U.PORTO
FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

Agents and Multi-Agent Systems

Agent-based Computing

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Computing Trends

- Important continuing trends
  - Ubiquity
    - Costless computing devices
  - Interconnection
    - Networked large distributed systems
  - Intelligence
    - Higher complexity of automatable tasks
  - Delegation
    - Safety-critical tasks controlled by computer systems
  - Human-orientation
    - Concepts, abstractions and metaphors reflecting the way we understand the world

Computing Trends

- Ubiquity and Interconnection
  - Exploit ubiquitous processor power
  - Build reliable distributed systems
- Intelligence and Delegation
  - Need to build computer systems that can act *effectively* on our behalf
    - Operate independently, without our direct intervention
    - Represent our best interests while interacting with other humans or systems
- Distribution and Delegation
  - *Decentralized* systems
  - Computer systems with different interests: ability to *cooperate* and *reach agreements*
- Human-orientation
  - Programmers conceptualize and implement software in successively more human-oriented abstractions
    - Machine code → Assembly → machine-independent languages → procedures and functions → ADTs → objects → agents

Intelligent Autonomous Agents

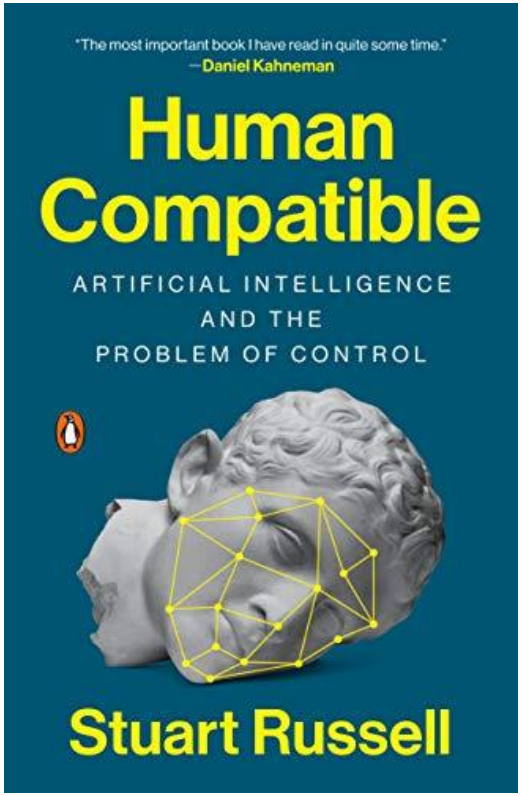
- What is an Intelligent Agent?
  - Human performance (too limiting?)
  - Rationality (too much?)
  - Competence (in "complex" tasks, e.g., those requiring intelligence)

- What is an Autonomous Agent?
  - Autonomy is the agent's ability to master a set of tasks to achieve certain goals in a given environment without recourse to the agent's designer

➢ It is a matter of the nature of the environment whether an agent needs intelligence to master its tasks

Autonomy and Alignment

- How autonomous do we want an agent to be?
  - When is autonomy too much?
- How can we make sure we properly specify the agent's objectives?
  - The alignment problem
- Adjustable autonomy
  - Human-in-the-loop whenever needed



If we use, to achieve our purposes, a mechanical agency with whose operation we cannot interfere effectively … we had better be quite sure that the purpose put into the machine is the purpose which we really desire.

[Wiener, 1960]

Agents vs Artificial Intelligence

- Multi-agent systems as Distributed AI
  - a subfield of AI?

- AI: constructing intelligent agents
  - *"The main unifying theme is the idea of an intelligent agent. We define AI as the study of agents that receive percepts from the environment and perform actions."*

[Russel & Norvig]

Agents vs Artificial Intelligence

- AI has been concerned with the *components of intelligence*: learn, plan, understand, …

- The agent field is concerned with entities that *integrate* these components in order to make independent decisions
  - But: we do not need to solve all problems in AI
  - *"Intelligent agents are ninety-nine percent computer science and one percent AI"* [Etzioni, 1996]
    - In some applications, capabilities such as learning may even be undesirable!

- Classical AI has ignored the social aspects of agency
  - Communicating, cooperating, reaching agreements, trust – social ability

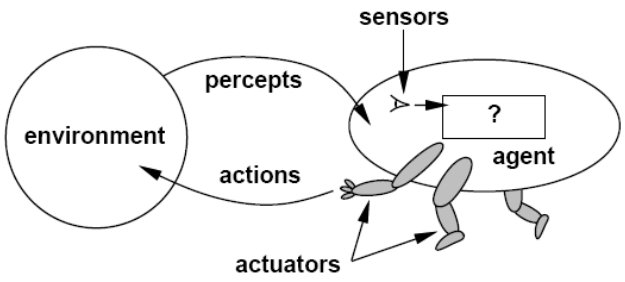
Agent-based Computing

- *Agents as a paradigm for software engineering*
  - Better understanding of the characteristics of complexity in software
  - Interaction is probably the most important single characteristic of complex software
  - Agents as an abstraction to simulate or develop *complex systems*
  - ➢ Computer science, software engineering, artificial intelligence

- *Agents as a tool for understanding (human) societies*
  - A tool for simulating societies, which may help shed some light on various kinds of social processes
  - Complex system behavior, emergent phenomena
  - ➢ Social sciences, biological sciences, environmental modeling, …

General Definitions

- Agent
  - A computational entity situated in an environment, capable of *autonomous* action in order to meet its design objectives



- Multi-agent system
  - A system consisting of a number agents *interacting* in a common (physical or virtual) environment

Micro and Macro

- Agent design problem (micro)
  - How to build agents whose behavior enables them to meet their design objectives?

- Society design problem (macro)
  - Which mechanisms should be in place that model and enable the interactions between agents in a multi-agent system?

→ In this course we will address both of these problems

Some (Single Agent) Applications

Google ASSISTANT

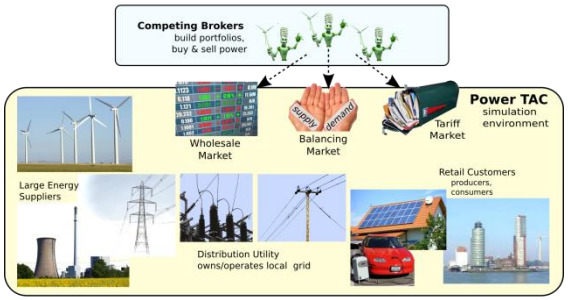
MAS Applications

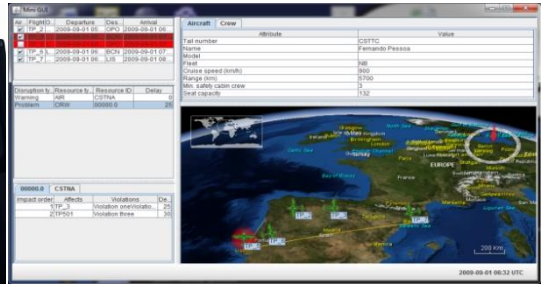
- General characteristics:
  - Each agent has **incomplete information or capabilities** for solving the problem
  - There is **no system global control**
  - Data is **decentralized**
  - Computation is **asynchronous**

- Distributed, decentralized, complex, heterogeneous systems

MAS Applications

- E-commerce / e-procurement
- Transportation and logistics
- Distribution networks
- Intelligent transportation systems
- Teamwork
- Air traffic control
- Disruption management
- Social simulation
- …

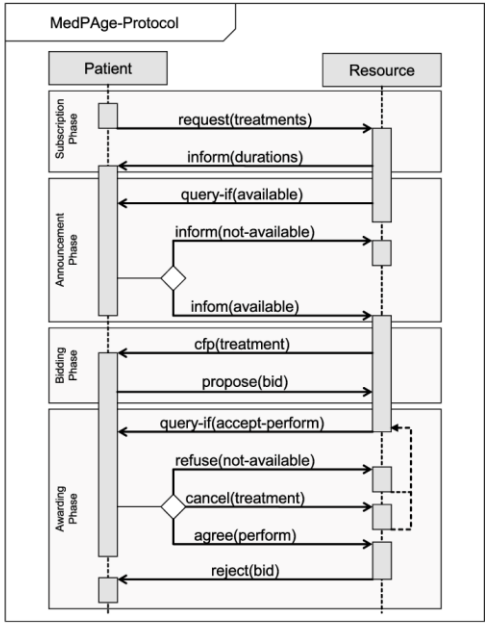




Further Reading

- Wooldridge, M. (2009). *An Introduction to MultiAgent Systems*, 2nd ed., John Wiley & Sons: Chap. 1, 10

Assignment Example 1



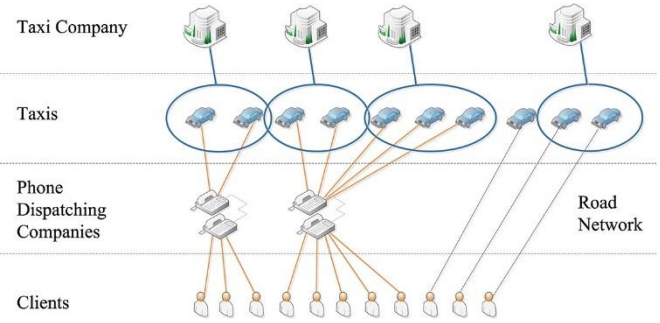
Negotiation-based Patient Scheduling in Hospitals: a decentralized coordination problem

Patient care in a hospitals is a complex task. Each patient has **medical tests** to perform, depending on their pathology and associated treatment. From a medical point of view, patients have different **priorities** according to their **health status**. The **resources** available in the hospital are scarce (diagnosis tests such as ECG, ultrasound or X-ray, medical staff, ...), and the aim is to make the best use of them. Given the complexity of this scenario, we intend to develop a **MAS**-based approach to the problem of **allocating** hospital resources to patients, where the agents represent, on one hand, the patients, and on the other hand, the available resources. The allocation of resources to patients should be **dynamic**, through **negotiation** between the agents involved.

- *Braubach, L., Pokahr, A., & Lamersdorf, W. (2014). Negotiation-Based Patient Scheduling in Hospitals - Reengineering Message-Based Interactions with Services. Advanced Intelligent Computational Technologies and Decision Support Systems.*

Dependent variables	Independent variables
Waiting times	Number and type of available resources
Health status	Medical tests to perform per patient
Resource occupation	Characteristics of each patient

Assignment Example 2



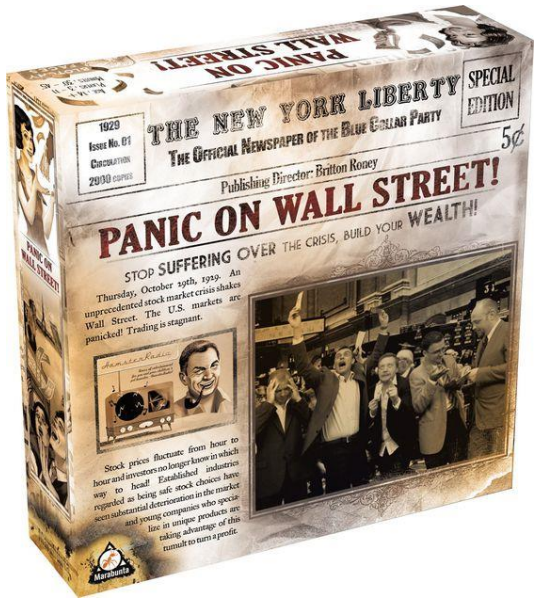
Agent-based Taxi-sharing solution

We want to evaluate the usage of **shared-use taxis**. When in service, a taxi can pick up new users (up to its maximum **capacity**) provided that this does not involve an excessive increase in the **journey time** of passengers already in the vehicle. The **cost** of the distances travelled in common is **shared** between the passengers. The customer calls the central office, which **negotiates** the allocation of a taxi with those close to the point of origin. The one which allows a better **return** on the use of the service, or which allows a better **customer experience** (quality/price) will be allocated.

– *Martinez, L. M., Correia, G. H. A. and Viegas, J. M. (2015), An agent-based simulation model to assess the impacts of introducing a shared-taxi system: an application to Lisbon (Portugal). J. Adv. Transp., 49: 475–495.*

Dependent variables	Independent variables
Waiting and traveling times	Sharing criteria
Travel prices	Cost splitting criteria
Taxi costs	Client types

Assignment Example 3



Trading agents for the stock market

Panic on Wall Street is a board game on buying and selling **stocks** on the **stock exchange market**. There are two types of players: **managers** and **investors**. The former try to sell **investment** opportunities to investors at the highest possible **price**. Investors try to buy investments from each manager for the best price. **Investment funds** range from very **safe** but **unprofitable** to very **volatile** but also **very profitable**. At the end of each **negotiation** round, a die is rolled for each fund type and their values fluctuate accordingly.

Dependent variables	Independent variables
Stock value for each player	Number of companies for each type of investment fund
Market volatility	Stock variation range
Final rank of each player	Manager and investor types