TÉCNICO LISBOA

Introduction to multiagent systems

Perspectives on agent systems

Outline

- **Motivation**
- Agent and Multiagent Systems, a definition
- Examples of Agent-based Systems
- Challenges in Multiagent Systems
- Relevance of Multiagent Systems
- Frequently Asked Questions
- History and prospect

Motivation

- Five ongoing trends have marked the history of computing:
  - *ubiquity*;
  - *interconnection*;
  - *intelligence*;
  - *delegation*; and
  - *human-orientation*

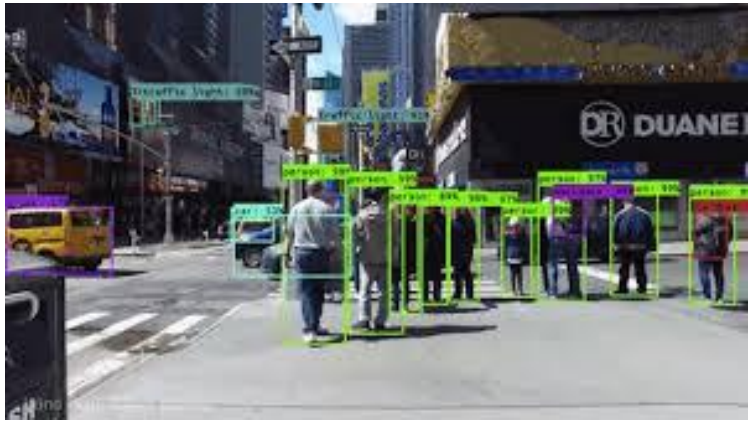
Motivation

- ***Ubiquity:*** **We now see processing power in places and devices that would have once been uneconomic**

Motivation

- *Interconnection :* **Computer systems today no longer stand alone, but are networked into large distributed systems**

Motivation



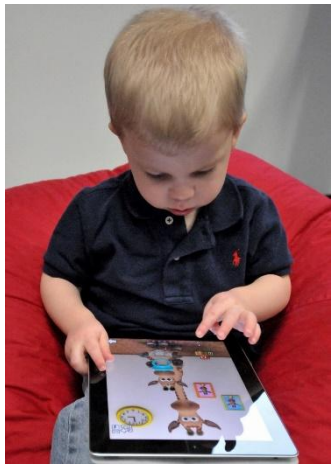
- ***Intelligence:*** **We are now engineering complex systems that perform tasks that were unthinkable only a short time ago**

Motivation

- ***Delegation:*** **We are giving more and more control to computers (devices, robots, cars,…)**

Motivation

- ***Human-orientation:*** ***In the past, users had to program computers with low-level code. We now use computers with more human-oriented abstractions***



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

Where does it bring us?

- *Interconnection* and *Distribution* have become a very important topic 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*)

Where does it bring us?

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

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Agents, a Definition

- An agent is a computer system that is capable of *independent (autonomous)* action on behalf of its user or owner

- *Autonomy* is a key aspect of an agent!
  - An agent should figure out what to do
  - Rather than constantly being told what to do

Multiagent Systems, a Definition

- A multiagent system is one that consists of a *set 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

The two key problems

- The course covers two key problems:
  - *Agent design: How do we build agents?*
    - Agents that are independent, autonomous, and able to carry out tasks we delegate to them
    - Decision making is a key aspect!
  - *Society design: How do we build agents that are capable of interacting?*
    - cooperating, coordinating, negotiating with other agents
- These are the ***micro*** and ***macro*** perspectives

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Examples of Agents

- *Autonomy - NASA's Mars 2021 Perseverance rover*

https://www.youtube.com/watch?v=M4tdMR5HLtg

Examples of Agents

- *Cooperation and Coordination - RoboCup*

https://www.youtube.com/watch?v=_Y5_iGxWFrQ

Examples of Agents

- *Trading Agent – Automated/Algorithmic Trading*

https://www.youtube.com/watch?v=OPm_EDTrz7Y

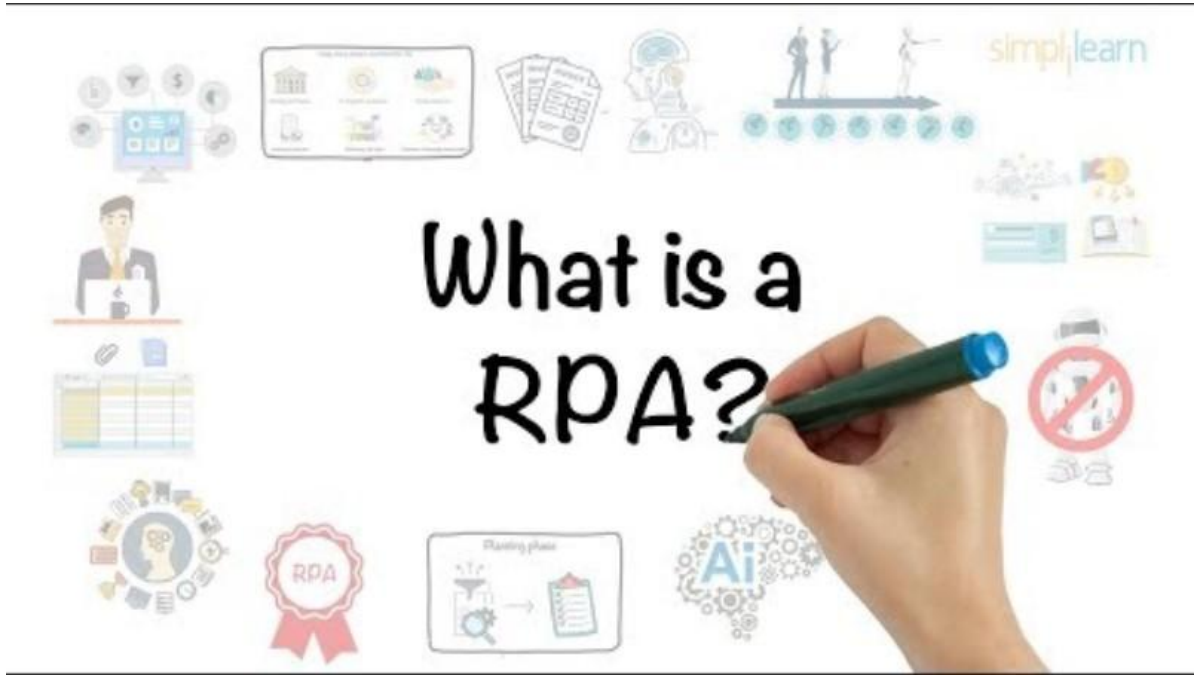
Examples of Agents

- *Unitree Dancing Robots*

https://www.youtube.com/watch?v=Fw_dSNxhhY4

Examples of Agents

- *Business Process Automation – Robotic Process Automation*



https://www.youtube.com/watch?v=9URSbTOE4YI

Forbes

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Agentic AI: The Next Big Breakthrough That's Transforming Business And Technology

By Bernard Marr, Contributor.

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Challenges in Multiagent Systems

- In Multiagent Systems, we address questions such as:
  - How can agents *interact with each other*?
  - How can *cooperation emerge in societies* of self-interested agents?
  - What kinds of *languages can agents use to communicate*?

Challenges in Multiagent Systems

- In Multiagent Systems, we address questions such as:
  - How can *self-interested agents recognize conflict*, and how can they (nevertheless) *reach agreement*?
  - How can autonomous agents *coordinate their activities* to *cooperatively achieve goals*?

Multiagent Systems

- 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.

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On the relevance of agent systems

Many different views of what multiagent systems are:

- Agents as a paradigm for *software engineering*
- Agents as a tool to *understand societies*
- Agents as a way to search for *theoretical foundations*
- Role of *agents in other sciences*

Agents as a paradigm for software engineering

Engineering multiagent systems = Engineering complex software

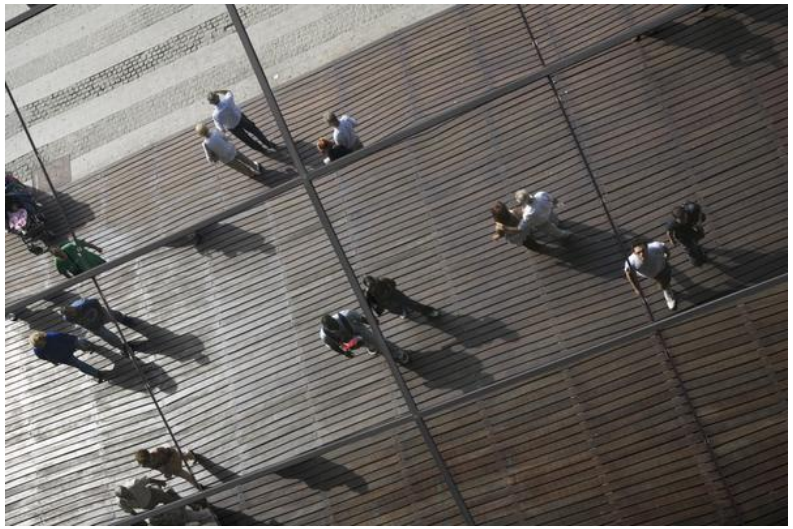
- Many dynamically interacting components
- Decentralized approach
- Unforeseen situations
- Fault-tolerant (one component fails, others still alive)
- Adaptive/Flexible behavior

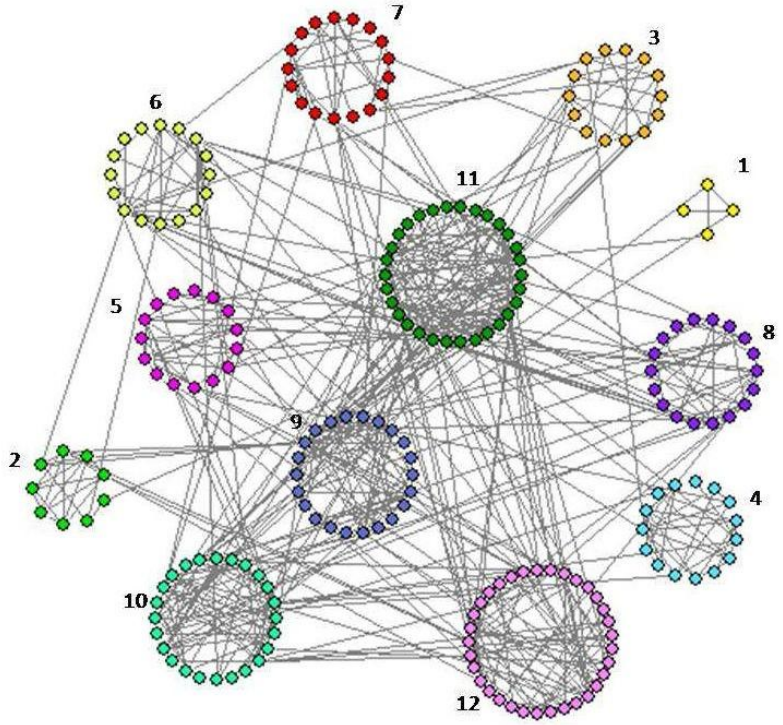
"interaction is probably the most important single characteristic of complex software"

Agents as a tool to understand societies

New tool for simulating society

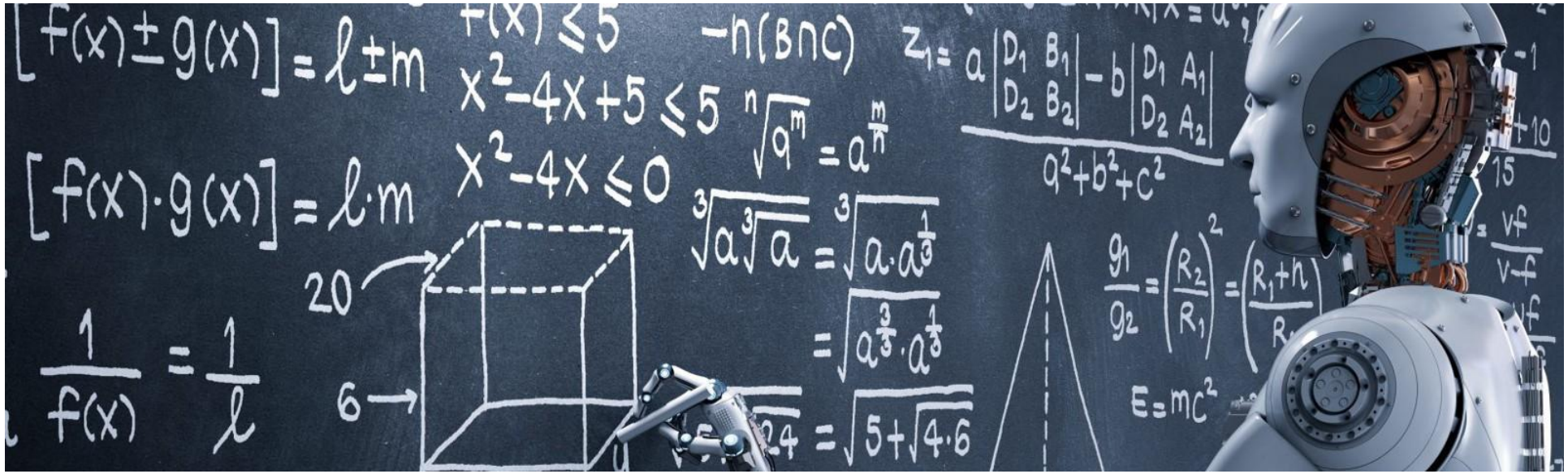
- multiagent based simulations
- understand dynamics/behavior





Agents as a way to search for theoretical foundations

- Derive formal properties from single/multi agent behavior
- Theorem proofs



Multi-agents is interdisciplinary

- Economics/game theory
  - Interactions among self-interested agents / economic entities
  - Rational agents able to mimic humans / organizations

- Social sciences
  - Interested in MAS to model/simulated social behavior
  - Model of emotions and their impact
  - Inspiration from agent traits

Multi-agents is interdisciplinary

Influenced by and influences many other fields:

- *ecology*
- *ethology*
- *philosophy*
- *logic*
- *psychology*
- *sociology*
- *cognitive science*
- *anthropology*

Strength: one can use well-founded methodologies

Weakness: many different views as to what an agent is about

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Agents and Artificial Intelligence

Isn't it all just artificial intelligence?

Isn't building an agent what AI is all about?

- AI is largely concerned with the *components of intelligence*
  - Ability to learn, plan, act, etc.

- Classical AI ignores the *social* aspects of agency
  - Ability to communicate, coordinate, cooperate, and reach agreements

Agents and Distributed Systems

Isn't it all just Distributed/ Concurrent Systems?

- There is much to learn from this community, but:
  - Agents are assumed to be autonomous
  - Agents are (can be) self-interested

Agents and Economics

Isn't it all just Economics/Game Theory?

- These fields also have a lot to teach us in multiagent systems, but:
  - Many concepts in Game Theory (e.g., Nash equilibrium) were developed without a view to computation
  - Some assumptions in economics/game theory (such as a rational agent) may not be valid or useful in building artificial agent societies

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History

- First conference *Workshop on Distributed Artificial Intelligence* in **1980**
- MAAMAW in Europe in **1980** (after launch in European Conference on AI)
- First international meeting ICMAS in **1995**
- *Workshop Agent Theories, Arch. and Languages* (ATAL) launched in ECAI in **1994**
- Finally: *Autonomous Agents Conference* held in 1997-99 (US) and 2000 in Europe
- In **2002**: ICMAS and AA merged to launch the largest conf. on agents: **AAMAS**

Thank You

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