Introduction to Multiagent Systems

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Webpage: http://www.cs.uu.nl/docs/vakken/mas

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The Aim of this Course

- The course consists of lecture and lab sessions.
- Lecture sessions provide an introduction to the field of multiagent systems and covers:
  - decision theory
  - game theory
  - social choice
  - mechanism design
  - auctions
- Lab sessions aim at giving you experience in engineering multiagent systems and covers:
  - Multiagent negotiation
  - Preference modeling and utility theory
  - Group decision-making
  - Opponent modeling
  - Decision-making under uncertainty
  - Development of Multiagent Systems

Lab Sessions

- The lab sessions are organised around a student group assignment
- The assignment
  - concerns the design and development of a multiagent system
  - consists of 3 reports and Java implementation of a negotiation agent
  - are performed in interdisciplinary groups
- Each group consists of five students
- Each group has a coordinator who is responsible for:
  - distributing the tasks,
  - communication with us and other students,
  - submission of reports and agent program, and
  - reporting on activities: experience of the team and a summary of who performed which tasks.

Exam and Marks

- The final exam is on Thursday, 14 April 2022 (17:00-20:30) in RUPPERT
- The final mark is based on the written exam (70%) and assignment (30%)
- The final mark of the written exam should be ≥ 5
- The final mark of the assignment should be ≥ 5
- To pass the course the final mark (70%w.ex. + 30%ass.) should be ≥ 5.5
- For the assignment part there is NO retake

Multiagent Systems: Literature

- Book (some sections): Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundation, by Yoav Shoham and Kevin Leyton-Brown, Cambridge University Press, 2009.
- Book (background): An Introduction to Multiagent Systems (second edition): Michael Wooldridge. John Wiley & Sons, LTD, 2009.
- See the home page of the course for other background literature.

Artificial Intelligence

Artificial Intelligence aims at continuously advancing computer technology to automate ever increasing complex tasks for which **human intelligence** is required.

Artificial Intelligence

Understanding human intelligence is inspiring, but designing artificial models is indispensable.

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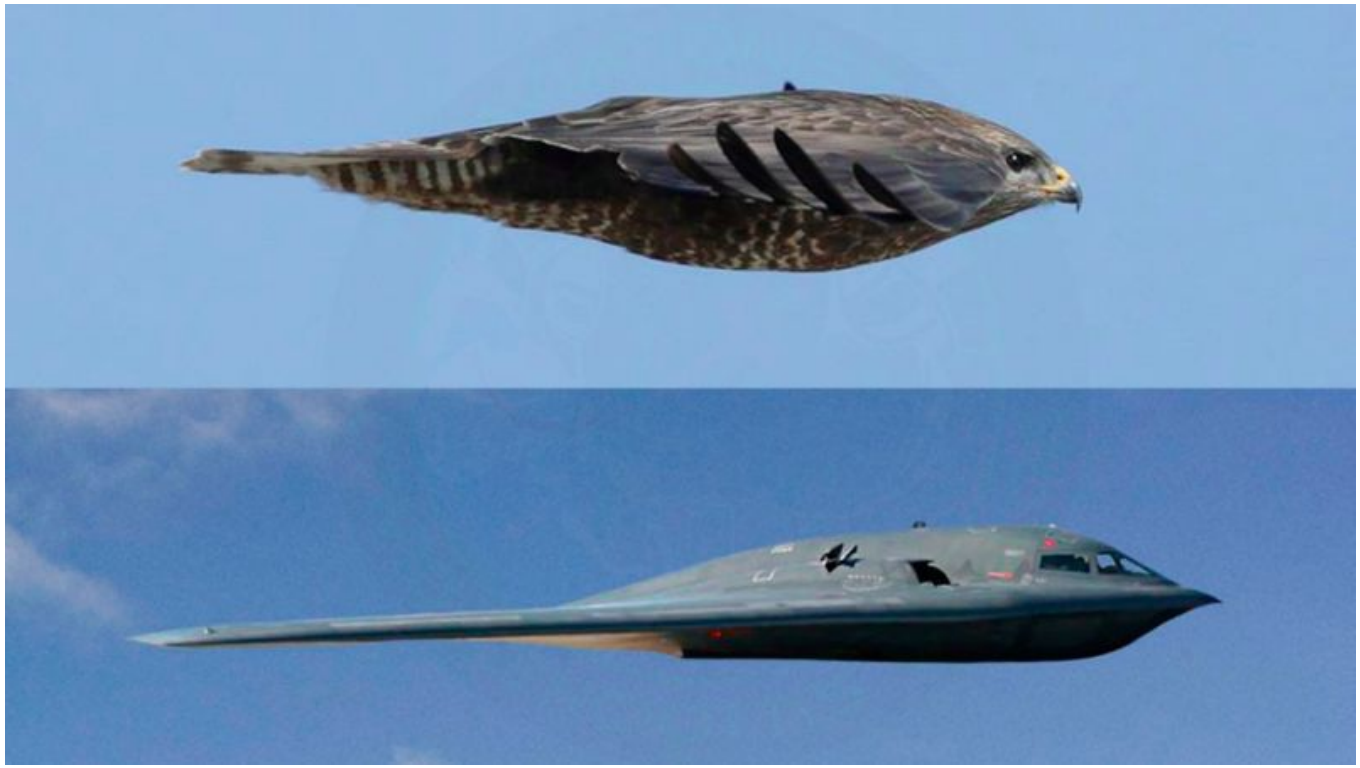
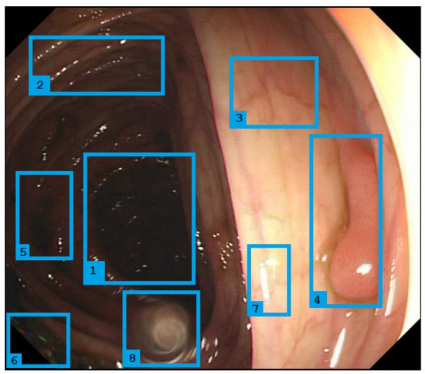
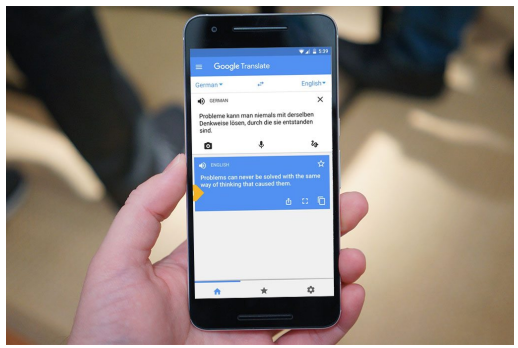


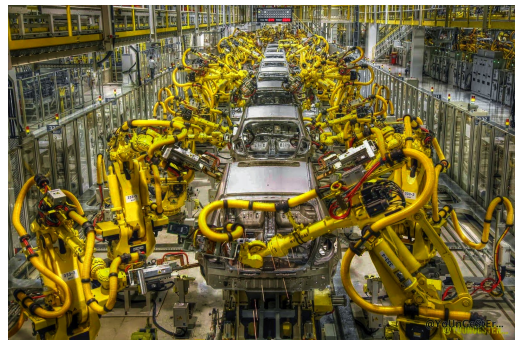
Artificial Intelligence: Early Days

Artificial Intelligence: Understand and model the behaviour of a *single intelligent autonomous agent*

- Automatic planning
- Machine learning
- Computer vision
- Computational linguistics
- Robotics

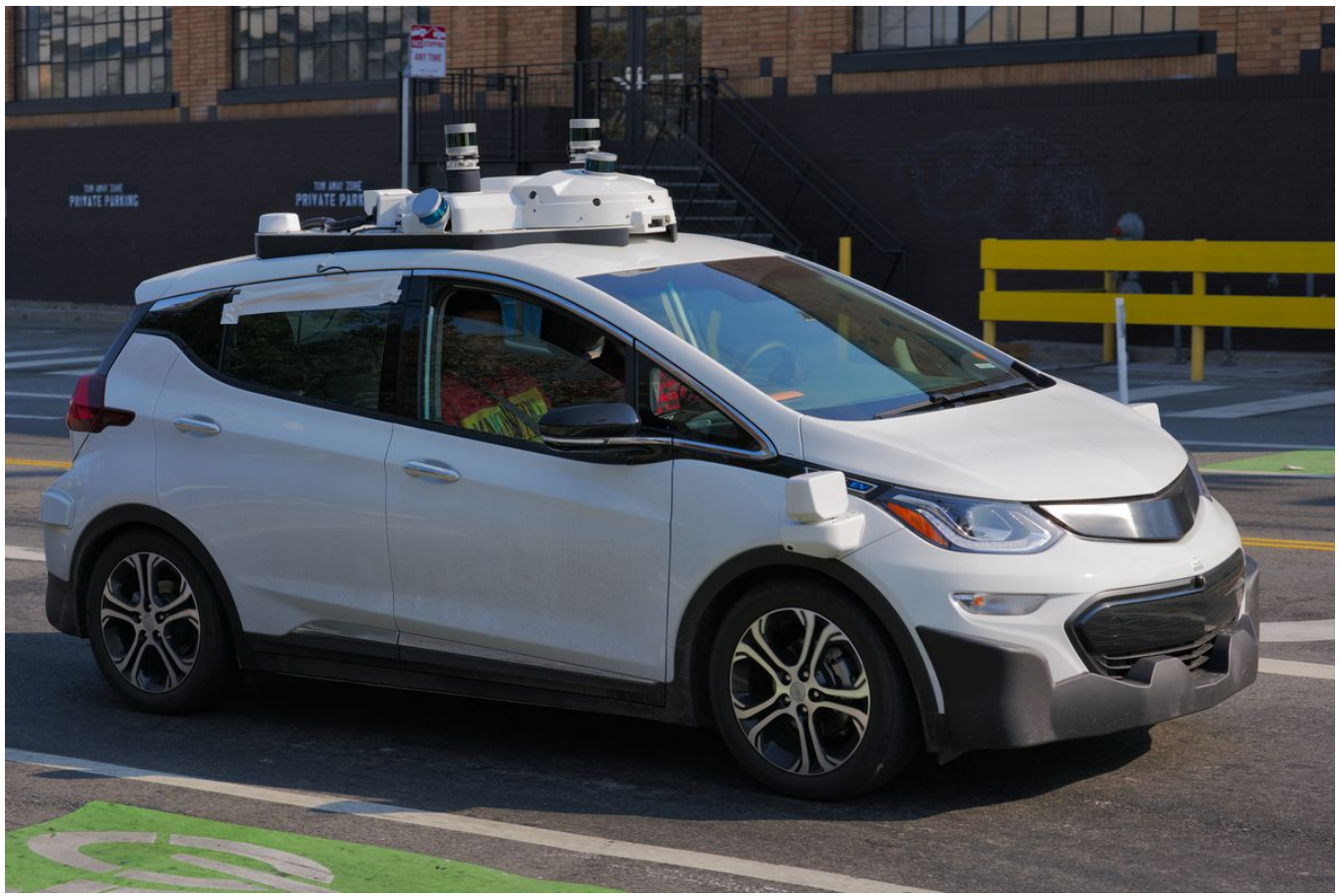






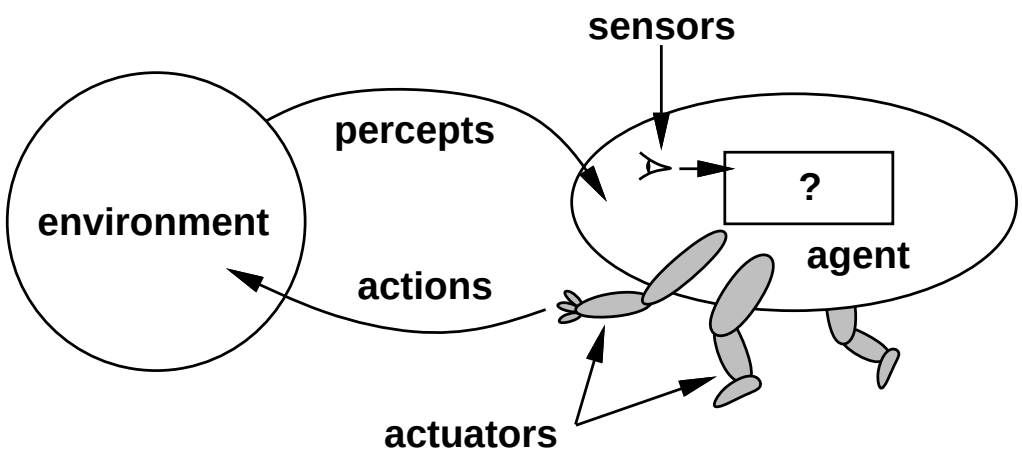
Autonomous Agents: Integrating AI Techniques

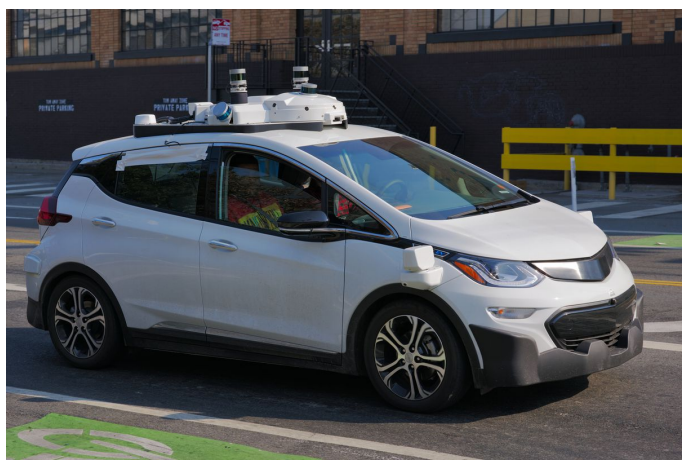
Autonomous Agents research aims at **integrating AI techniques** to design and develop autonomous systems.



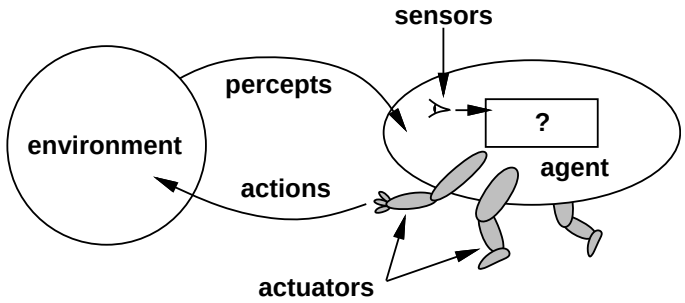
Autonomous Agents: Integrating AI Techniques

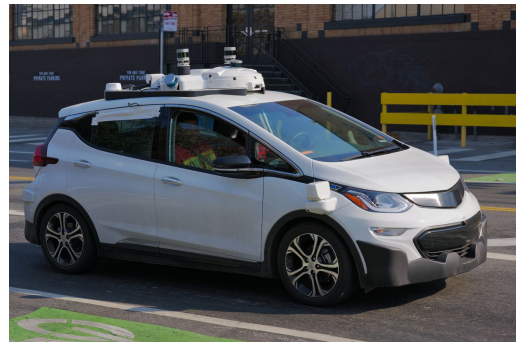
Autonomous agents **sense** their environments, **learn** and **reason** to decide and **execute** actions that maximize the chance to successfully achieve their objectives.





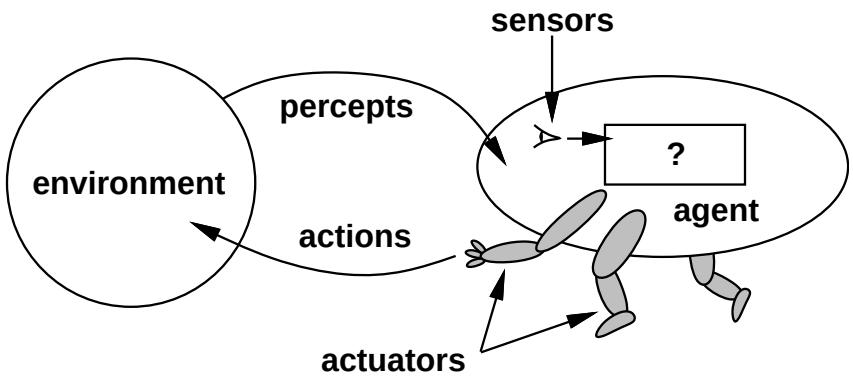
Autonomous Agents: Integrating AI Techniques

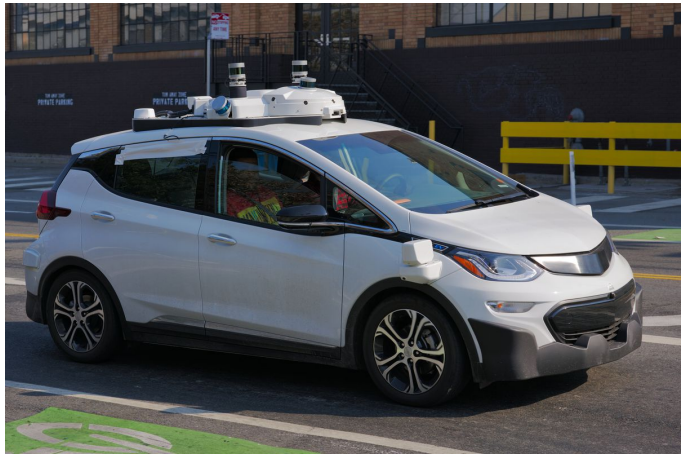




- Autonomous agents are:
  - Reactive (respond to changes in its environment),
  - Pro-active (deliberative/goal-directed behaviour),
  - Social (capable of interacting and communicating with other agents),
  - Adaptive (change its behaviour based on experience), and
  - Rational (behave to maximize its achievements).
- Agents *decide* which action to perform based on their *internal state*.
- The internal state of agents can be specified in terms of high-level abstract concepts such as *information*, *objective*, *action*, and *plan*.

Autonomous Agents: Integrating AI Techniques



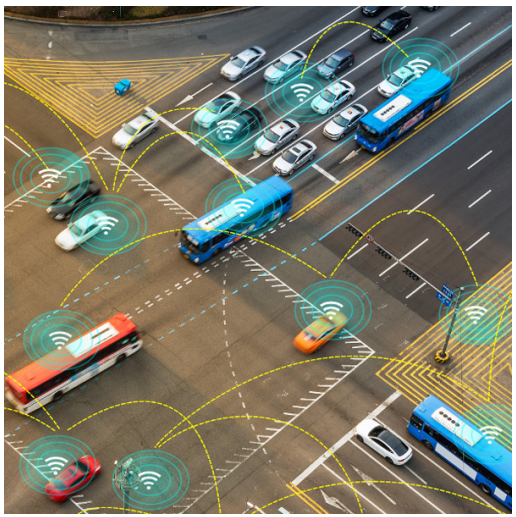


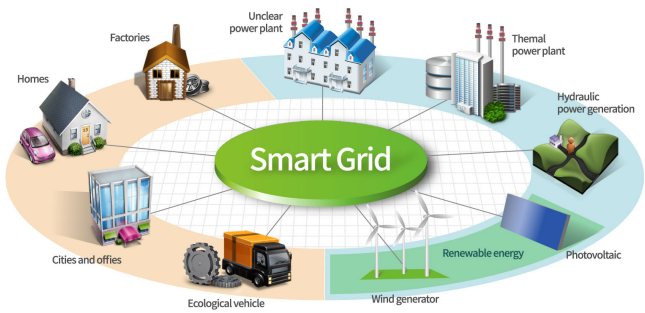
Some research issues

- Updating system state based on sensed data
- Learn and reason to decide actions and plans
- Coordinated execution of actions and plans
- Engineering autonomous agents

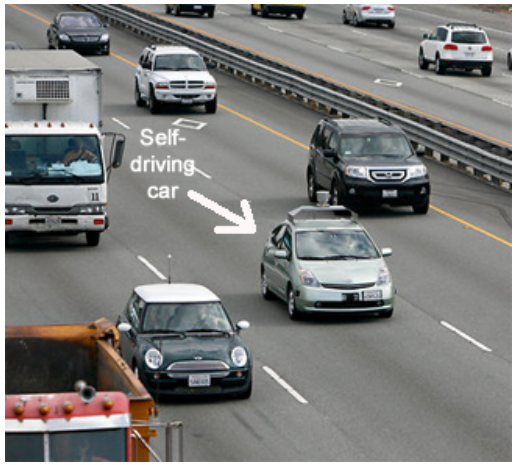
Multiagent Systems: Interacting Autonomous Agents

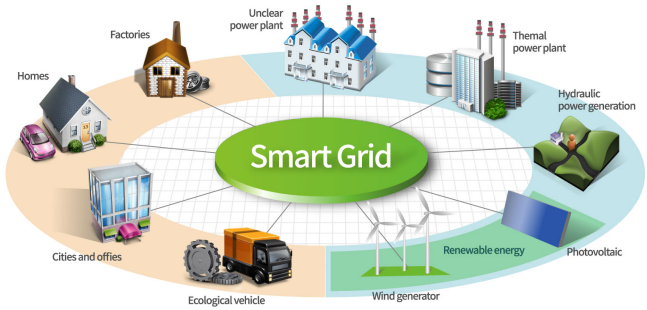
A multiagent system consists of a set of autonomous agents that interact with each other and their surrounding environment to achieve their (joint) objectives.





Multiagent Systems: Interacting Autonomous Agents



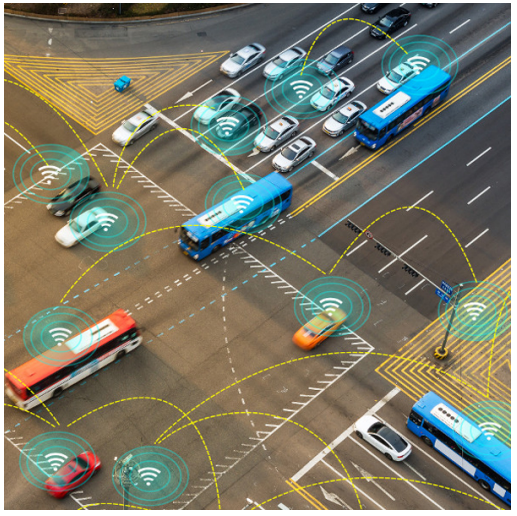


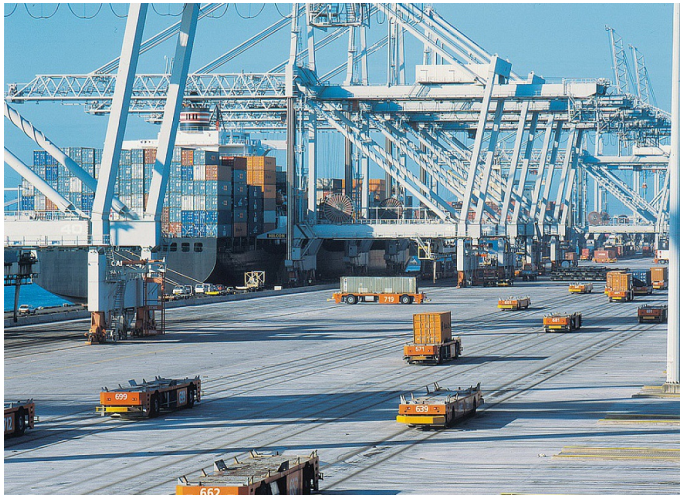
Engineering distributed systems requires **multidisciplinary** techniques to cope with the complexity caused by dynamic **emergent relations** between subsystems.

Some research issues

- modelling and assessing overall system behaviour
- designing interaction mechanisms to achieve optimal collective behaviour
- monitoring and controlling interaction between subsystems
- simulating interacting systems

Interaction





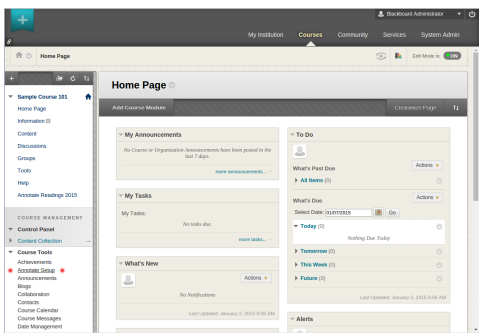
Some issues:

- Agents interact directly via communication or indirectly via environment
- Interaction can be formally investigated and modelled using game theory
- Interaction can be designed to achieve and ensure overall system property
- Interaction compliance with laws and norms

Coordination: Cooperation, Organisation, and Negotiation

Coordination aims at avoiding extraneous activities by synchronising and aligning agents' activities.

- Agents can coordinate their behaviours to solve their problems
  - Task sharing: tasks are decomposed and distributed among agents.
  - Result sharing: information and partial results are distributed.
- Organisations aim at arranging and managing the agents' interaction
  - Electronic institutions
  - Market places
- Agents negotiate to reach agreements
  - Auctions: auctioneer allocates item(s) to the bidding agents
  - Argumentation: agents convince each other to agree on an outcome.



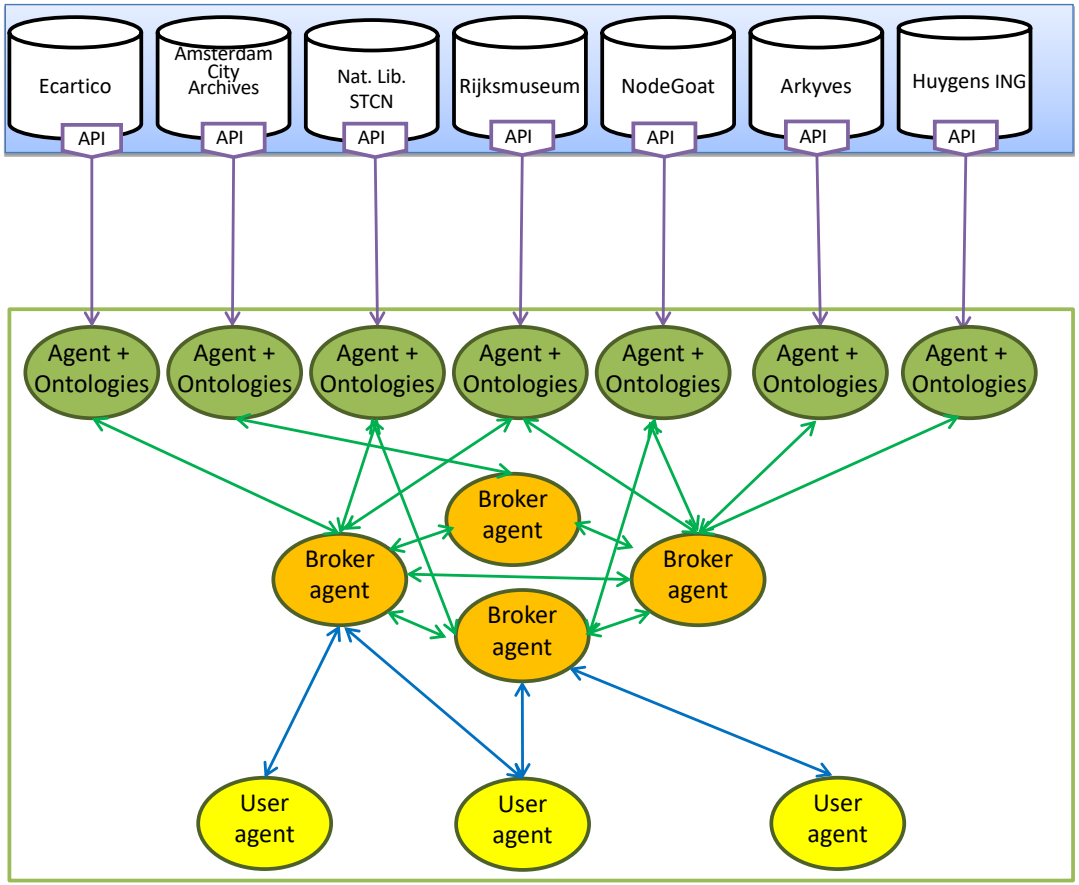
Applications of Multiagent Systems

Causality & Responsibility in Multiagent Environments

NS & ProRail aims at improving the transport capacity of the Dutch railway system by allowing trains to drive closer to each other.

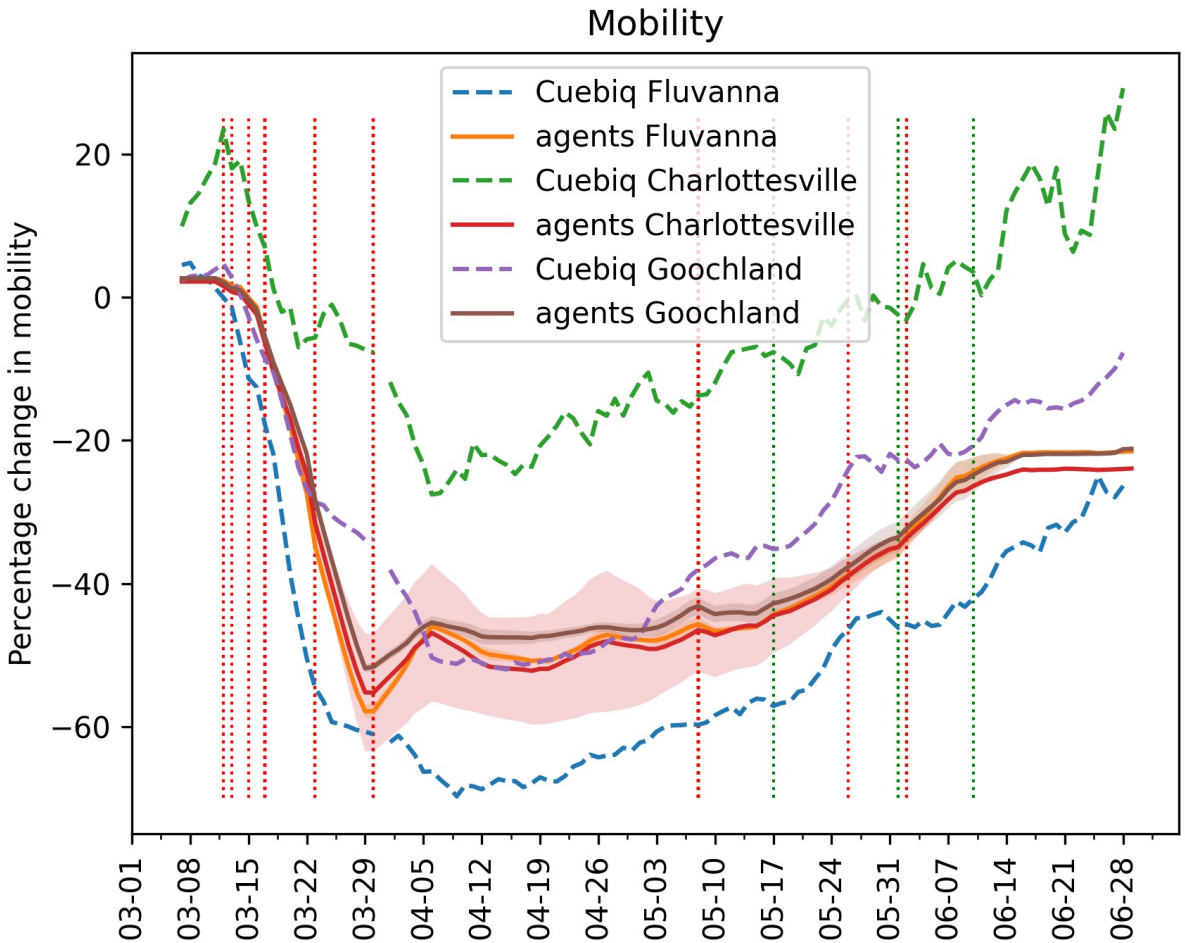
Querying Multiple Data Sets

Golden Agents project investigates systematic integration of multiagent systems and semantic web technology.



A Covid-19 Epidemic Simulation with Norm-aware Agents

Non-pharmaceutical interventions are used to control the spread of Covid-19. Agent-based simulations is a technology to model and understand the efficacy of these interventions.



Multiagent System Development

- Tools and languages to analyse and specify multiagent systems, e.g., game theoretic concepts and frameworks, logical formalisms, and notations.
- Architectures, frameworks and infrastructures supporting distributed, heterogenous, open multiagent systems.
- Programming languages and integrated development environments to facilitate the implementation of multiagent systems.
- Verification and debugging tools to test multiagent programs and ensure their correctness.

Multiagent Systems: Objectives

- How to analyse, specify, design and build individual agents that are capable of independent, autonomous action in order to successfully carry out the tasks that we delegate to them?

- How to analyse, specify, design and 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?