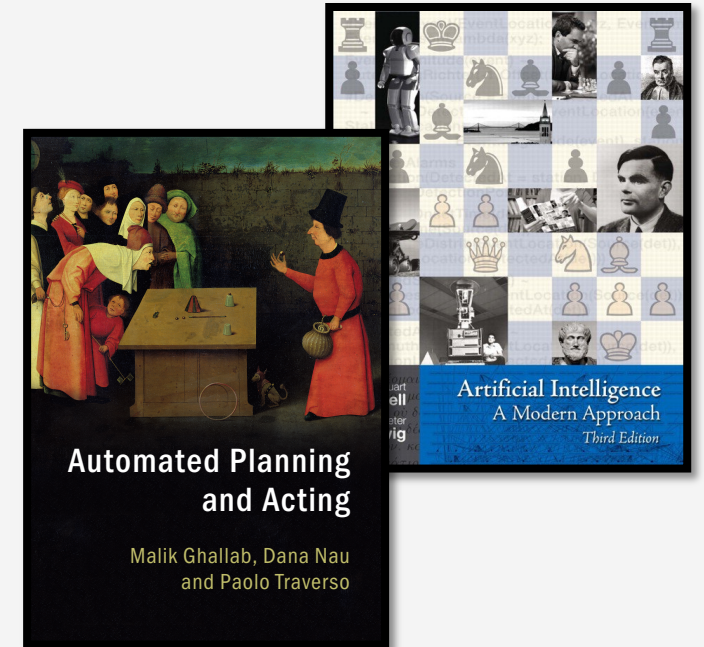


Automated Planning and Acting

Introduction



Organisational Stuff: Lecture

- Topic: **Automated Planning and Acting**
 - Module: Formal Methods (small, 3 + 1)
 - Language: English
 - Schedule: Tuesdays, 16.15-17.45 pm
Thursdays, 16.15-17.45 am
 - Overview on dates and progress in Learnweb
 - *Every two weeks: last 15 minutes on Thursdays explicitly for Q&A*
- There are lecture recordings available from a previous incarnation of this lecture (@Uni Lübeck) that are available in the Learnweb
 - Mostly same content, different layout (some cross-references updated here)
 - Warning: May not correspond one to one regarding progress in presence
 - Warning: new topic situation calculus and relational MDPs

Organisational Stuff: Lecture

- Topic: **Automated Planning and Acting**
- Goal:
 - Get to know a set of deliberation methods for automated planning and acting
 - Bring you up to speed on the foundations of current research
 - Most research on planning and acting is in English → lecture in English
 - So, the goal is at the end of semester to be able to understand and explain
 - what inputs are necessary, what is the output, and how does a method proceed on a high level,
 - what advantages and shortcomings exist,
 - when which method works in contrast to other methods.

Organisational Stuff: Exercises → Seminar

- Schedule: *tba* (towards end of semester)
- Task: Give a presentation on a selected topic
 - Ties to lecture expected
 - How to fill the time is up to you!
 - Theory
 - Exercises
 - Programming
- Goal: Practice to talk in English, carry a presentation for an extended period of time, the skill set necessary to understand and present an advanced topic
- Exact setup depends on the number of course participants
 - Duration: *45 minutes*
 - On your own or in teams of two to three people

Show of hands who plans to participate as of now? (Not binding!)

Organisational Stuff: Exercises → Seminar

- Assignment of topics in Learnweb
- Topic areas
 - Topics 1-2 on deterministic planning
 - Topic 3 on refinement methods
 - Topic 4-6 on nondeterministic planning
 - Topics 7-8 on other deliberation methods
 - Topic 9-12 on probabilistic planning and decision making
- Find a starting point for each topic in the main books
 - Look at references in book for more info
 - * these topics do not appear in the book but get a paper/article as a starting point
- Topics
 1. Hierarchical Task Network Planning
 2. Planning with Control Rules
 3. REAP
 4. Symbolic Model Checking Techniques
 5. Planning based on Search Automata
 6. Acting with Input/Output Automata
 7. Hybrid Models
 8. Ontologies for Planning and Acting
 9. Finite State Controllers for Dec POMDPs
 10. Shared Experience Actor-Critic for MARL*
 11. Continuous State and Observation POMDP*
 12. Expectation-Aware Planning*

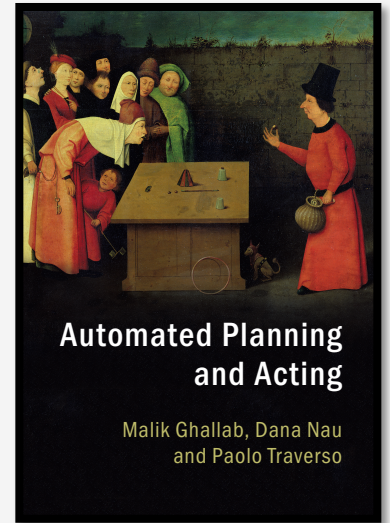
Organisational Stuff: Exam

- ≤ 20 participants: **Oral** exam at the end of the semester
- > 20 participants: **Written** exam

- Prerequisites to participate in exam
 - Seminar presentation
 - Exam registration

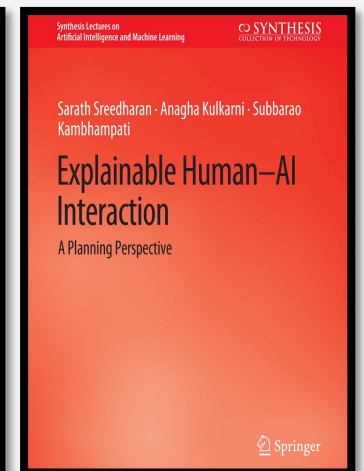
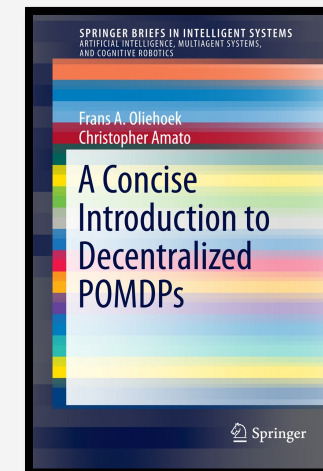
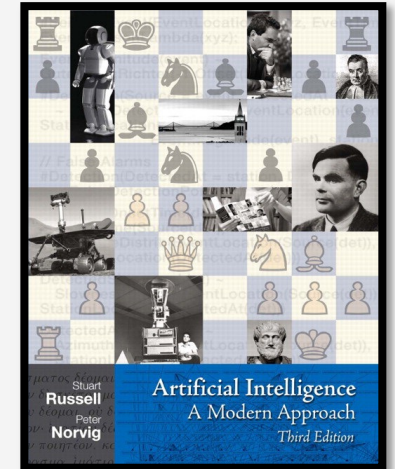
Literature

- Automated Planning and Acting
 - Malik Ghallab, Dana Nau, Paolo Traverso
 - Main source for the first half of the lecture



Literature

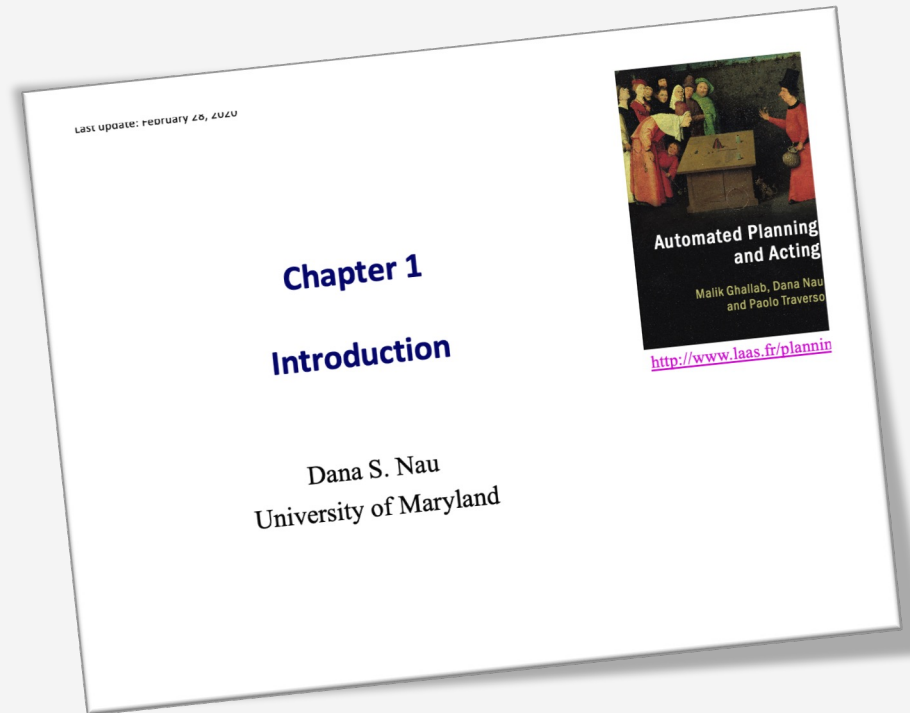
- Second half presents different directions research has taken
- Content based on
 - Artificial Intelligence: A Modern Approach (3rd ed.; abbreviation: *AIMA*)
 - Stuart Russell, Peter Norvig
 - Decision making (Chs. 16 + 17), reinforcement learning (Ch. 21)
 - A Concise Introduction to Decentralized POMDPs (*DecPOMDP*)
 - Frans A. Oliehoek, Christopher Amato
 - Explainable Human-AI Interaction: A Planning Perspective (*HA-AI*)
 - Sarath Sreedharan, Anagha Kulkarni, Subbarao Kambhampati
 - Further research papers announced in lectures
- I do not expect you to read all the books!



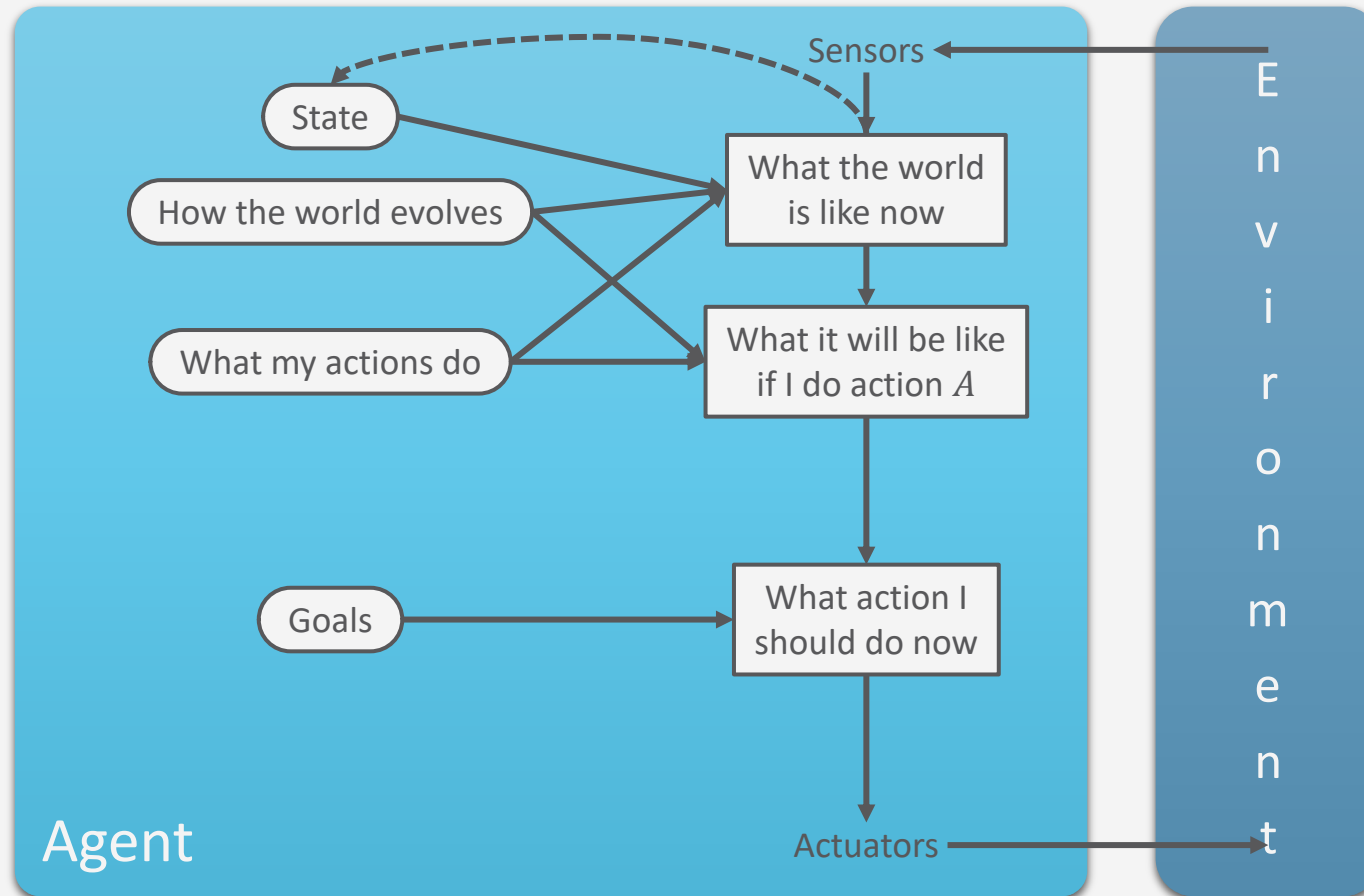
<http://aima.cs.berkeley.edu>

Acknowledgements

- For the first half, slides are adapted from material provided by Dana Nau
 - After that, it is a mix of different sources and own material

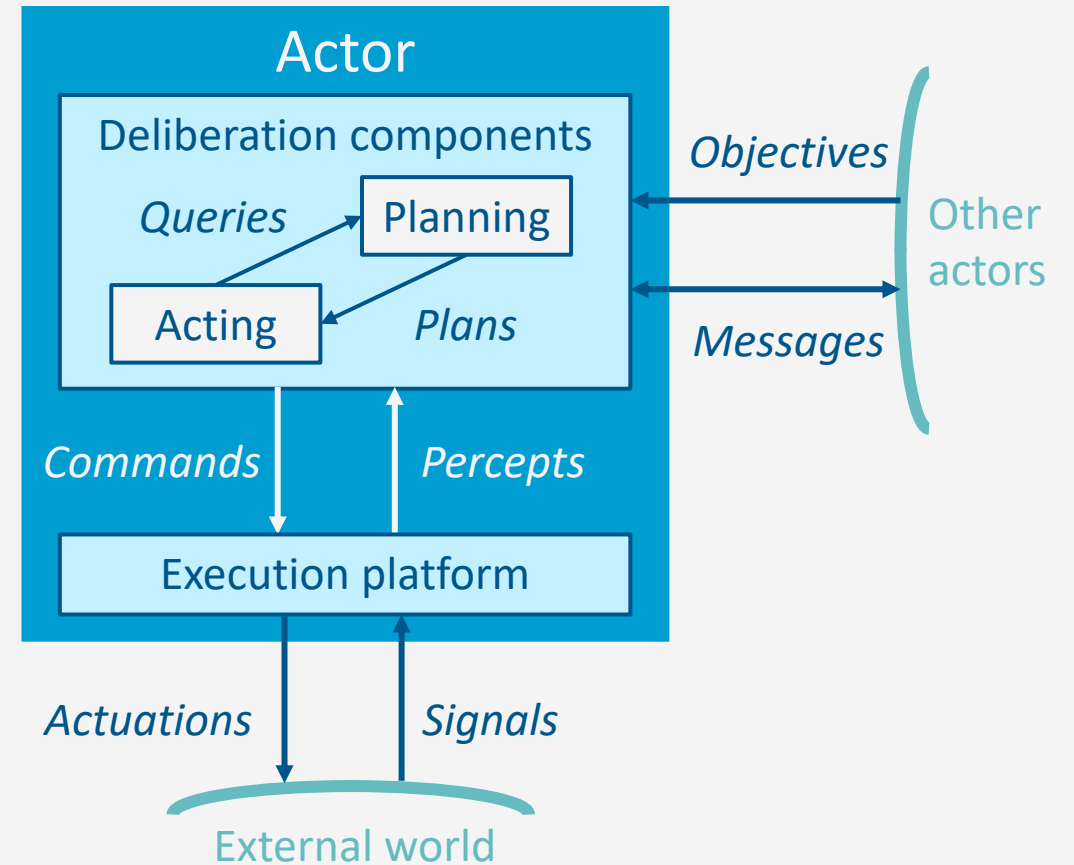


General Agent Setting



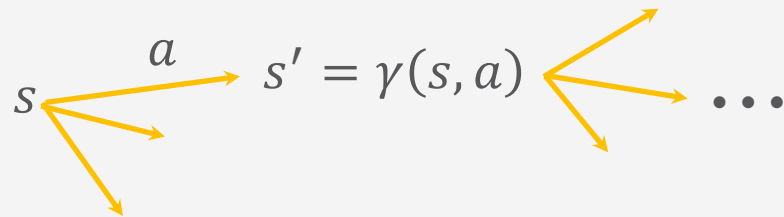
Setting Specific to Planning and Acting

- **Actor**: agent that performs actions
- Deliberation functions
 - Planning
 - What actions to perform
 - Acting
 - How to perform them



Planning

- Relies on **prediction** + **search**
- Uses **descriptive models** of the actions
 - Predict **what** the actions will do, but do not tell **how** to do them
- Search over **predicted states** and possible organisations of feasible actions

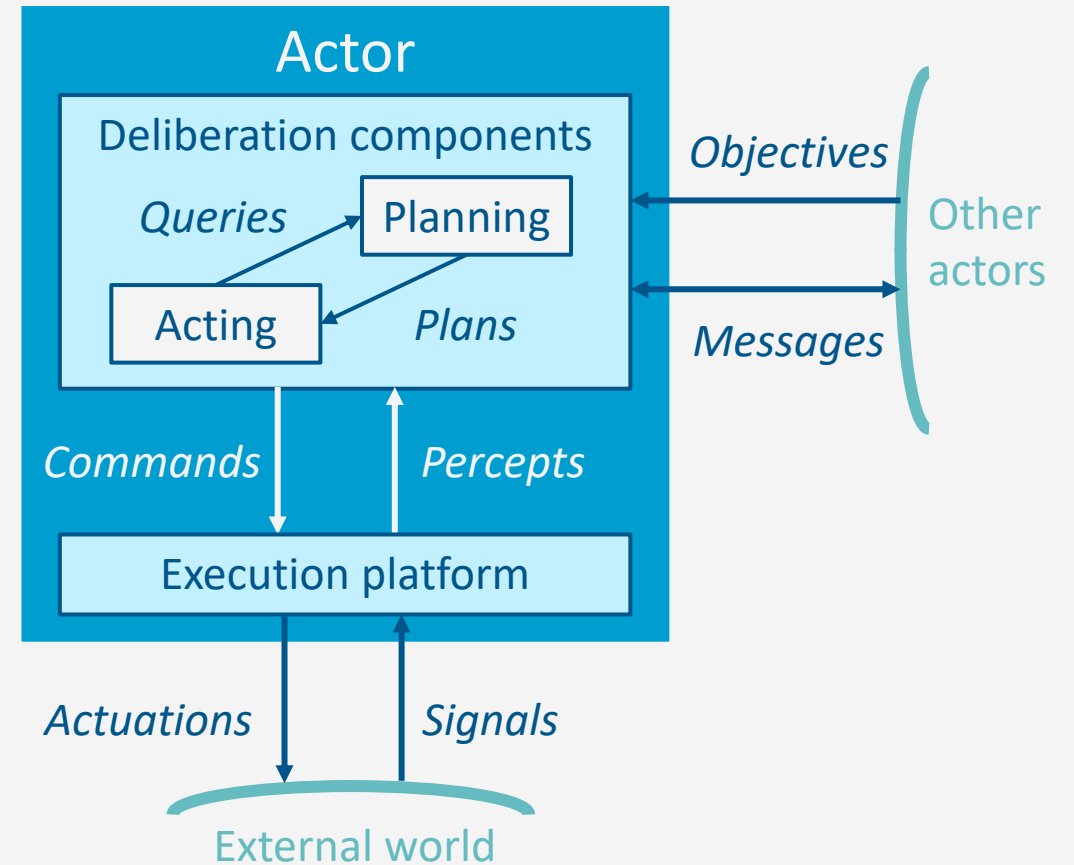


- Different types of actions
 - Different predictive models
 - Different planning problems and techniques
- Motion and manipulation pl.
- Perception planning
- Navigation planning
- Communication planning
- **Task planning**



Acting

- Traditional “AI planning” view does not consider acting specially:
 - Carrying out an action is just execution
 - Does not require the actor to think about how
- **Sometimes** that is true
 - If the environment has been engineered to **make** it true
- Usually acting is more complicated

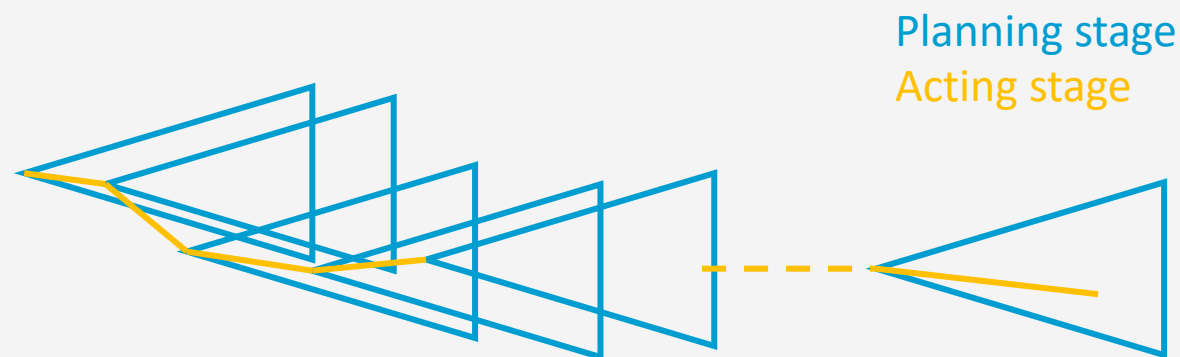


Acting as Execution



Deliberative Acting

- Actor is situated in a dynamic unpredictable environment
 - Adapt actions to current context
 - React to events
- Relies on
 - **Operational models** telling **how** to perform the actions
 - Observations of **current state**

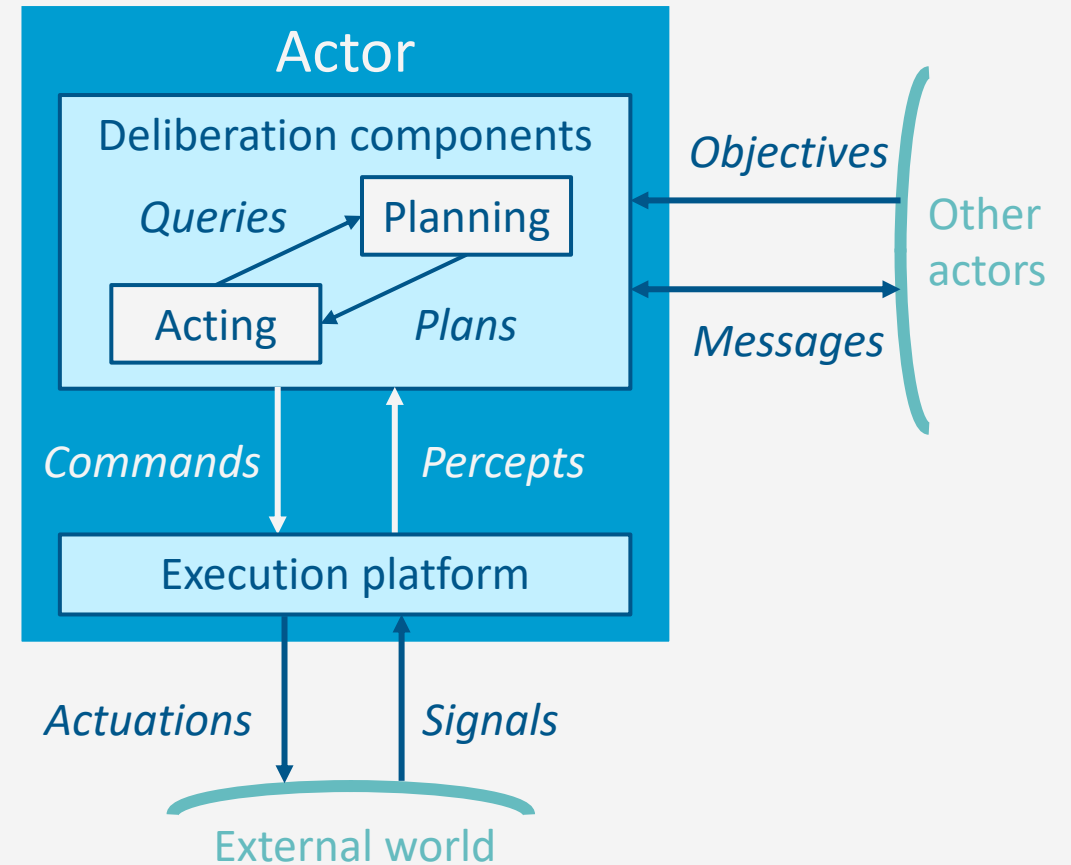


Deliberative Acting



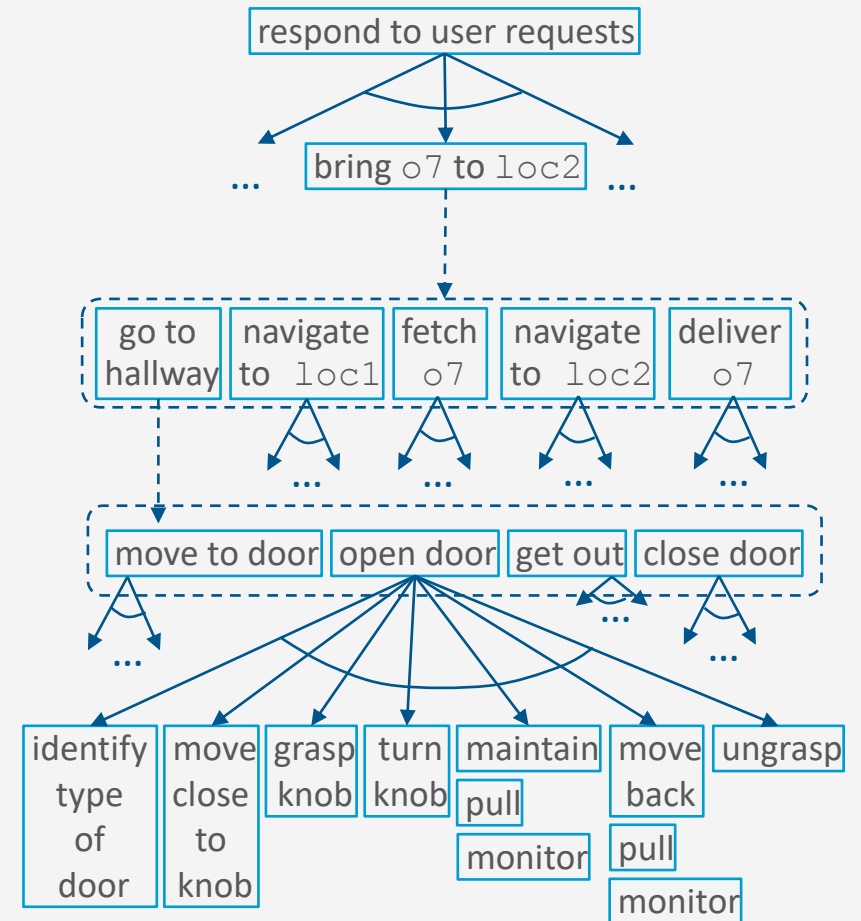
General Characteristics

- Multiple levels of abstraction
 - Actors are organised into physical subsystems
- Heterogeneous reasoning
 - Different techniques
 - At different levels
 - In different subsystems at same level
- Continual online planning
 - Cannot plan everything in advance
 - Plans are abstract and partial until more detail is needed



Example: Service Robot

- Multiple levels of abstraction
 - Higher levels: more planning
 - Lower levels: more acting
- Heterogeneous reasoning
 - bring o7 to room2: abstract steps
 - navigate to room1: path planning
 - open door: reactive
- Continual online planning
 - Is o7 really in room1?
 - What kind of door?
 - Close enough to the doorknob?

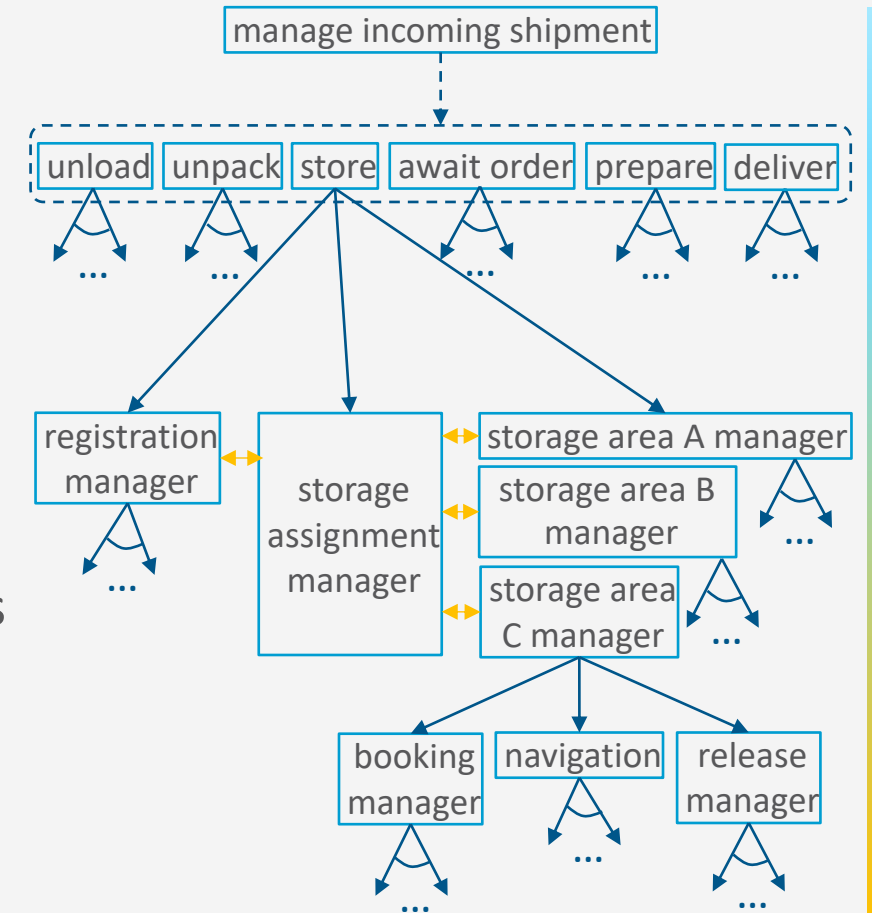


Planning

Acting

Example: Harbour Management

- Importing / exporting cars
 - Based on Bremen Harbour
- Multiple levels of abstraction
 - Reflect physical organization of harbour
- Heterogeneous reasoning
 - Different components work in different ways
 - Online synthesis of automata to control their interactions
- Continual online planning
 - Top level can be planned offline
 - The rest is online, based on current conditions



Content: Planning and Acting

1. With **Deterministic** Models
 - Conventional AI planning
2. With **Refinement** Methods
 - Abstract activities → collections of less-abstract activities
3. With **Temporal** Models
 - Reasoning about time constraints
4. With **Nondeterministic** Models
 - Actions with multiple possible outcomes
5. With **Probabilistic** Models
 - Actions with multiple possible outcomes, with probabilities
6. By **Decision Making**
 - A. *Foundations*
 - Utility theory, Markov decision process (MDP)
 - Reinforcement learning
 - B. *Extensions*
 - Partially observable MDP (POMDP)
 - Decentralised POMDP (decPOMDP)
 - C. *Structure*
 - Lifted decPOMDP
 - Factored MDP, relational MDP
 - Situation calculus, first-order MDP
7. With **Human-awareness**
 - Planning with a human in the loop