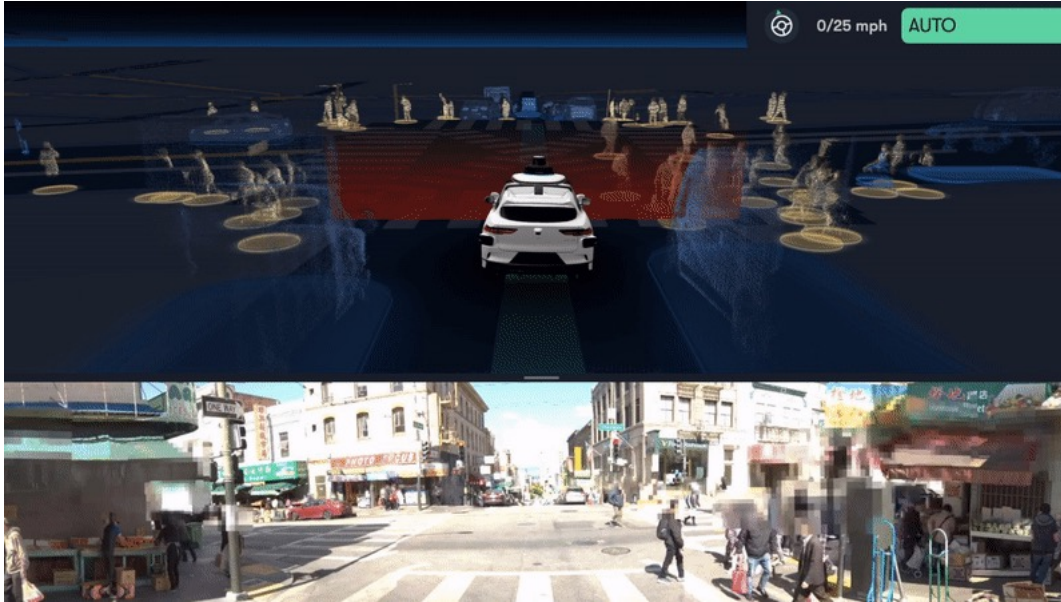


Intelligence and delegation

- The complexity of tasks that we are capable of **automating** and **delegating** to computers has grown steadily
- Computers are doing more for us – without our intervention
- We are **giving control** to computers, even in safety critical tasks



Google's Driverless Car – Waymo Driver



How safe driver is your average robot? Safer than your average American, at least by one measure.

- Since 2009, billions of miles driven (millions in public roads) over +13 US states.

The 6 Levels of Vehicle Autonomy

- Level 0 (No Driving Automation)
 - The automated system issues warnings and may momentarily intervene but has no sustained vehicle control
- Level 1 (Driver Assistance)
 - The driver and the automated system share control of the vehicle
- Level 2 (Partial Driving Automation)
 - The automated system takes full control of the vehicle: accelerating, braking, and steering.
- Level 3 (Conditional Driving Automation)
 - The driver can safely turn their attention away from the driving tasks
- Level 4 (High Driving Automation)
 - As level 3, but no driver attention is ever required for safety
- Level 5 (Full Driving Automation)
 - No human intervention is required at all

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**
 - The ability of computer systems to act in a way that **represents our best interests** while **interacting** with other humans or systems

Programming progression...

Programming has progressed through:

- machine code;
- assembly language;
- machine-independent programming languages;
- sub-routines;
- procedures & functions;
- abstract data types;
- objects;
- services;

to **agents**



Human Orientation

- Movement away from machine-oriented views of programming toward concepts and metaphors that more closely reflect the way we ourselves understand the world
- Programmers (and users!) relate to the machine differently
- Programmers conceptualize and implement software in terms of **higher-level** – more human-oriented – **abstractions**
 - **Abstractions** to cope with complexity



Agent, a first definition

An agent is a computer system that is capable of **independent** actions on behalf of its user or owner (figuring out what needs to be done to satisfy design objectives, rather than constantly being told)
[Wooldridge&Jennigs]



Interconnection

- Computer systems today no longer stand alone, but are networked into **large distributed systems**
 - The internet is an obvious example, but networking is spreading its ever-growing tentacles...
- Since distributed and concurrent systems have become the norm, some researchers are putting forward theoretical models that portray computing as primarily a **process of interaction**

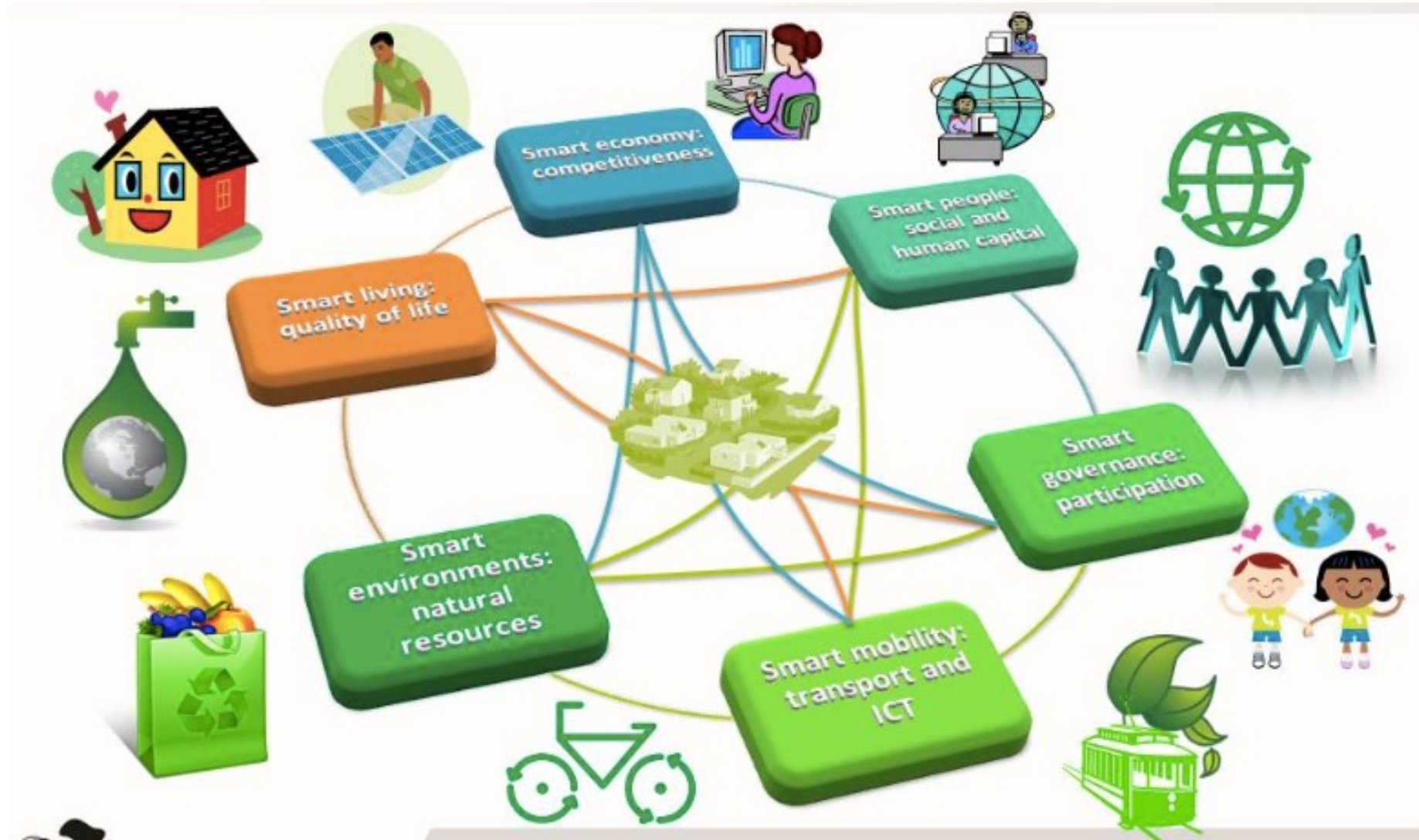


Where we are ...

- Computing is now about **interaction** and **coordination** between **distinct piece of software**
- More and more **independent software** able to coordinate with others (including humans)
 - The final objective is obtained as an emergent behaviour of multi-software behaviours
 - Open environment (new piece of software can be added or removed)
 - Multi-objective problem



Interconnection: smart city



Services, Cloud and Edge computing

- Services are made available to be used and combined together
 - Data storage, software as service, platform as service, infrastructure as service
 - Interaction between different systems is the key issue
 - Quality and security control problems
 - Services availability
 - Run-time composition
 - Flexibility and scalability issues
- Edge computing brings computation and data storage closer to the sources of data



Ubiquity

- The continual reduction in cost of computing capability has made it possible to introduce **processing power** into places and devices that would have once been uneconomic
- As processing capability spreads, sophistication (and intelligence of a sort) becomes **ubiquitous**
- What could benefit from having a processor embedded in it...?



Internet of Things

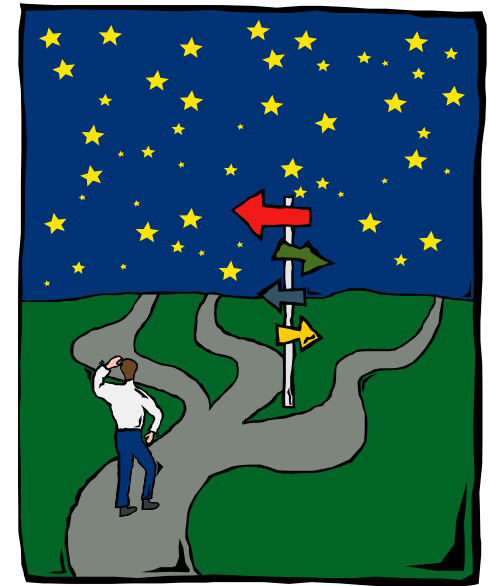
- The **Internet of Things** refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure
 - If all objects of daily life were equipped with radio tags, they could be identified and inventoried by computers
- Ambient Intelligence (AI) and Autonomous Control (AC) are not part of the original concept of the Internet of Things
 - How to use the Internet of Things for AI and AC?



Computer Science expands...

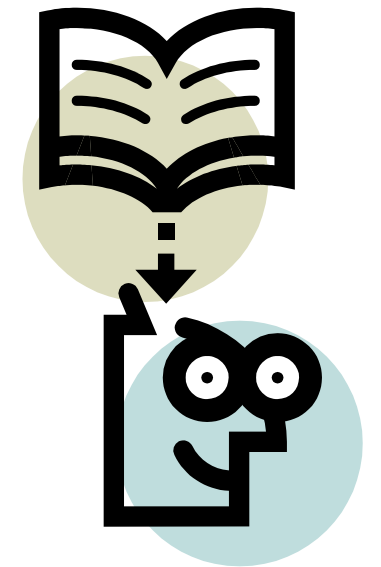
All of these trends have led to the emergence of a new field in Computer Science:

Agent Systems provide us with the means to design and implement interactive computing, whether between machines, or people, or both
[Michael Luck]



Interconnection and distribution

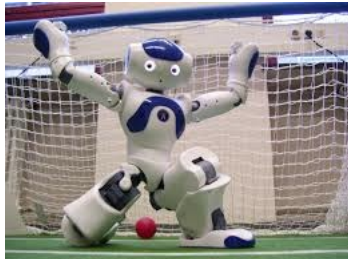
- Interconnection and distribution have become core motifs in Computer Science
- But Interconnection and distribution, coupled with the need for systems to represent our best interests, implies systems that can **cooperate** and **reach agreements** (or even **compete**) with other systems that have different interests (much as we do with other people)



Examples



Robocup



Swarm intelligence



Distributed Sensing



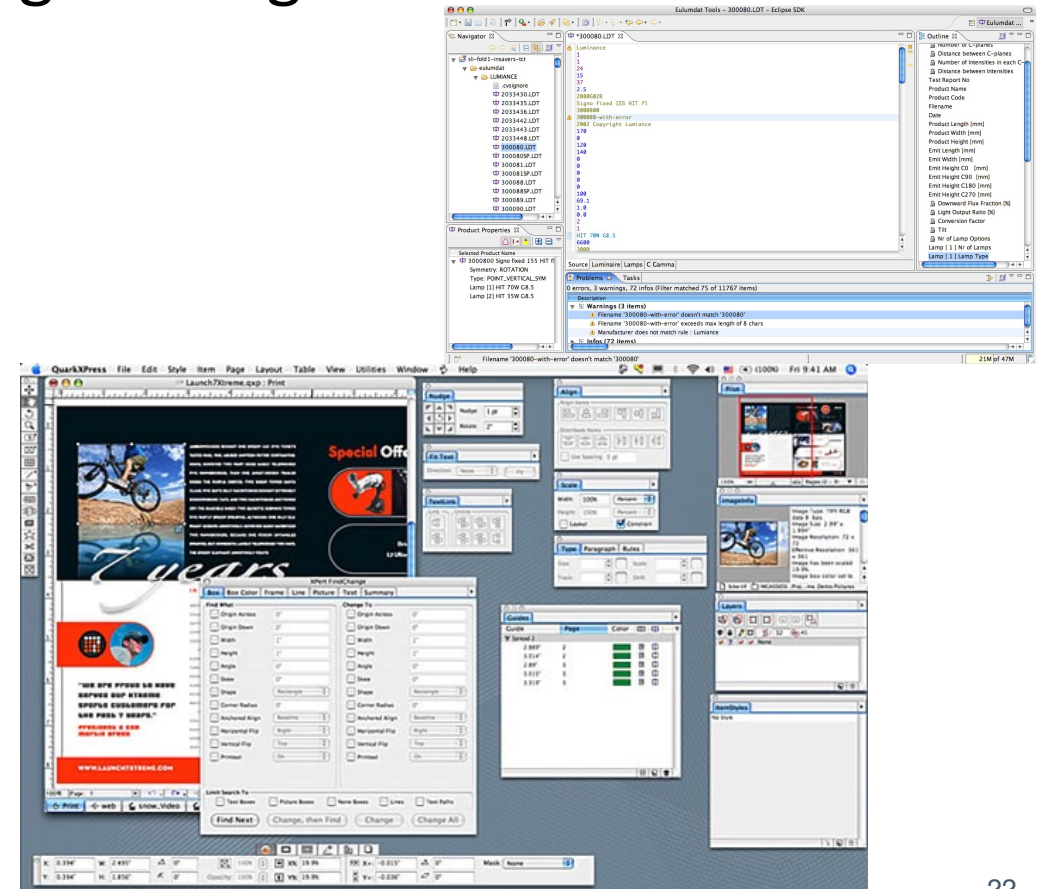
Multi-Agent System, a definition

- A multi-agent system is one that consists of a number of agents, which **interact** with one-another
- In the most general case, agents will be **acting on behalf of users** with different **goals** and motivations
- To successfully interact, they will require the ability to **cooperate**, **coordinate**, and **negotiate** with each other, much as people do



How can we develop such complex software?

- A good (**Agent-Oriented**) Software Engineering Methodology
 - Modeling languages
 - Analysis techniques
 - Design Techniques
 - Supporting Tools

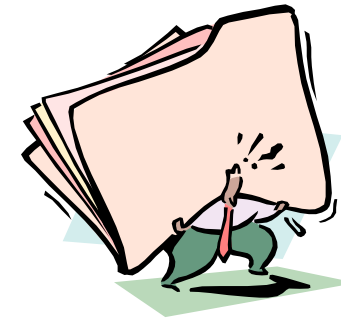


Objective of the Course

- The objective of the course is to examine and explore the credentials of **agent-based approaches** as a **software engineering paradigm**, and to gain an insight into what agent-oriented software engineering will look like
 - Agents as building blocks of a software system
 - Agent as basic concept to develop a software system
 - Knowledge level Software Engineering
 - Agent concept and its mentalist notions (e.g., goal, plan, and belief) are used along all the software engineering process
 - Agent as main concept to
 - model and analyse and organizational setting
 - design a system
 - implement a system ...

Structure of the course

- Very **practical** course
 - You will learn how to develop both a single and a team of autonomous software systems
- **Theory**
 - We will explore concepts of autonomous software agents and multi-agent systems, software architectures, interaction and communication techniques, planning techniques
- **Laboratory**
 - Tutorial + project development



Tentative Theory content

Introduction

- Introduction to the agent paradigm and multi-agent systems
- Applications and problems

Interaction and cooperation

- Types of interaction
- Forms of Cooperation
- Methods of cooperation
- Organization and cooperation

Communication

- Aspects of communication
- Speech acts
- Conversation
- KQML/ACL

Collaboration and distributed tasks

- Models of tasks allocation
- Centralized allocation
- Decentralized allocation
- Emergent allocation

The BDI Architecture

- The agent control loop
- The deliberation process

Planning

- Exploring the space of alternatives
- Planning in the agent control loop

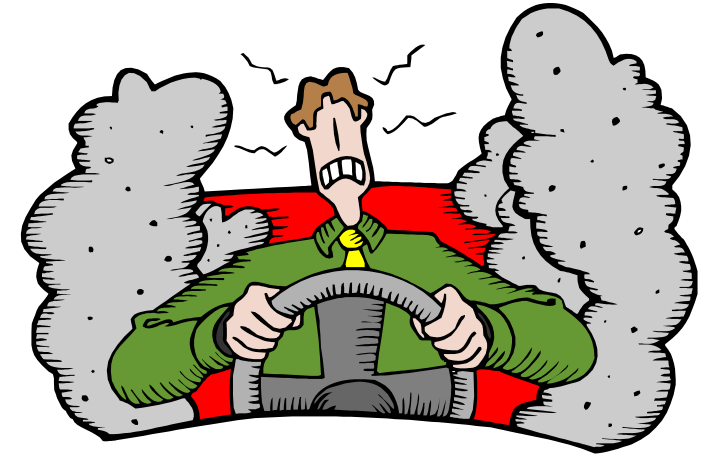
Agent-Oriented Methodologies

Agent-oriented development tools

Laboratory

- Hands-on with exercises
- Node.js – javascript
- Planning
 - PDDL
- Project development

→ (Take your laptop with you)



Exam and prerequisites

Project: a scenario will be provided in a couple of weeks

- Groups of 2 students
- First part: single agent
- Second part: team of two collaborative agents
- **Exam**
 - Project deliverable - **Code** + **Report** (max 10 pages)
 - Oral presentation
- **Prerequisite for the course:** experience in programming
 - Better if you know Javascript (although, we will provide a Tutorial)





Books and Material

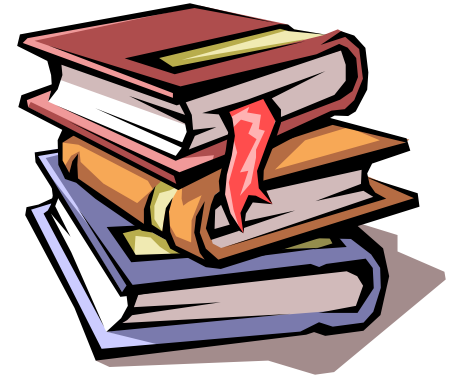
- Given the fact we will try and provide a broad coverage of various topics seems unrealistic an approach in which all the textbooks are adopted.

Therefore:

- We encourage the use of slides, papers, (on-line) material, etc.
- We provide a list of textbooks of which only parts are needed (no need to get all of them, though!)

Books...

- *Jacques Ferber. Multi-Agent System: An Introduction to Distributed Artificial Intelligence*, Addison Wesley Longman, 1999
- *Michael Wooldridge. An Introduction to Multiagent Systems*. John Wiley & Sons, 2002
- *Paolo Giorgini and Brian Henderson-Sellers. Agent-oriented Methodologies*, Idea Group Inc, 2004.
- *Fabio Bellifemine, Giovanni Caire, Dominic Greenwood. Developing Multi-Agent Systems with JADE*. John Wiley & Son Ltd, 2007
- *G. Weiss. Multiagent systems*, (second edition). MIT Press, 2013.



Next lectures

- Tuesday 11.30 -13.30 (A110)
- Wednesday 9.30-11.30 (A110)

Lectures will be in presence, but we will stream (zoom) and record them

All info and material is Moodle

- Zoom link for the lectures
- Slides + Video
- ... and much more

Contacts

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Q/A