

# Multi-Agent Systems

## Introduction

Albert-Ludwigs-Universität Freiburg



**UNI  
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## Where

Building 101, Room 01-018

## When

Tuesday 16–17, Friday 14–16

## Web page

<http://gki.informatik.uni-freiburg.de/teaching/ws1920/multiagent-systems/>



## Where

Building 101, Room 01-018

## When

Tuesday 17 – 18



- Exercises will be handed out and posted on the web page the day of the Friday lecture.
- You work in groups of size 2–3.
- Each group hands in one solution (in English or in German).
- Solutions to previous week's exercise sheet have to be handed in until Friday 14:00 to
  - Thorsten Engesser, [engesser@informatik.uni-freiburg.de](mailto:engesser@informatik.uni-freiburg.de)



- **Studienleistung:** you must reach at least 50% of the points on exercises.
- **Prüfungsleistung:** An oral or written examination takes place during the semester break. The examination is obligatory for all Bachelor students (oral) and Master students (oral or written – depends on the number of students taking the exam).

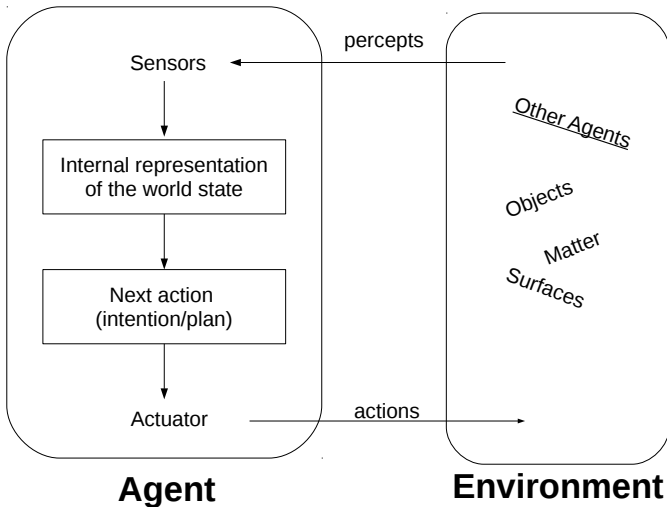
## Goals

- You can read and understand MAS research literature
- You can formulate problems as multi-agent problems
- You know about MAS algorithms and some of their formal properties
- You can complete a project/thesis in this research area

## Helpful

- Basic knowledge in general Computer Science, i.e., programming, algorithms, and computational complexity
- Basic knowledge in the area of AI
- Basic knowledge in formal logics

# Agents: Standard View





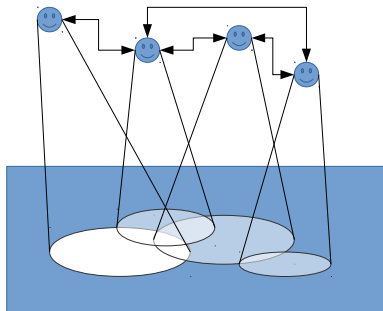


Which of these entities qualify as agents:

- Human beings
- Animals
- Plants
- (Non-)Self-driving cars
- Light switches
- Tables

Shoham, Layton-Brown, 2009

Multi-agent systems are those systems that include multiple autonomous entities with either diverging information or diverging interests, or both.





- Video: Kilobots Formation
- Common goal, different local views, different capabilities
- Cooperation, Communication protocol, Assembly

# Agent-oriented paradigm versus Object-oriented paradigm



- “Objects do it for free; agents do it for money.” (Jennings, Sycara, Wooldridge, 1998)
- “Objects do it because they have to; agents because they want to.” (Joseph, Kawamura, 2001)
- Objects are passive service providers but agents are:
  - autonomous: Decide themselves whether or not to perform an action
  - smart: reactive, pro-active, social behavior
  - active: MAS is inherently multi-threaded (at least one thread per agent)
- (However, this does not imply that agents cannot be implemented in an OOP framework; actually, they are most of the time.)



- Distributed/Concurrent Systems
  - Similarity: Agents too are autonomous systems capable of making independent decisions → need for mechanisms to synchronize and coordinate at run time
- Economics/Game Theory
  - Game theory is heavily used in MAS, but
  - MAS is more concerned with computational aspects in context of resource-bounded agents
  - Some assumptions (such as rational agency) may not entirely match with requirements of some kinds of artificial agents
- Artificial Intelligence
  - MAS often seen as a sub-field of AI
  - Historically, MAS stresses the **social** aspect of agency more than classical AI does



- 1 Introduction to MAS
- 2 Recap. propositional logic
- 3 Modal logic for MAS
- 4 Epistemic logic for MAS
- 5 Public announcement logic and the muddy children
- 6 Epistemic MAS planning
- 7 Multi-agent pathfinding
- 8 Speech acts
- 9 Deontic logic
- 10 Belief, Desire, Intention
- 11 Distributed constraint satisfaction
- 12 Cooperative game theory



- A significant part of this lecture will be about **representations** of what agents **know**, **belief**, **intend**, and **ought to do**; and about ways to **reason** about such representations.
- Logic is one of the best developed systems for **knowledge representation and reasoning**.
- Logic can be used for analysis, design, specification, and implementation.
- Understanding formal logic is a prerequisite for understanding much of MAS research.

- Factual knowledge: Deriving knowledge from a given knowledge base to determine what to do next.
  - Because Tina knows that it is raining, she takes an umbrella with her.
- Knowledge about knowledge: Deriving what other agents know.
  - Because Tina knows that Ben knows that it is raining, Tina knows that it is raining.
- System level: Distributed knowledge and common knowledge.
  - Tina knows that it is raining. Ben knows that if it is raining, then the street gets wet. Together, they know that the street is wet.





- Agents can communicate with other agents thereby causing changes of other agent's knowledge.
- E.g., if both Tina announces the fact **it is raining** and Ben announces the rule **if it is raining, then the street gets wet**, then it is **common knowledge** that the street is wet.
- Other types of speech acts: Request, CauseToWant, ...



- Cohen & Levesque's logic for Beliefs, Desires, Intentions
- The GOAL Agent Programming Framework (Koen Hindriks, TU Delft <https://goalapl.atlassian.net/wiki/>)






- Socialization is the process of internalizing the norms and ideologies of society, e.g., Kohlberg (1996):
  - Pre-conventional phase
  - Conventional phase
  - Post-conventional phase
- Modal logics for obligations, permissions, prohibitions
- Brief outlook on machine ethics



- Multi-Agent Path Finding
- Distributed Constraint Satisfaction
- Cooperative Games: Distributing value among group members (Optimality & Fairness)



-  M. Wooldridge, An Introduction to Multi-Agent Systems, 2nd Edition, John Wiley & Sons, 2009.
-  D. Easley, J. Kleinberg, Networks, Crowds, and Markets: Reasoning about a Highly Connected World, Cambridge University Press, 2010.
-  Y. Shoham, K. Leyton-Brown, Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Cambridge University Press, 2009.



This course has evolved over the years. The following people have contributed to its development and the design of the slides:

- Dr. Alexander Kleiner (Bosch)
- Prof. Dr. Christian Becker-Asano (Hochschule der Medien, Stuttgart)
- Prof. Dr. Felix Kleiner (Univ. Ulm)