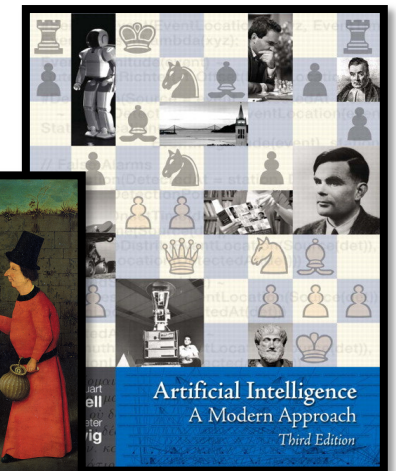
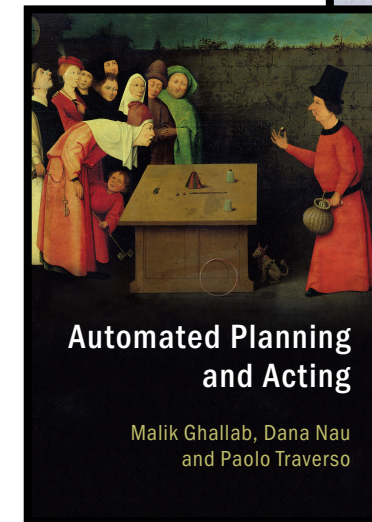




UNIVERSITÄT ZU LÜBECK  
INSTITUT FÜR INFORMATIONSSYSTEME

# Intelligent Agents: Automated Planning and Acting

## Introduction



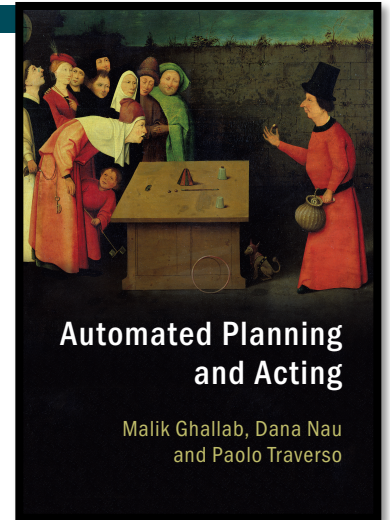
# Organisational Stuff: Lecture

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- 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 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.

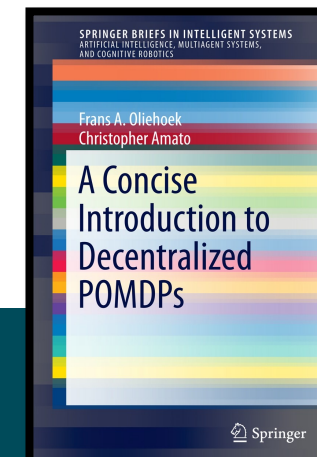
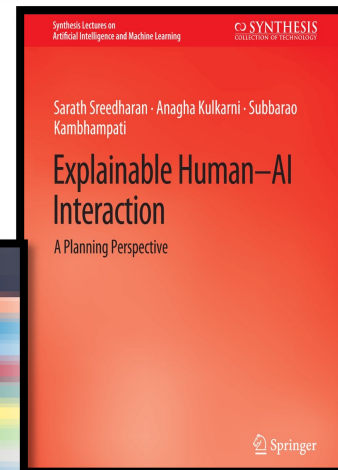
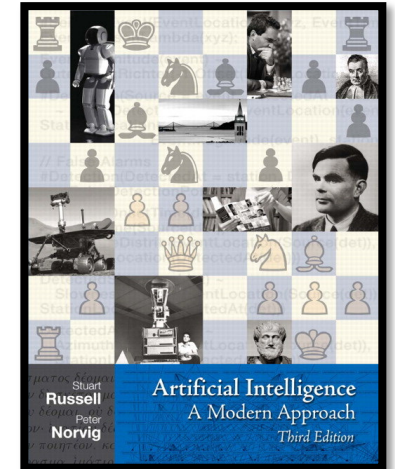
# Literature

- 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 (3<sup>rd</sup> 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!



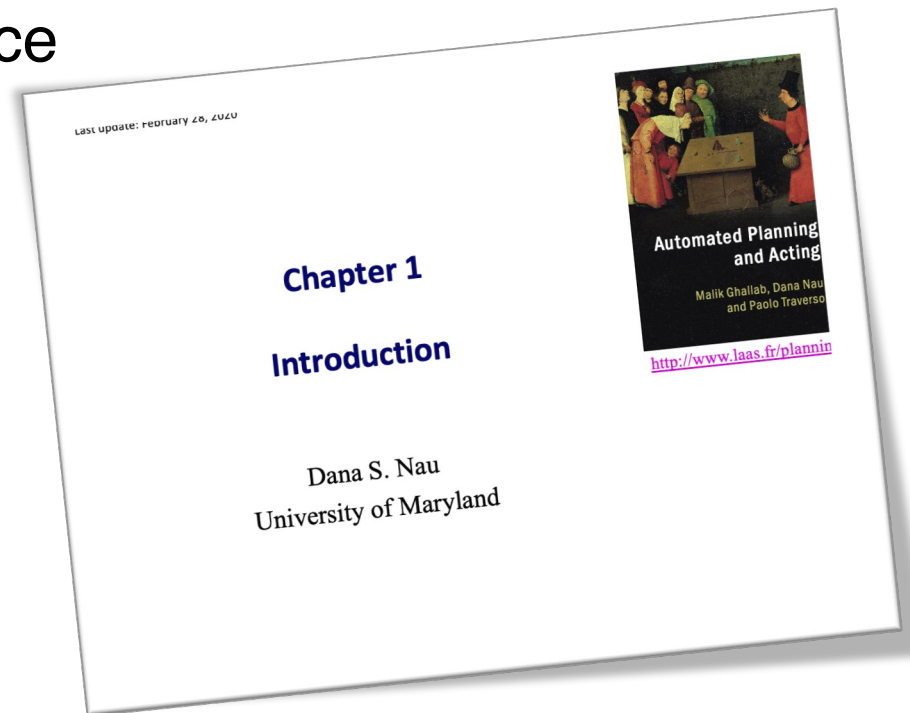
<http://aima.cs.berkeley.edu>

<https://link.springer.com/book/10.1007/978-3-319-28929-8>

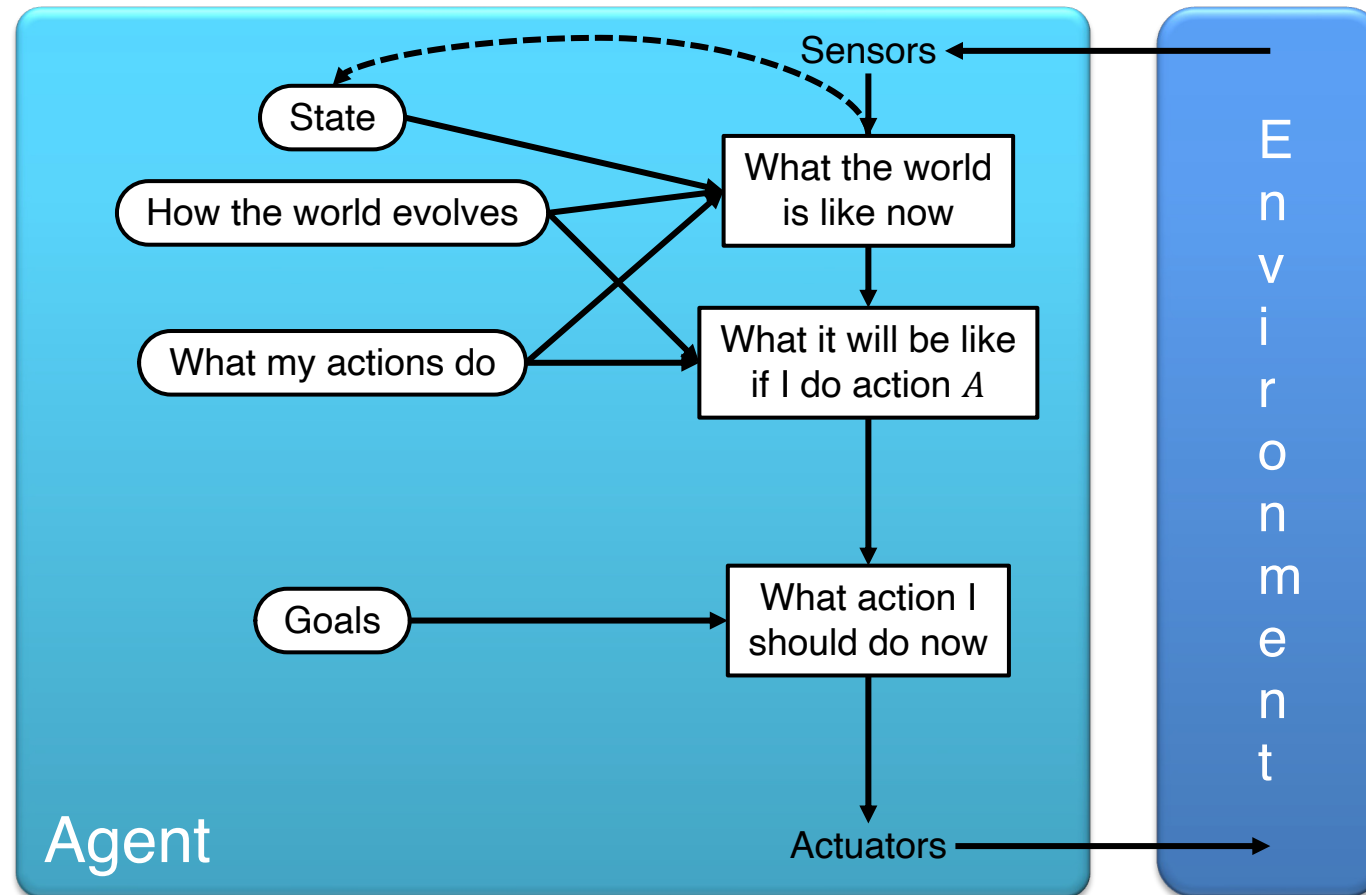
<https://link.springer.com/book/10.1007/978-3-031-03767-2>

# 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
  - The slides are taken from Tanya Braun, University of Münster, who adapted them in the first place

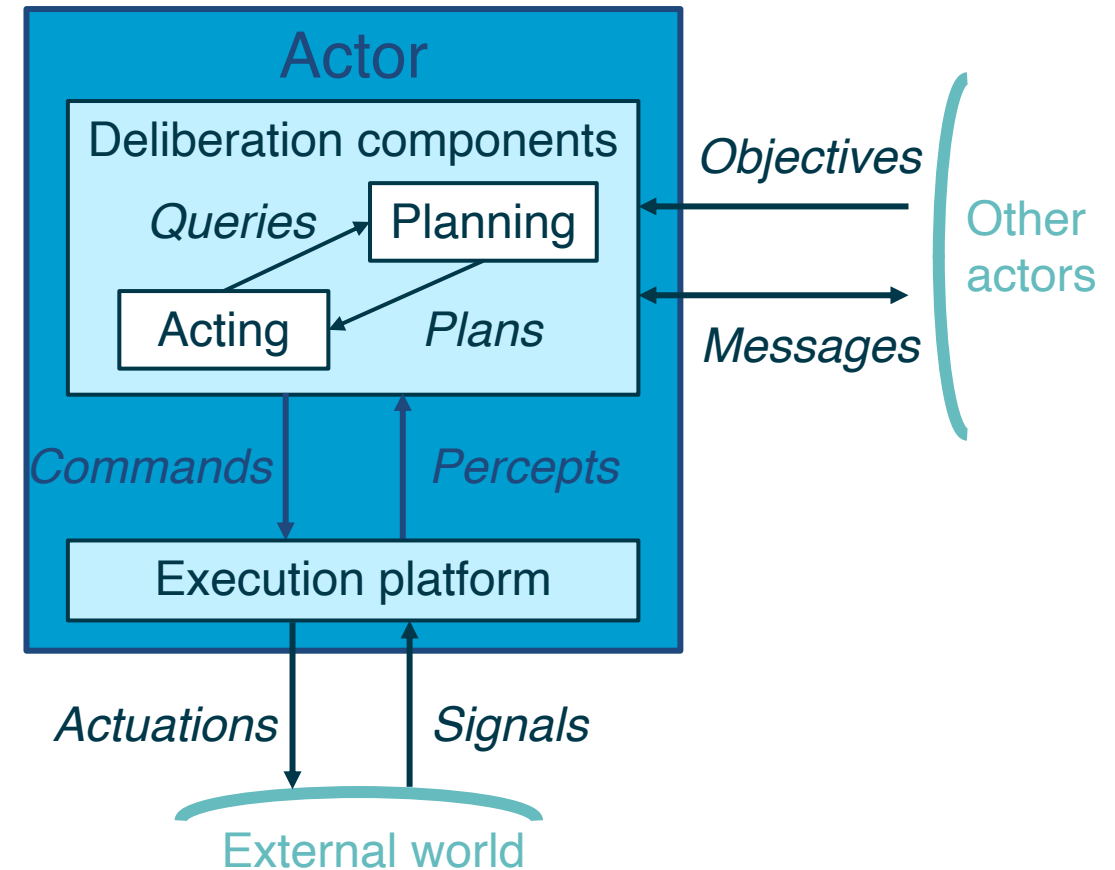


# General Agent Setting



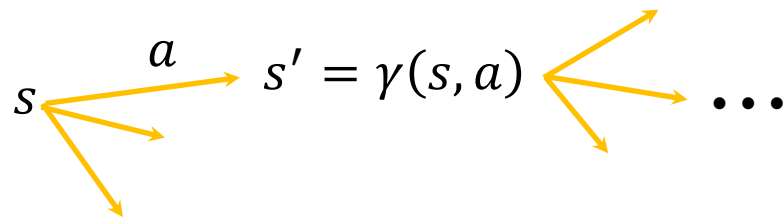
# Setting Specific to Planning and Acting

- **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 don't tell **how** to do them
- Search over **predicted states** and possible organizations 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**

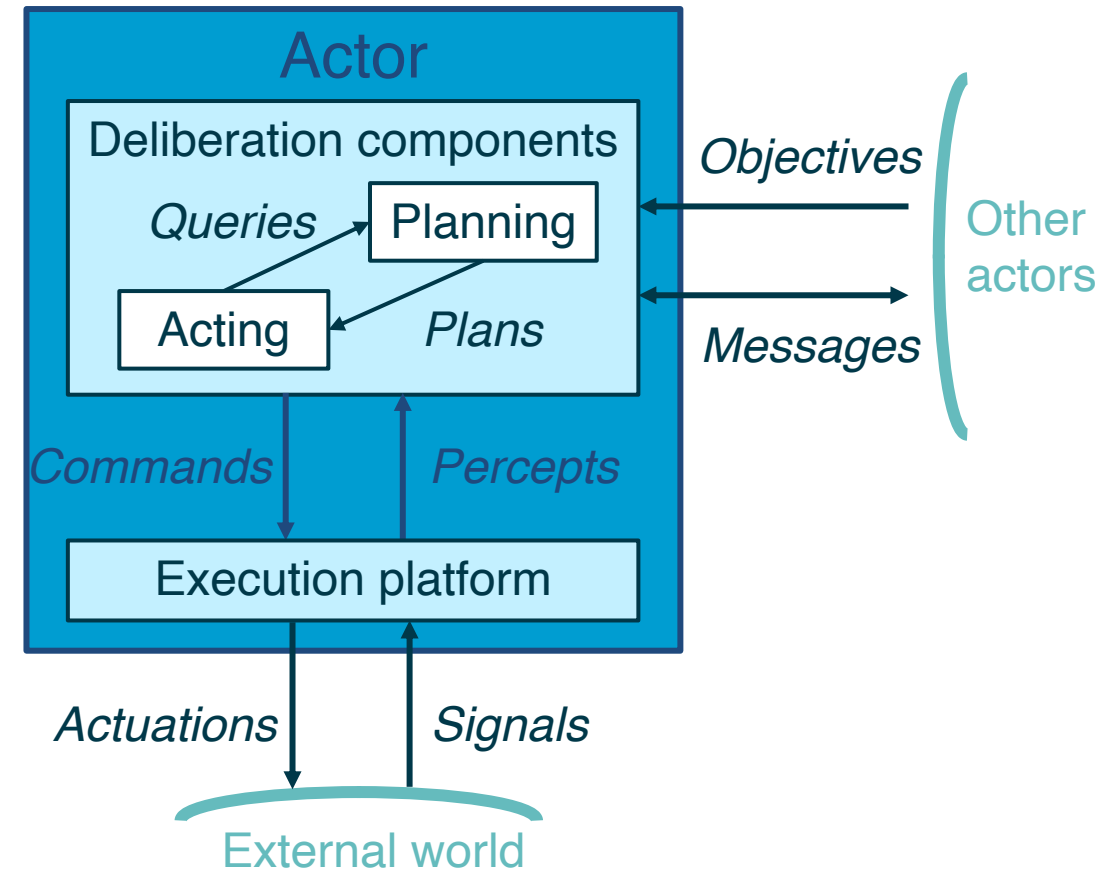


Most AI planning



# Acting

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



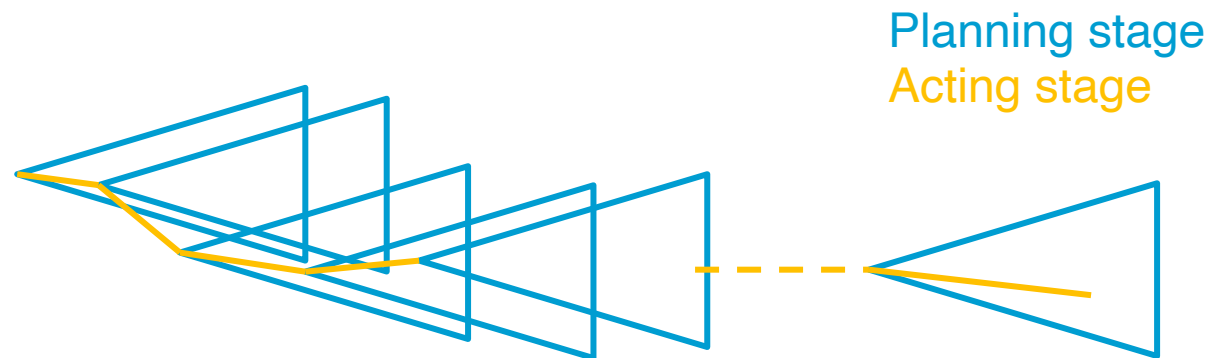
# Acting as Execution

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# 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**



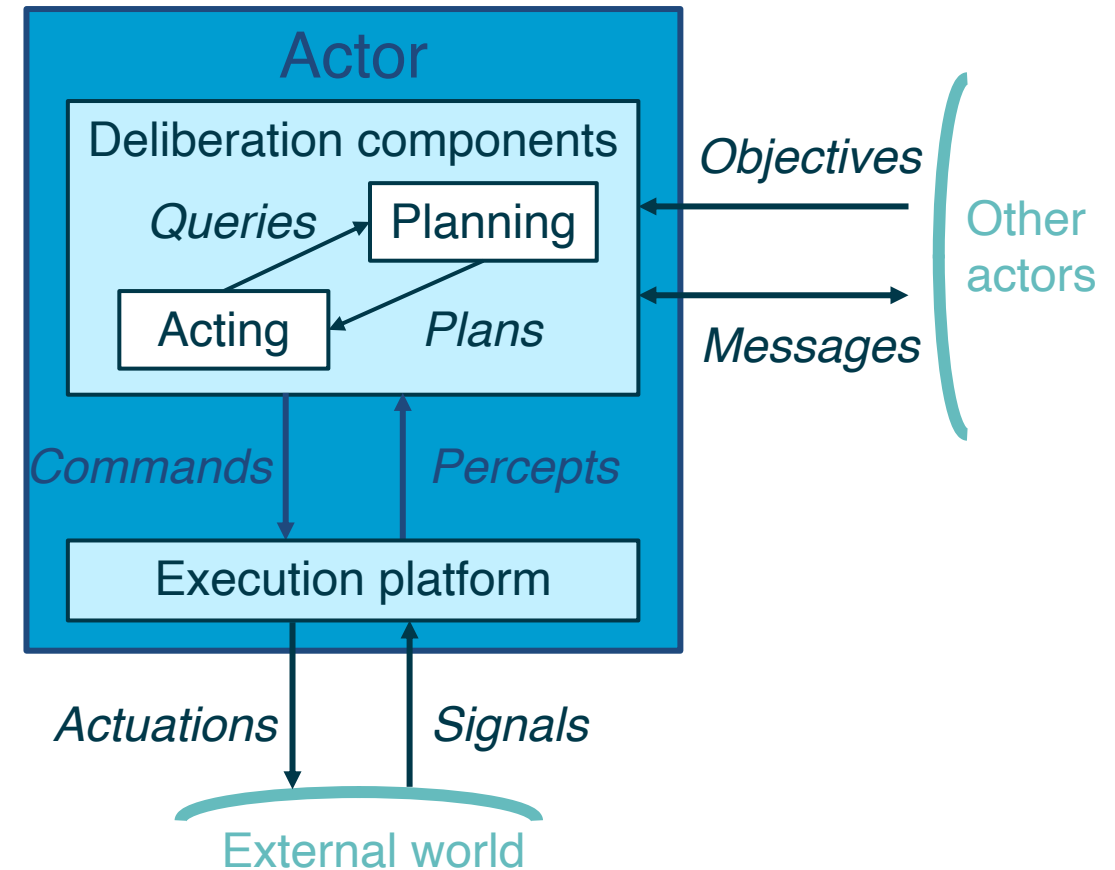
# Deliberative Acting

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# General Characteristics

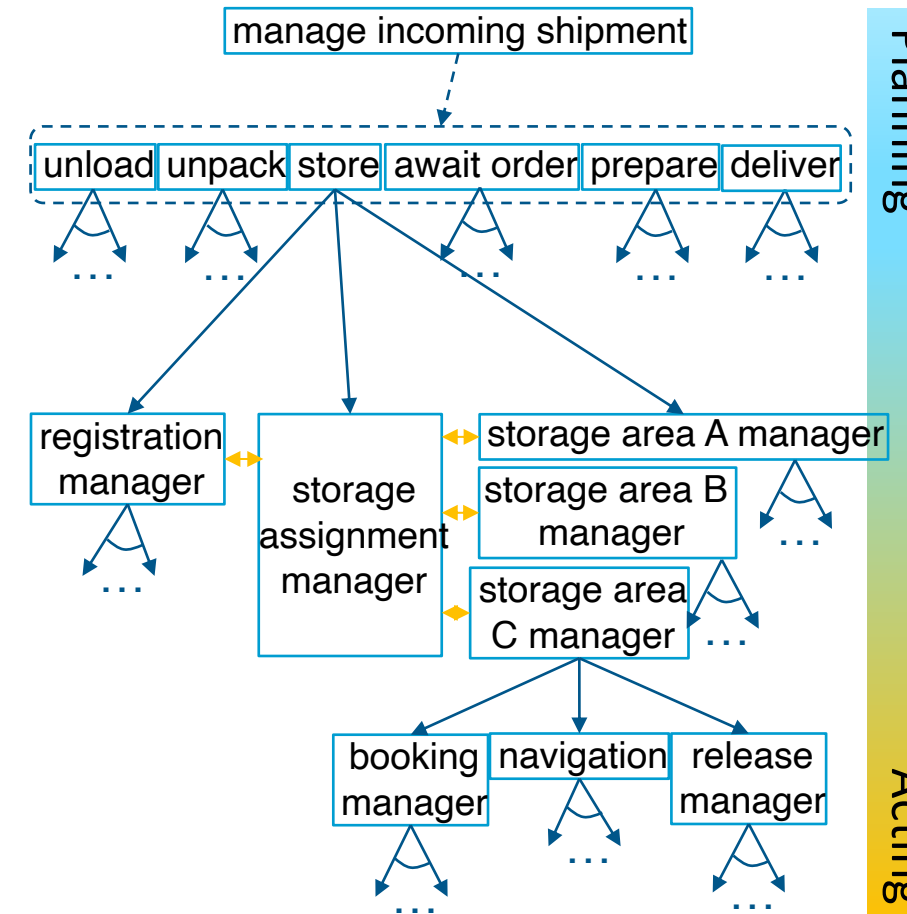
- **Multiple levels of abstraction**
  - Actors are organised into physical subsystems
- **Heterogeneous reasoning**
  - Different techniques
    - At different levels
    - In different subsystems at same level
- **Continual online planning**
  - Can't plan everything in advance
  - Plans are abstract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





# 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 **Temporal** Models
  - Reasoning about time constraints
3. With **Nondeterministic** Models
  - Actions with multiple possible outcomes
4. With **Probabilistic** Models
  - Actions with multiple possible outcomes, with probabilities
5. 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
6. With **Human-awareness**
  - Planning with a human in the loop