Multi-Agent Systems

Albert-Ludwigs-Universität Freiburg

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Winter Term 2018/19

Lecturers

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Lectures

Where

Building 101, Room 01-014

When

Monday 16 – 18, Wednesday 16 – 17

Web page

http://gki.informatik.uni-freiburg.de/teaching/ws1819/multiagent-systems/

Exercises: Dates

Where

Building 101, Room 01-014

When

Thursday 17 – 18

Exercises: Procedure

- Exercises will be handed out and posted on the web page the day of the Wednesday 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 Wednesday 16:00 to
  - Thorsten Engesser, engesser@informatik.uni-freiburg.de

Examination

- Admission to the exam: you must reach at least 50% of the points on exercises.
- An oral or written examination takes place in the semester break.
- The examination is obligatory for all Bachelor students (oral) and Master students (oral or written).

Course goals

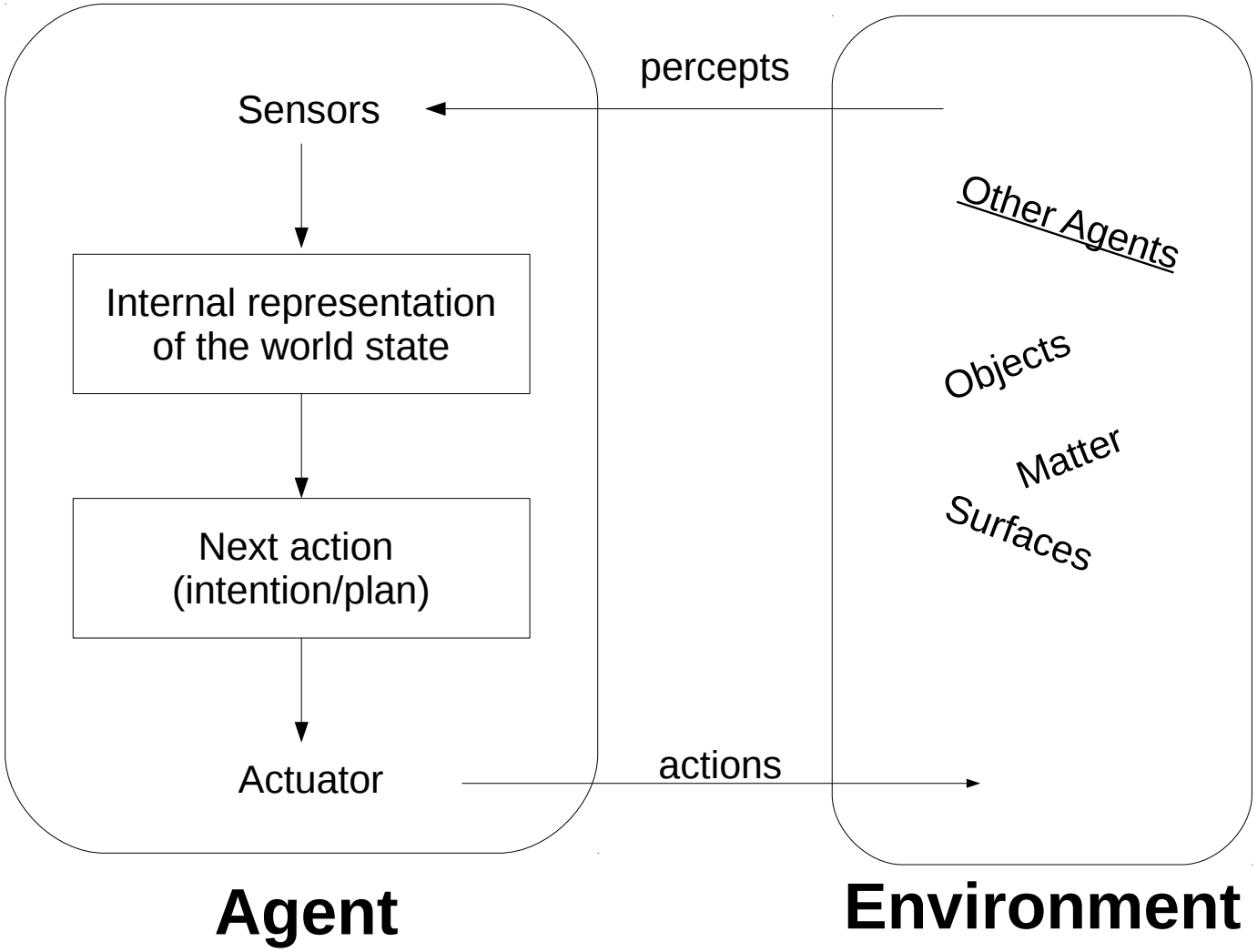
Goals

- 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 the area of AI
- Basic knowledge in formal logics

Agents: Standard View



Agents: Examples

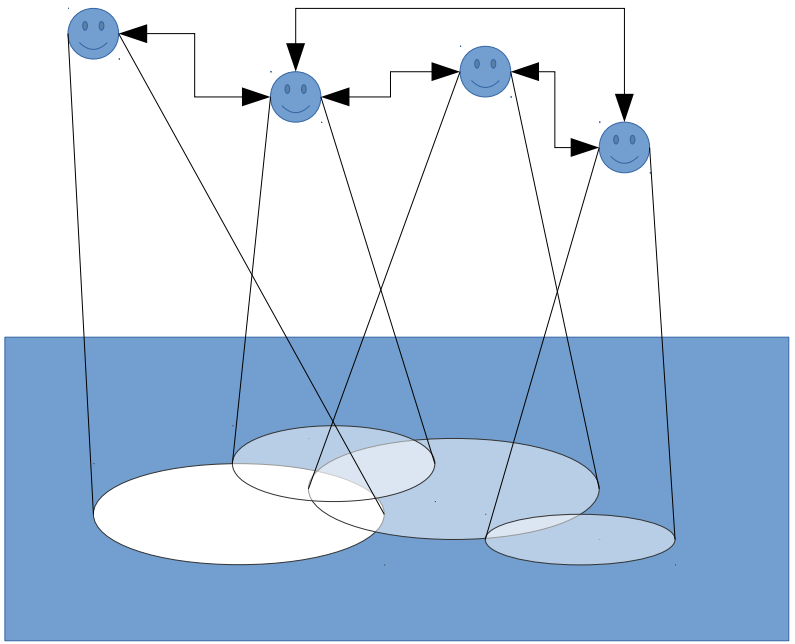
Which of these entities qualify as agents:

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

Multi-Agent Systems

Shoham, Layton-Brown, 2009

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



Multi-Agent Systems: Example

- Video: Cooperation
- 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.)

Connection to other areas

- Distributed/Concurrent Systems
  - Similarity: Agents too are autonomous systems capable of making independent decisions $\rightarrow$ 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

Course outline

1. 15.10.2018: Introduction, Recap Prop. Logic
2. 17.10.2018: Recap Prop. Logic
3. 22.10.2018: Modal Logic for MAS
4. 24.10.2018: Modal Logic for MAS
5. 29.10.2018: Modal Logic for MAS
6. 31.10.2018: Epistemic Logic
7. 05.11.2018: Epistemic Logic
8. 07.11.2018: Muddy Children & Public Announcements
9. 12.11.2018: Speech Acts
10. 14.11.2018: Speech Acts
11. 19.11.2018: Deontic Logic
12. 21.11.2018: Deontic Logic
13. 26.11.2018: BDI Logic
14. 28.11.2018: BDI Logic

1. 03.12.2018: MAPF
2. 05.12.2018: MAPF
3. 10.12.2018: MAPF
4. 12.12.2018: MAPF
5. 17.12.2018: Programming BDI Agents
6. 19.12.2018: Programming BDI Agents
7. 07.01.2019: Programming BDI Agents
8. 09.01.2019: Programming BDI Agents
9. 14.01.2019: Distributed CSP
10. 16.01.2019: Distributed CSP
11. 21.01.2019: Coalitional Game Theory
12. 23.01.2019: Coalitional Game Theory
13. 28.01.2019: Responsibility & Blame
14. 30.01.2019: Responsibility & Blame
15. 04.02.2019: Responsibility & Blame
16. 06.02.2019: Final Session, Evaluation, Q & A

Why Logic?

- 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.

Knowledge

- 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.

Communication

- 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, ...

Beliefs, Desires, Intentions

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

Norms and Duties

- 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

Coordination and Decision Making

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

Responsibility & Blame

- When agents bring about new states of the world together, then the question arises who is responsible for good/bad aspects of that new world state.
- Basic idea based on counterfactuality: If agent A had not done X, then Y would not have occured.

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Literature I

- M. Wooldridge, An Introduction to MultiAgent 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. Layton-Brown, Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Cambridge University Press, 2009.