

# Advanced Topics Data Science and AI Automated Planning and Acting

## Introduction

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# Organisational Stuff: Lecture

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- Module number: CS5070-KP04 (Dataaktuell)
- Topic (summer term):

## Automated Planning and Acting

- (winter term lecture on **probabilistic differentiable programming** by Özgür Özcep)
- Language: English
- Schedule: Thursdays, 10.15-11.45 am

# Organisational Stuff: Exercises

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- Schedule: in flux
- Task: Give a presentation on a selected topic
  - 45 minutes
  - Ties to lecture expected
  - How to fill the 45 minutes is up to you!
    - Theory
    - Exercises
    - Programming
- Alternatives
  1. Webex Meeting
  2. Slides + script in Moodle
  3. Meeting @UzL once we are allowed back
    - May require switch to Alternative 1 or 2 if we are not allowed back before exams hit
- Each can decide for their presentation

# Organisational Stuff: Exercises

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- Assignment of topics now
  - In Moodle (after this lecture) if not everybody has a topic after we have moved passed this slide
- Topic areas
  - Topics 1-2 on deterministic planning
  - Topic 3 on refinement methods
  - Topic 4-6 on nondeterministic planning
  - Topic 7 on probabilistic planning
  - Topics 8-9 on other deliberation methods
- 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. First-order MDPs\*
  8. Hybrid Models
  9. Ontologies for Planning and Acting



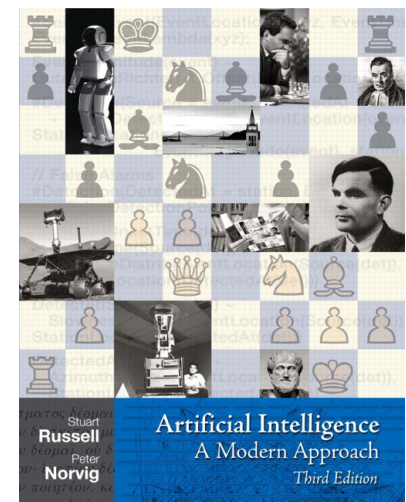
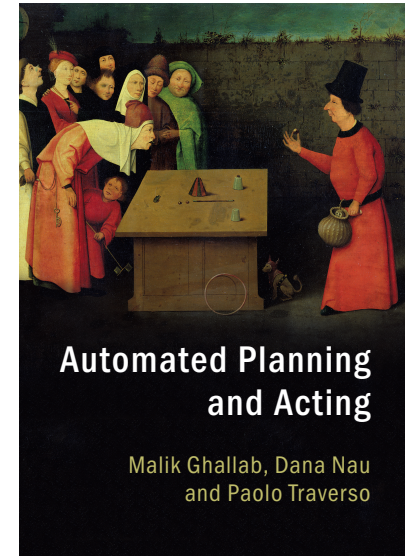
# Organisational Stuff: Exam

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- **Oral exam** at the end of the semester
- Prerequisites to participate in exam
  - **Registration** in Moodle course
  - Exercise presentation
- Registration for exam via Moodle

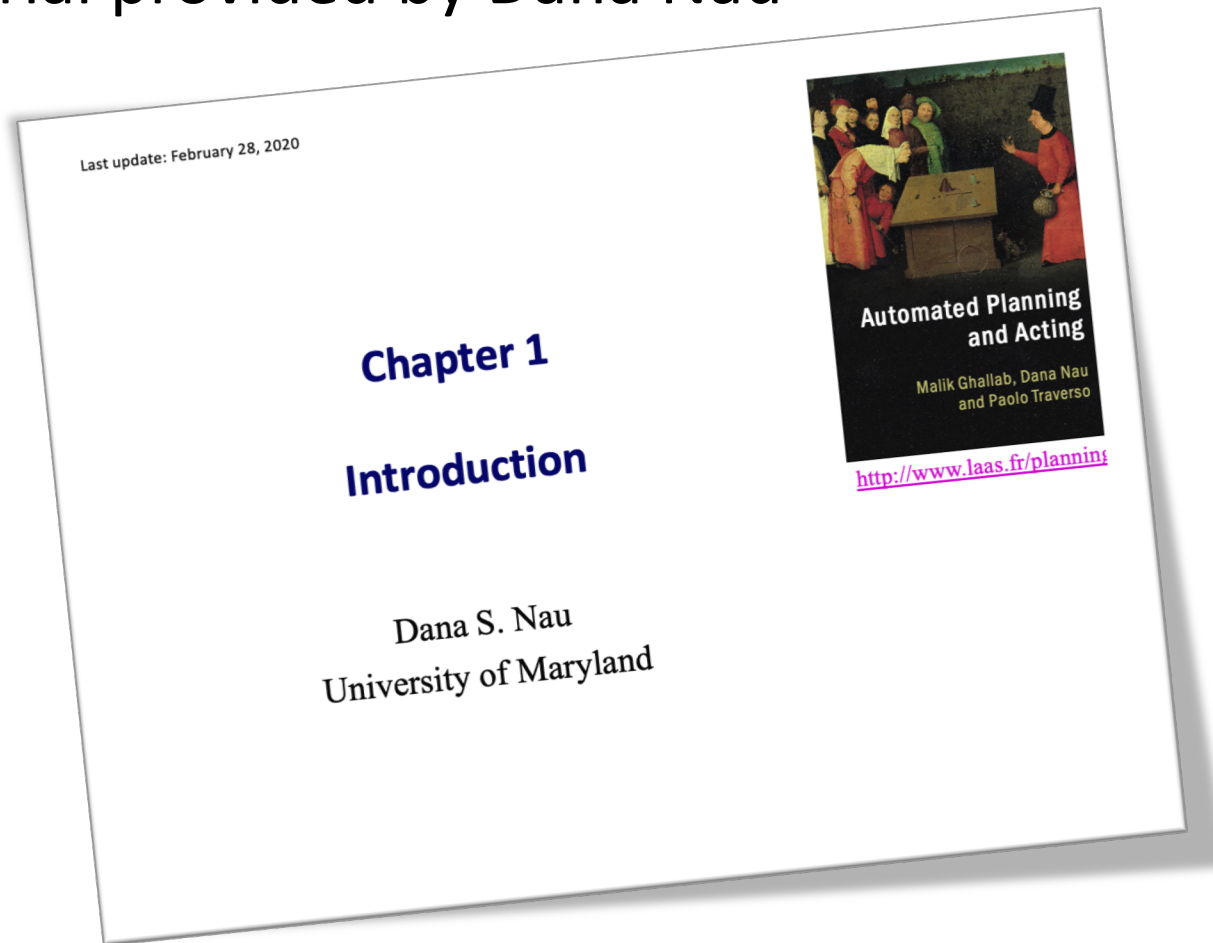
# Literature

- Automated Planning and Acting
  - Malik Ghallab, Dana Nau, Paolo Traverso
  - Main source
- Artificial Intelligence: A Modern Approach (3<sup>rd</sup> ed.)
  - Stuart Russell, Peter Norvig
  - Decision theory
    - Ch. 16 + 17
  - Reinforcement learning
    - Ch. 21
- Further research papers may be announced in lectures

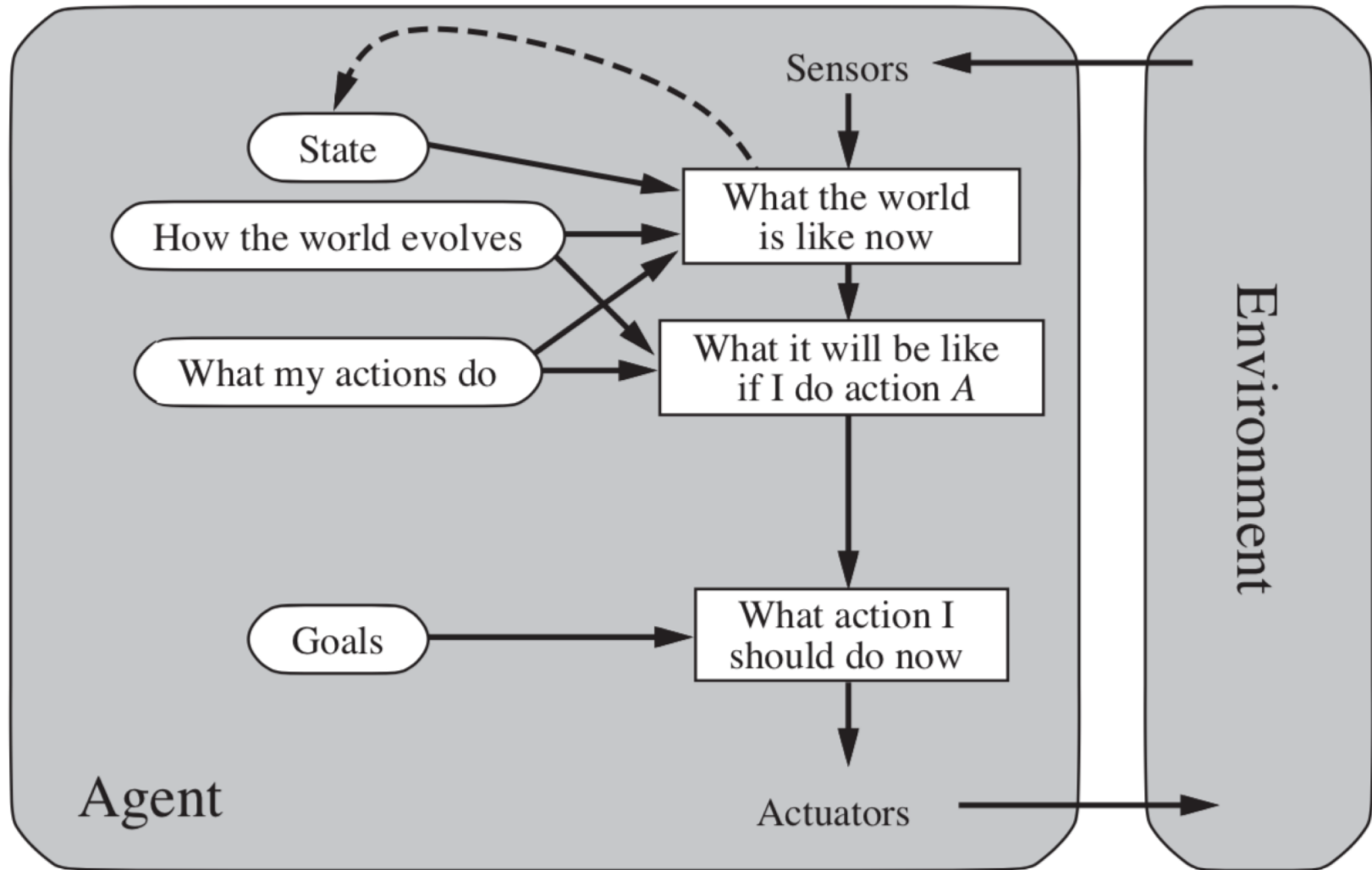


# Acknowledgements

- If not stated otherwise, slides are adapted from material provided by Dana Nau

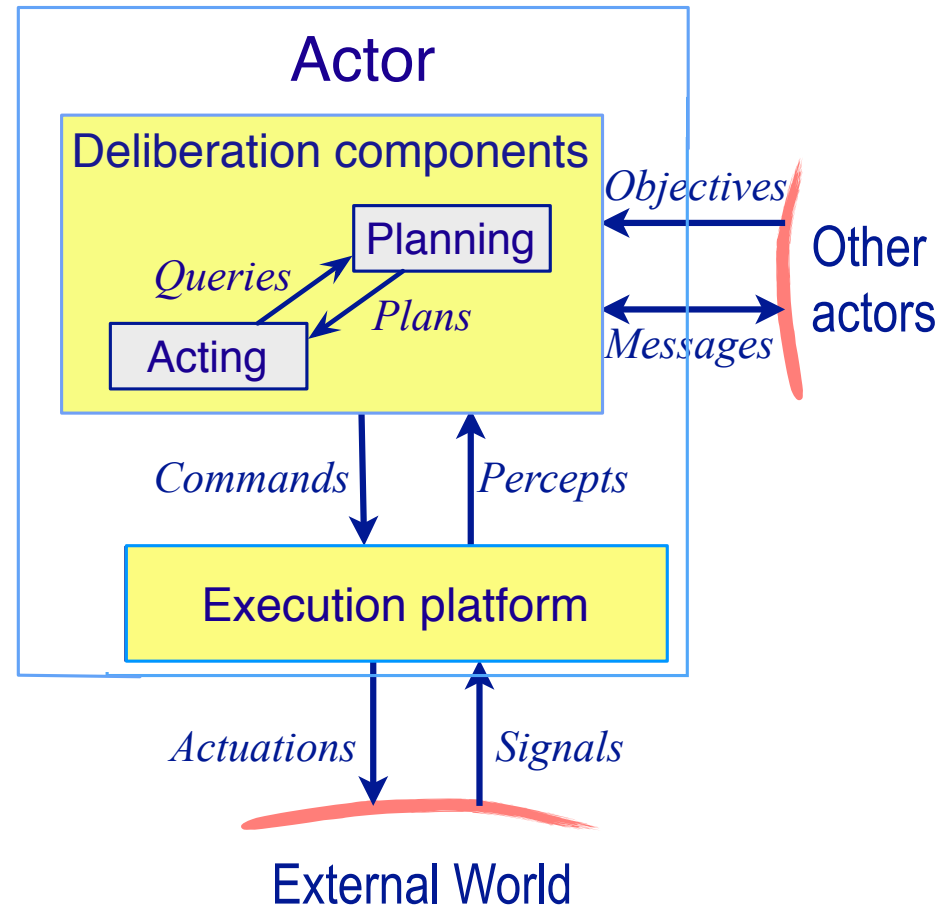


# Agent Setting



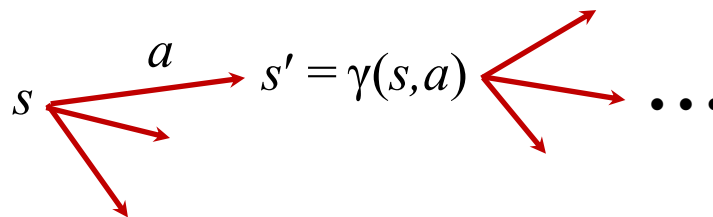
# Motivation

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



# Planning

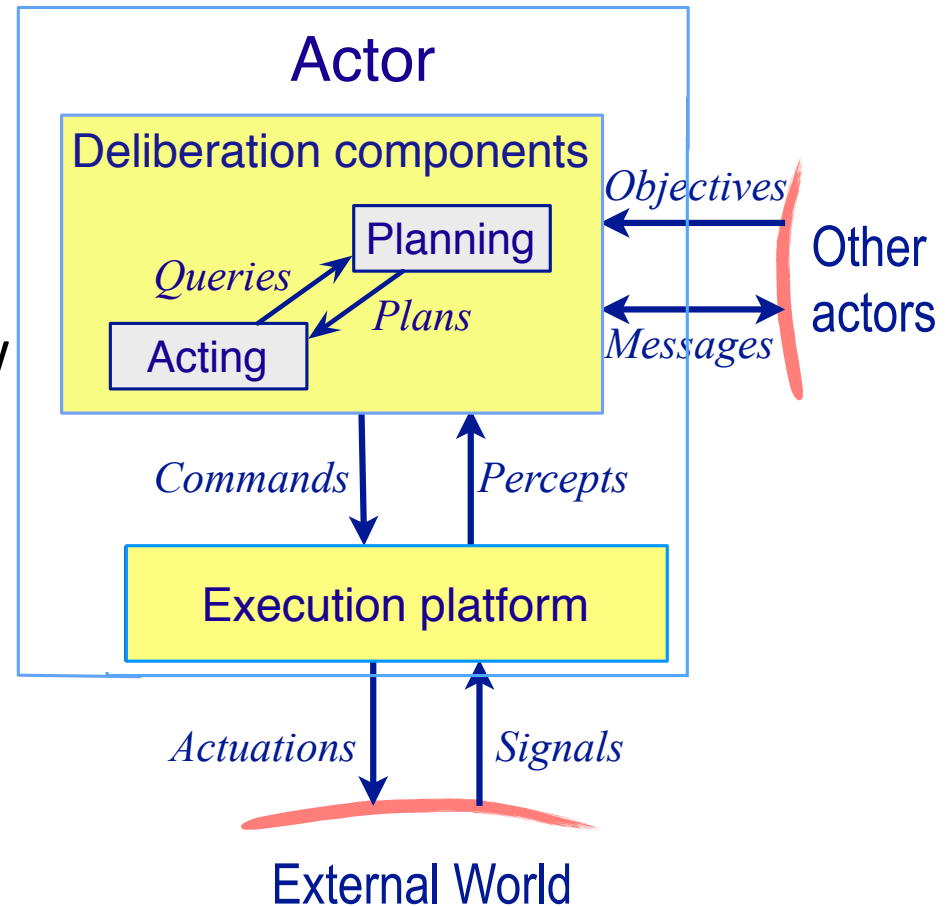
- Relies on **prediction** + **search**
- Uses **descriptive models** of the actions
  - Predict **what** the actions will do, but don't tell **how** to do them
- Search over **predicted states** and possible organizations of feasible actions
- Different types of actions
  - Different predictive models
  - 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:
  - 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

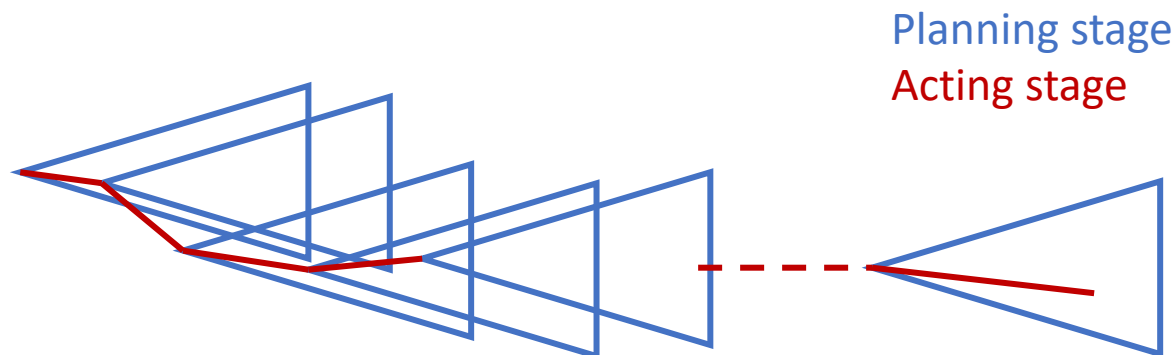
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# Deliberative Acting

- 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**



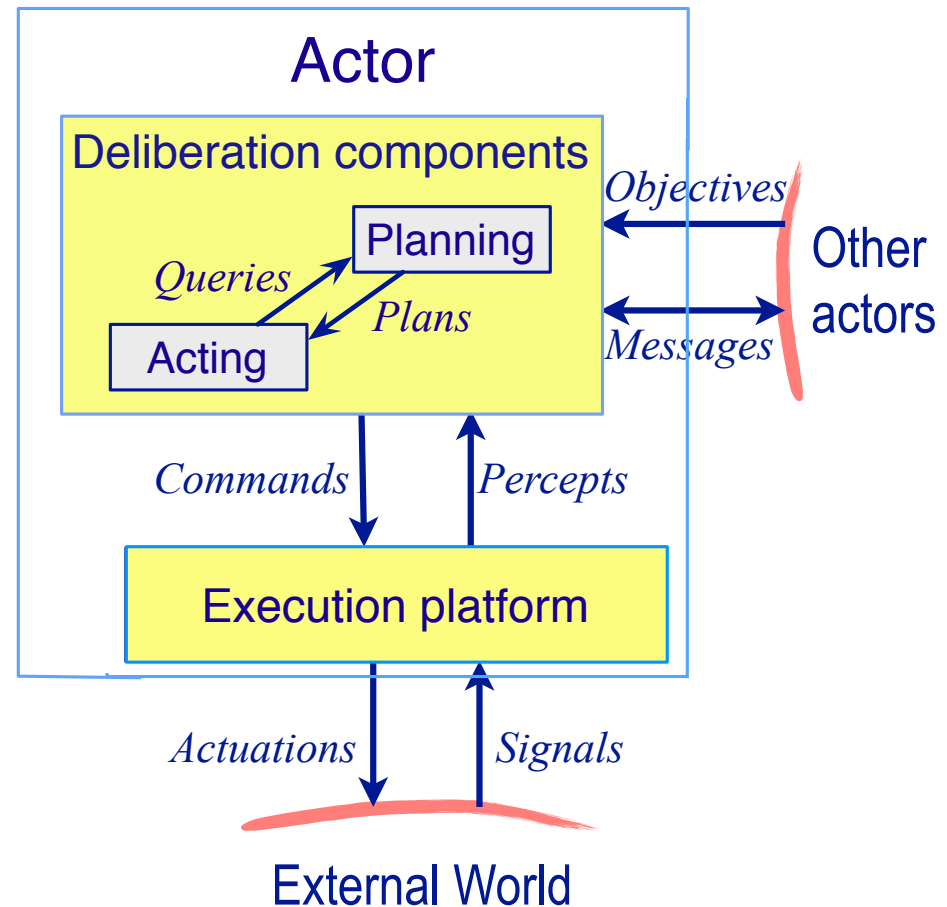
# Deliberative Acting

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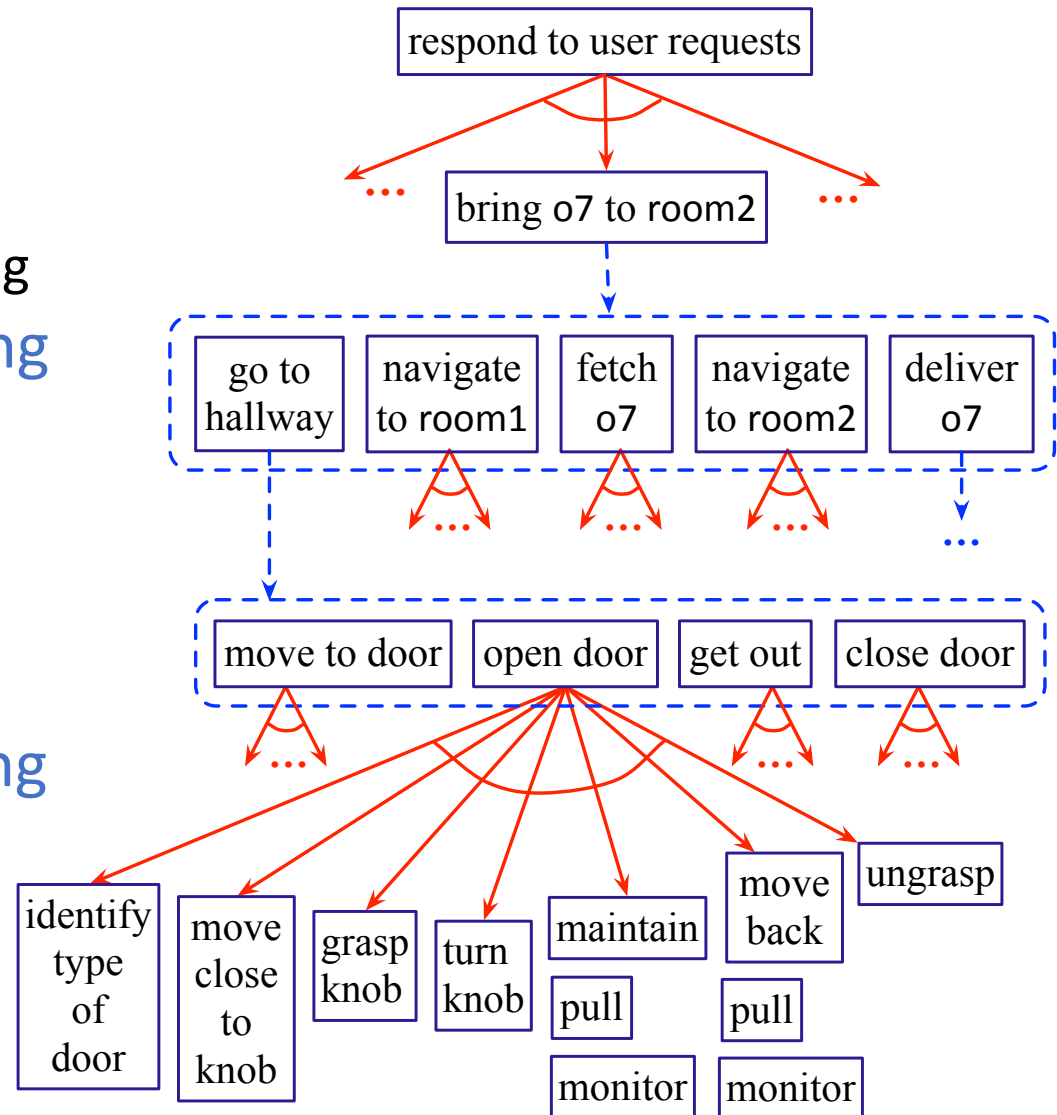
# General Characteristics

- 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



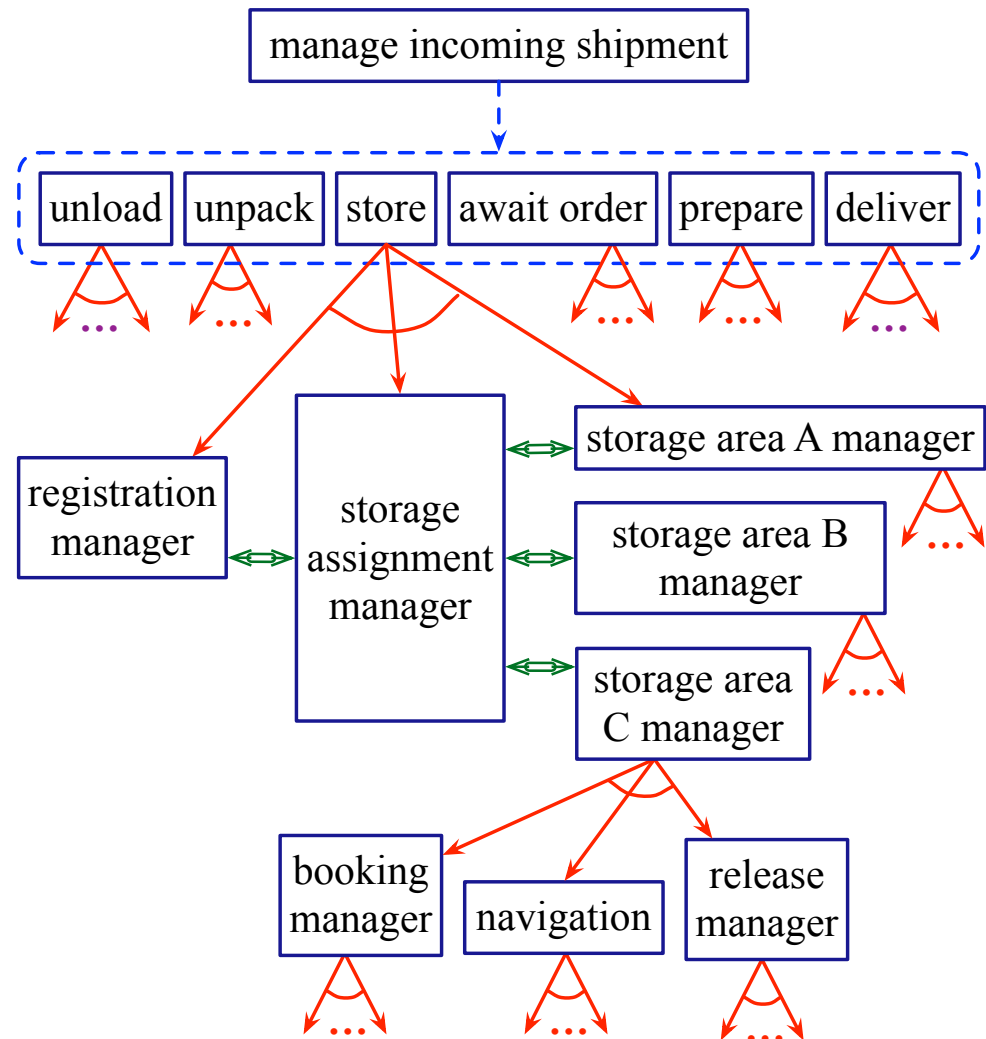
# Example: Service Robot

- 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?



# Example: Harbour Management

- Importing/exporting cars
  - Based on Bremen Harbor
- Multiple levels of abstraction
  - Reflect physical organization of harbor
- 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

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1. Planning and Acting with **Deterministic** Models
  - Conventional AI planning
2. Planning and Acting with **Refinement** Methods
  - Abstract activities → collections of less-abstract activities
3. Planning and Acting with **Temporal** Models
  - Reasoning about time constraints
4. Planning and Acting with **Nondeterministic** Models
  - Actions with multiple possible outcomes
5. Making **Simple** Decisions
  - Utility theory + probability theory = decision theory
6. Making **Complex** Decisions
  - (Partially observable) Markov decision processes ((PO)MDP)
  - Dynamic Models (online)
  - Reinforcement learning
7. Planning and Acting with **Probabilistic** Models
  - Actions with multiple possible outcomes, with probabilities
8. Provably **Beneficial** AI
  - Acting for the better of humanity (without destroying the world)
  - Other: open world, perceiving
    - If time permits