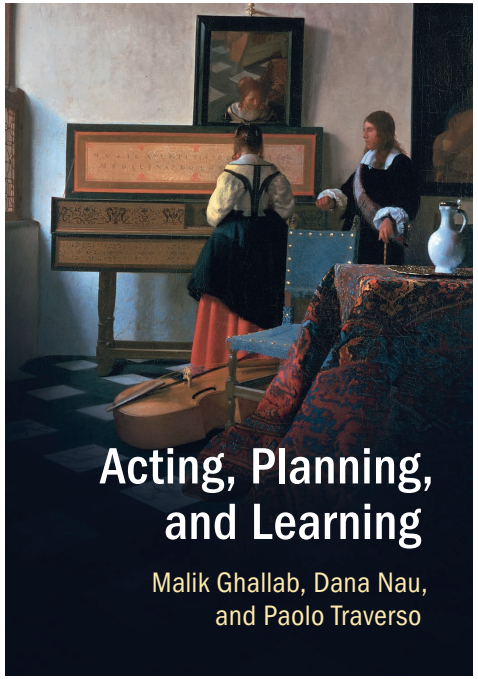
Last update: 11:09 PM, March 7, 2025



Chapter 1
Introduction

Dana S. Nau
University of Maryland

with contributions from
Mark “mak” Roberts

Deliberative Action

Poll
Name one component of "deliberative action".

- Deliberation (or thinking) implies:
  - A representation of the problem
  - A solver
  - An end to aim at
  - Potential application of experience
- Acting implies:
  - A boundary: exogenous and endogenous
  - Agency to modify the external world
  - Potential for exogenous activity

- For AI, deliberation often means:
  - An abstraction of the problem: Model
  - A solver: a search algorithm
  - An end to aim at: a goal or task
  - Potential application of experience: learning
- For AI, acting implies:
  - An actor
  - An external world or environment

- Scientific focus: how do we compute deliberative action: models and algorithms!

- Need not imply consciousness; we generally will not dwell on philosophy in this course

Ethical considerations

- Governing AI for Humanity, Interim Report (UN AI Advisory Board, 2023)
- Blueprint for AI Bill of Rights (White House OSTP, 2022)
- Reflections on AI for Humanity (Braunschweig and Ghallab, eds., 2021)
- 100 Year Study on AI (Stanford University, 2021, 2016)
- The alignment problem: How can machines learn human values? (Christian, 2021)
- Ethics guidelines for Trustworthy AI (EU High-level Group on AI, 2019)
- Responsible AI: requirements and Challenges (Ghallab, 2019)
- Lethal Autonomous Systems Pledge (Future of Life Institute, 2018)
- Study on Autonomy (US Defense Science Board, 2016)

Suggested readings on this topic:

- Human compatible: AI and the problem of control (Russell, 2019)
- Life 3.0 (Tegmark, 2017)
- The Myth of Artificial Intelligence (Larson, 2021)

Motivation

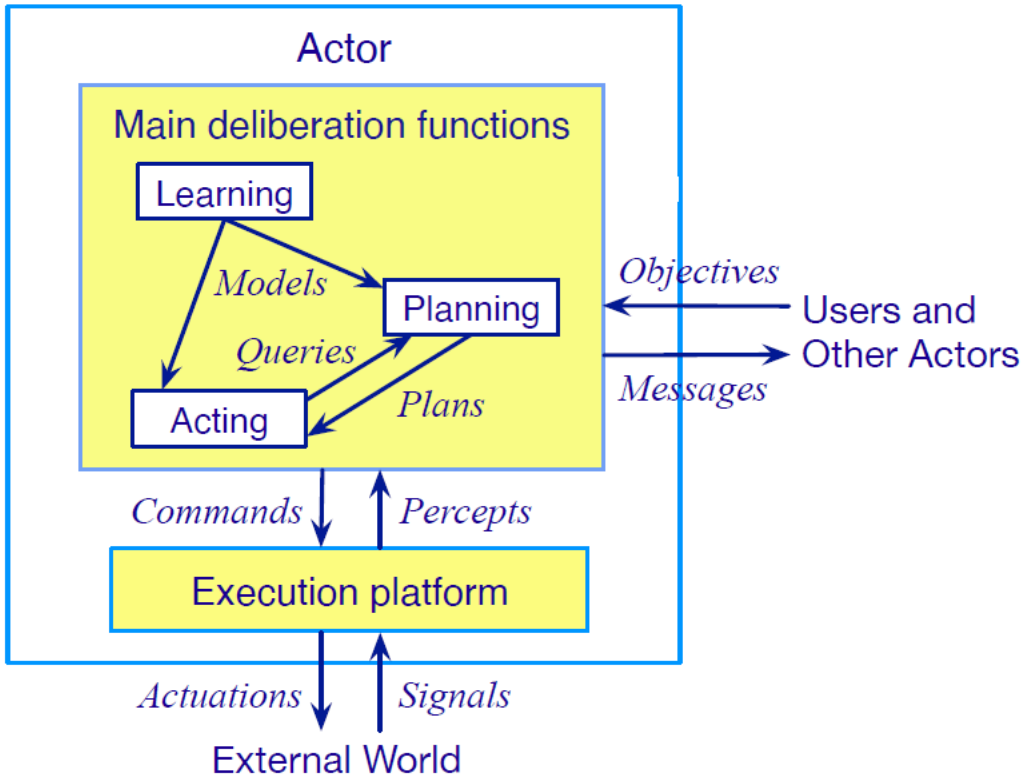
- *Actor*: agent that performs actions

- Deliberation functions
  - Planning

    What actions to perform
  - Acting

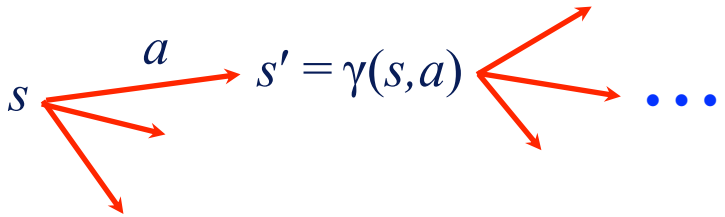
    How to perform them
  - Learning

    Acquire models and decide *When* to act or plan



Planning

- Relies on *prediction* + *search*
- Uses *descriptive models* of the actions
  - Predict *what* the actions will do
  - Don't tell *how* to do them
- Search over *predicted states* and possible organizations of feasible actions



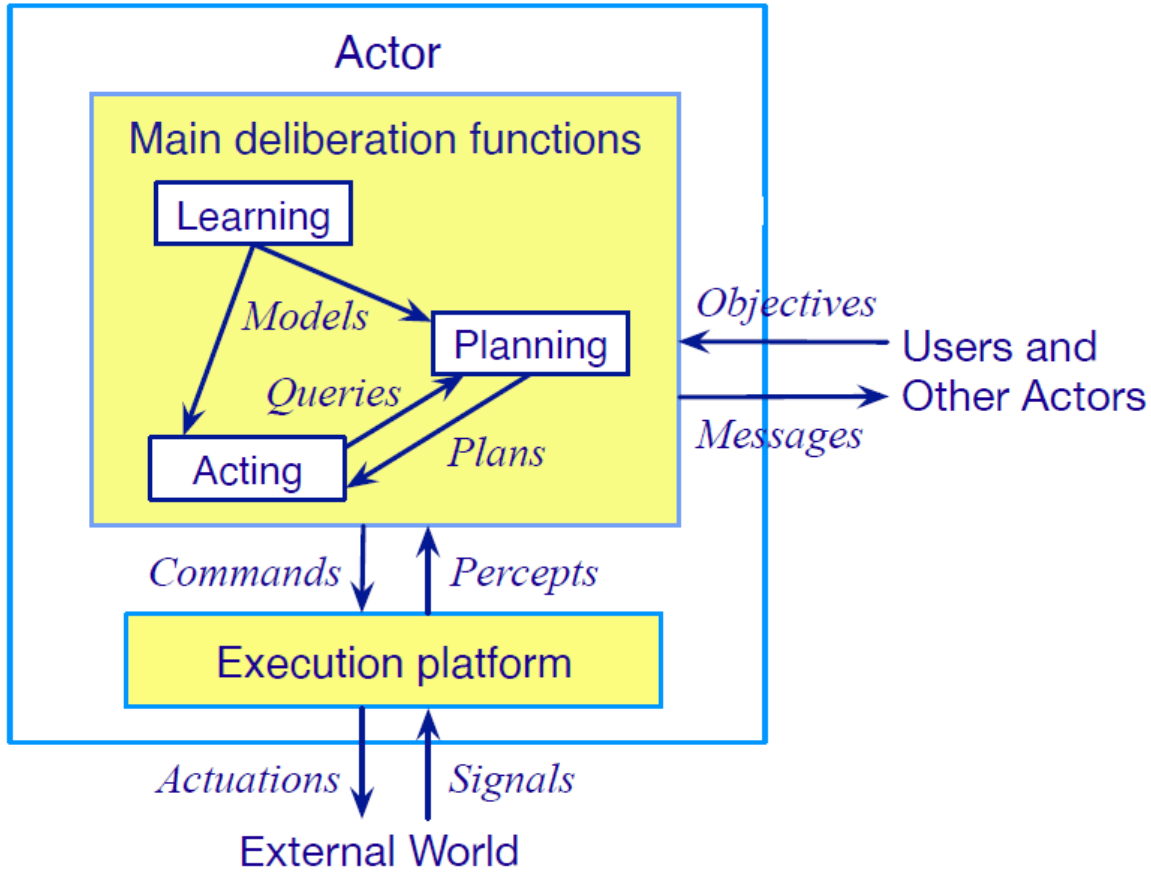
- Different types of actions ⇒
  - Different predictive models
  - Different planning problems and techniques

  - Motion and manipulation planning
  - Perception planning
  - Navigation planning
  - Communication planning
  - **Task planning**

Most AI planning

Acting

- Traditional "AI planning" view:
  - Carrying out an action is just execution
  - Can ignore how it's done
- *Sometimes* that's OK
  - If the environment has been engineered to make actions predictable
  - Example on next slide
- Usually acting is more complicated
  - Example later



Acting as Execution

- Kiva Systems
  - (now part of Amazon Robotics)
- Warehouse with items stored in “pods”
  - Portable warehouse-shelving units
- When an order comes in for an item
  - Software locates closest mobile robot
  - Directs it to go to the correct pod
- To navigate around the warehouse
  - Robot follows bar-code stickers on the floor
- When the robot reaches the target location
  - Slides underneath the pod
  - Lifts it off the floor
  - Carries it to the specified human operator
  - Operator picks items from the pod

https://youtu.be/1FKMniE_q1Q

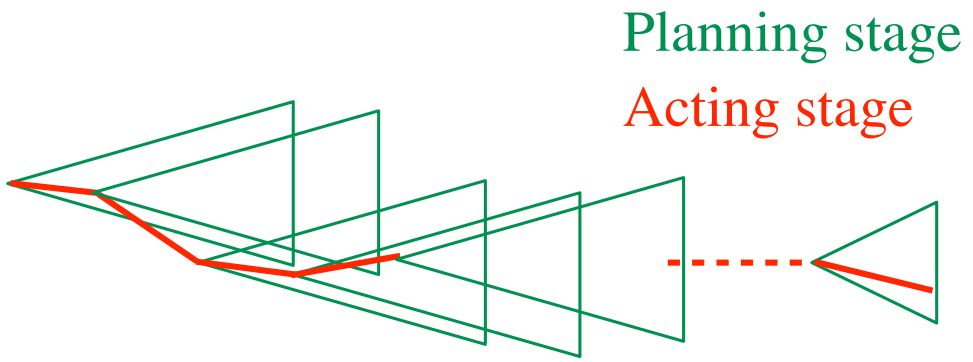
Deliberative Acting

- Experiment:
  - New Caledonian crow wants to retrieve a bucket of food from a vertical pipe
  - Nearby is a piece of wire
  - Crow tries to use the wire, fails
  - Bends the wire into a hook
  - Uses the bent hook to retrieve the bucket
- Crows make hooks in the wild
  - From sticks and leaves, not wire
- Adapted the technique to a new material

https://youtu.be/nTtDbyQTQV0

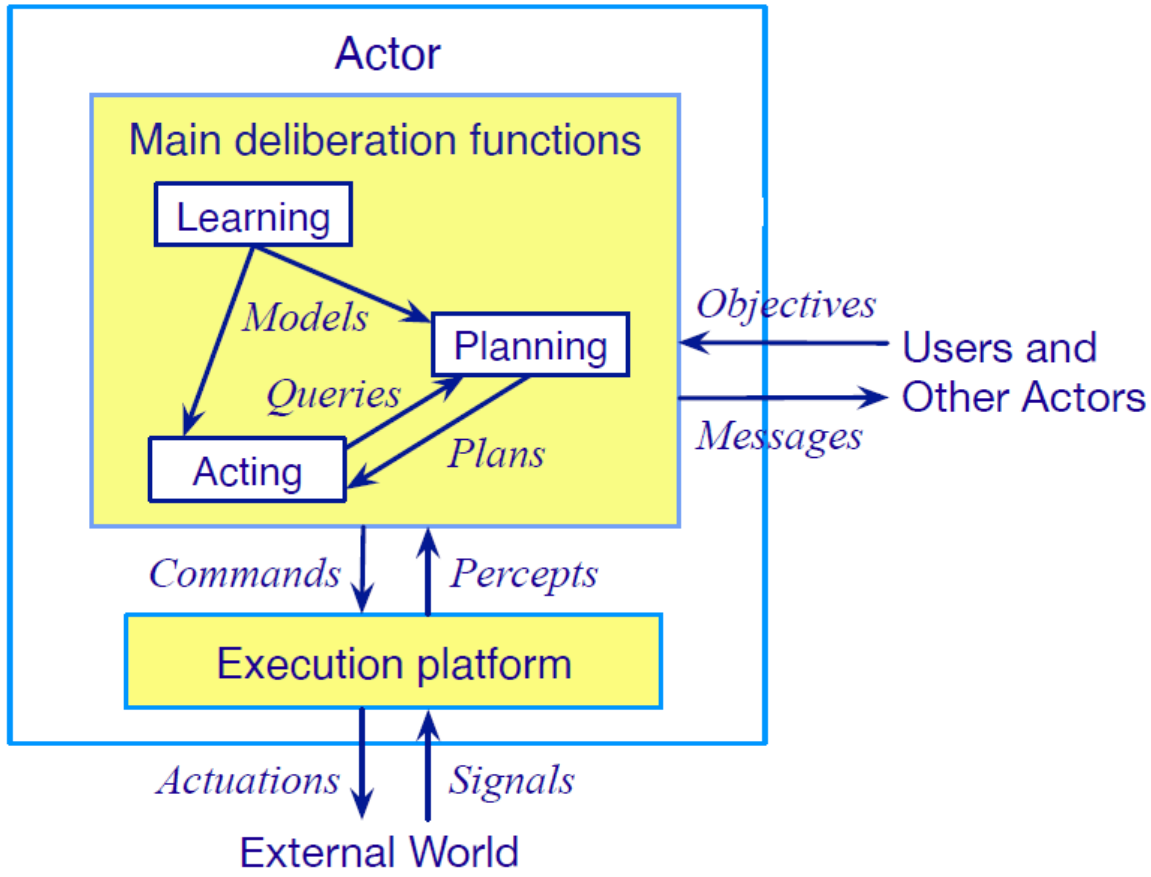
Interleaving Planning and Acting

- Actor is 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*



Planning and Acting

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

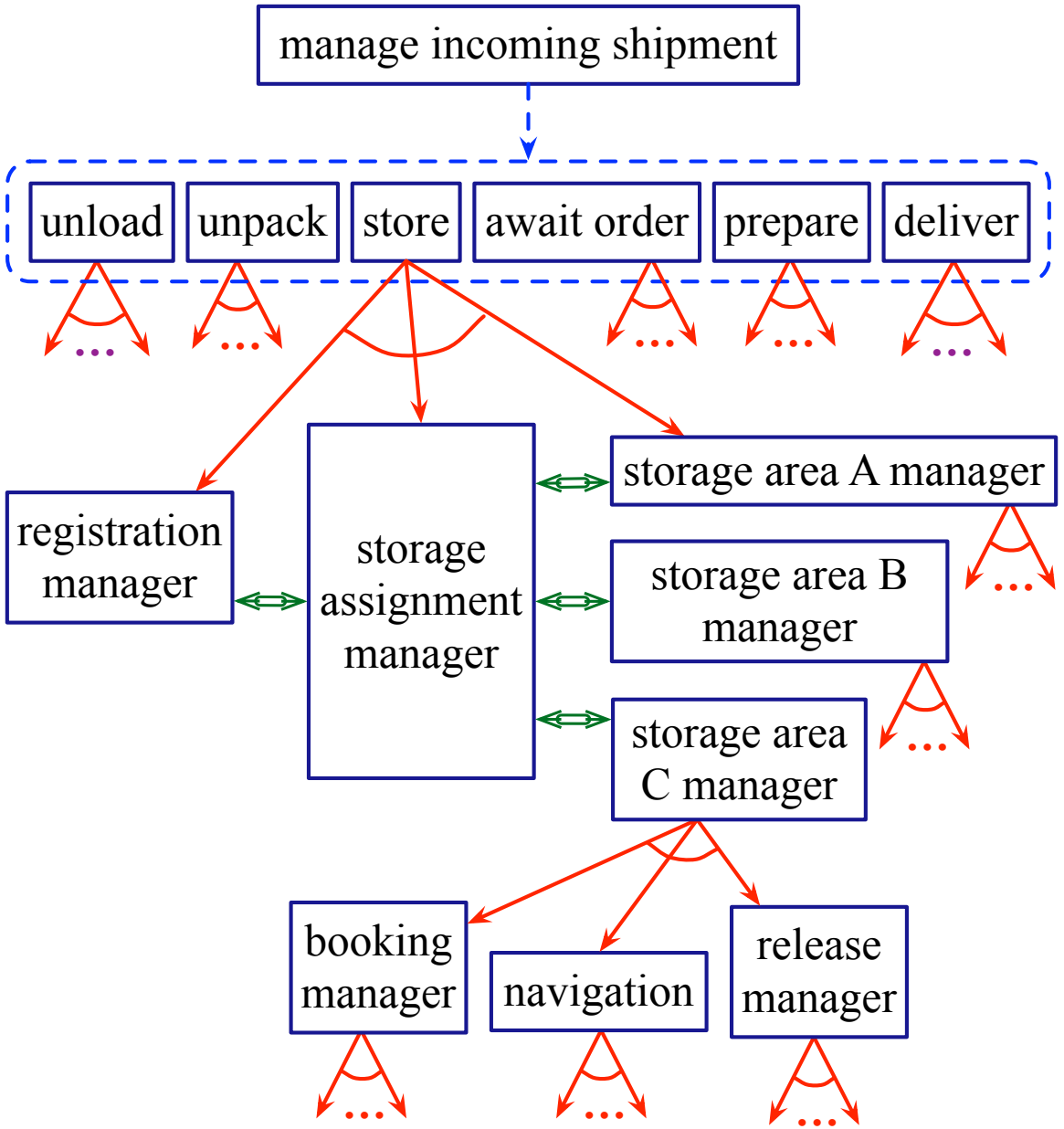


Bremen Harbor

Credit: Martina Nolte, CC BY-SA 3.0 DE

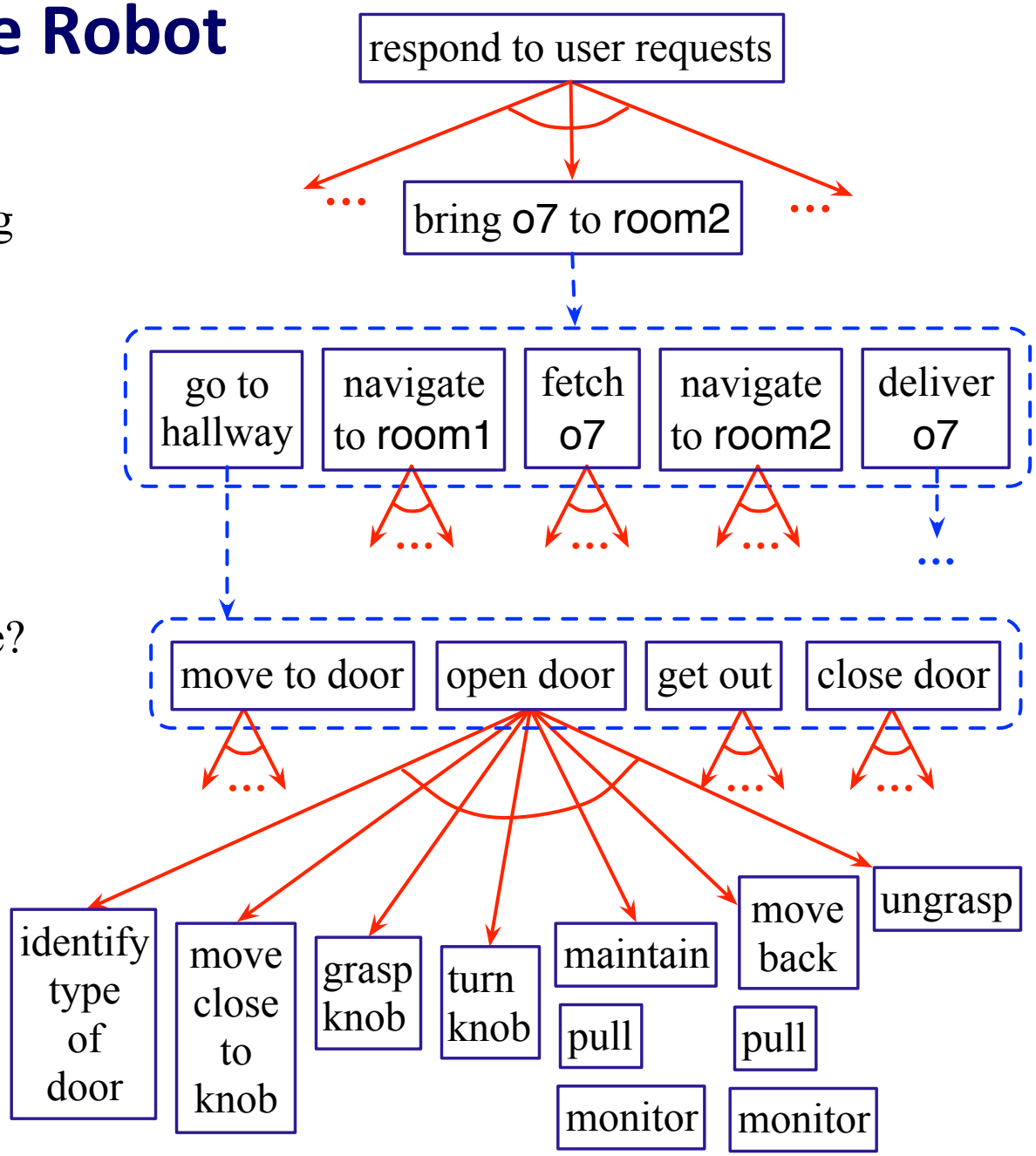
Example: Harbor Management

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



Example: Service Robot

- *Multiple levels of abstraction*
  - Higher levels: more planning
  - Lower levels: more acting
- *Continual online planning*
  - What room is o7 in?
  - What route?
  - What kind of door?
  - Close enough to door handle?
- *Heterogeneous reasoning*
  - planning abstract tasks
  - path planning
  - reactive (e.g., open door)



Planning

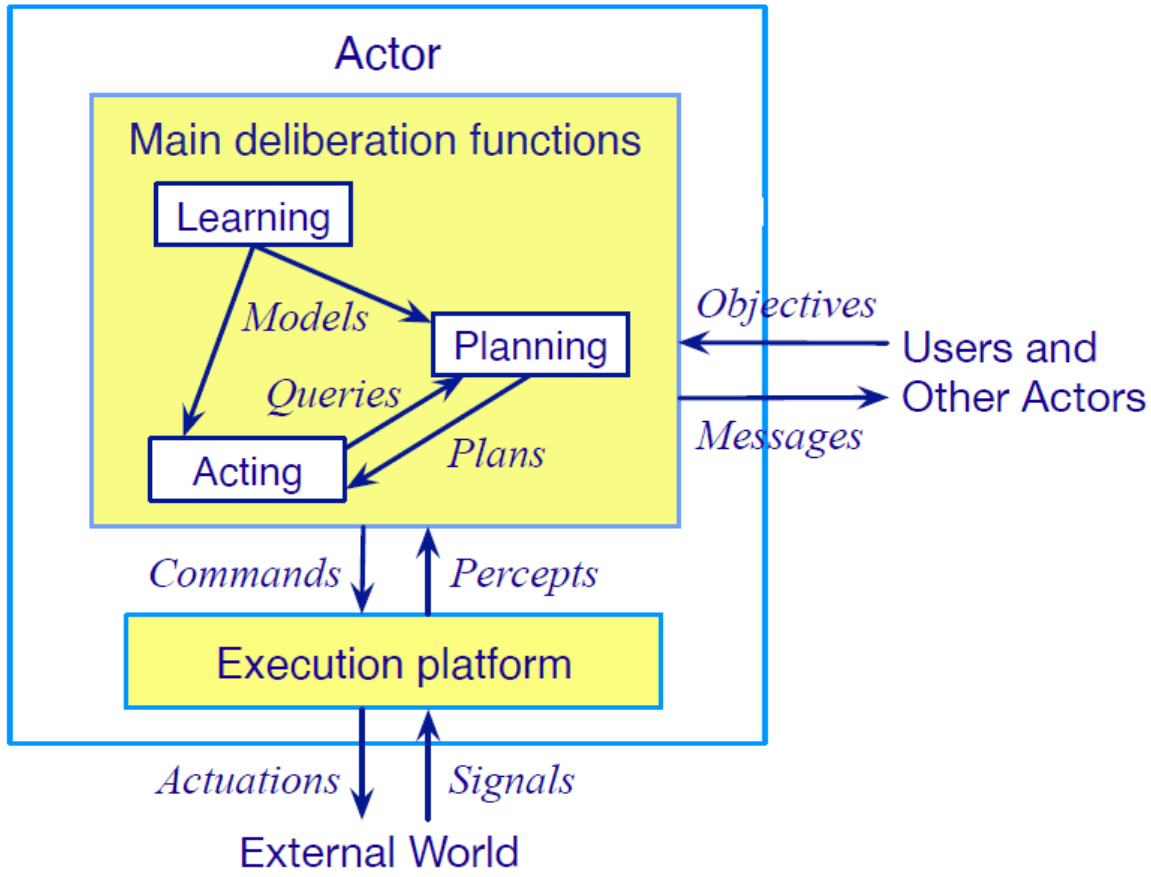
Acting

Models

"All models are wrong, but some are useful."

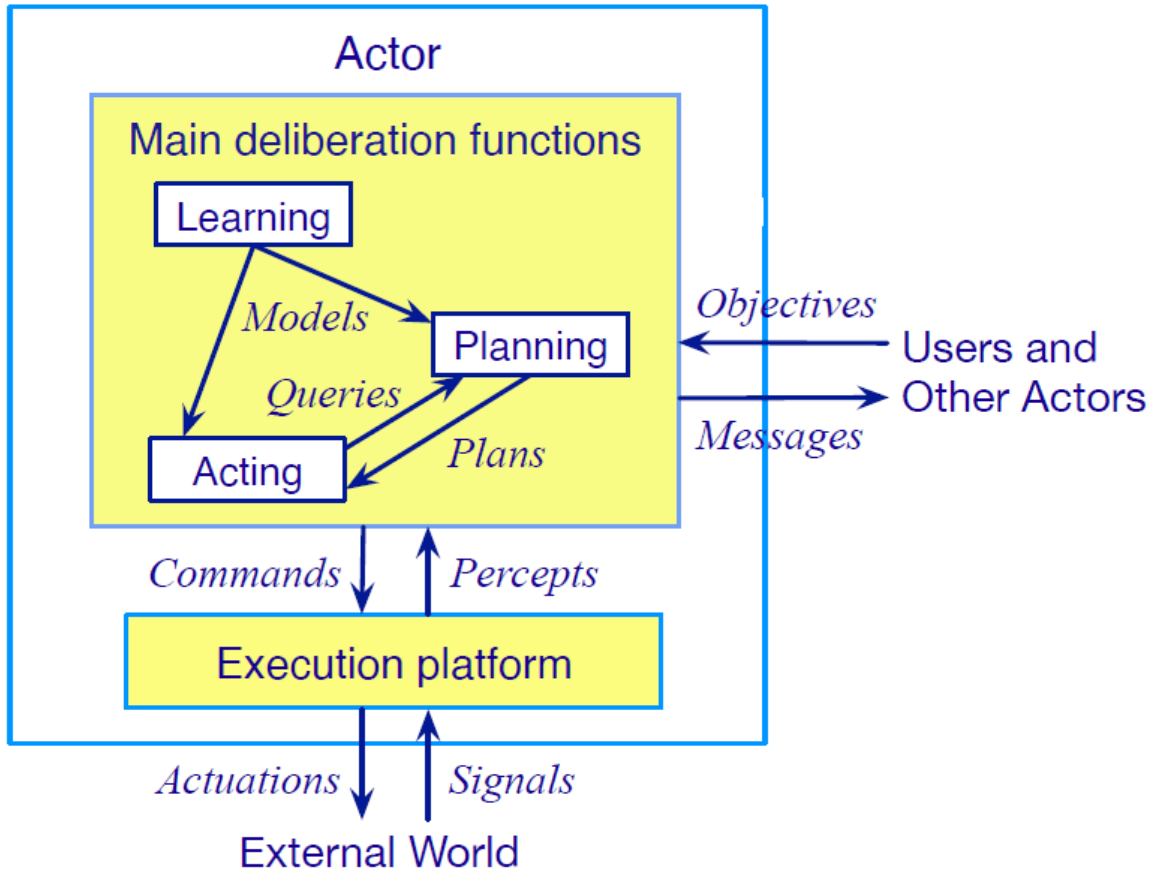
- George Box

- Models are an *abstraction* of the world
  - Good abstractions capture salient details
- Planning and Acting models approximate the causality of taking action:
  - Describe the necessary *preconditions* and expected *effects* for each action
  - May indicate the *expected utility* of taking action toward some end
- Hierarchical models describe how to break down a complex task
  - Example: a recipe describes how to cook a dish without reference to a specific kitchen



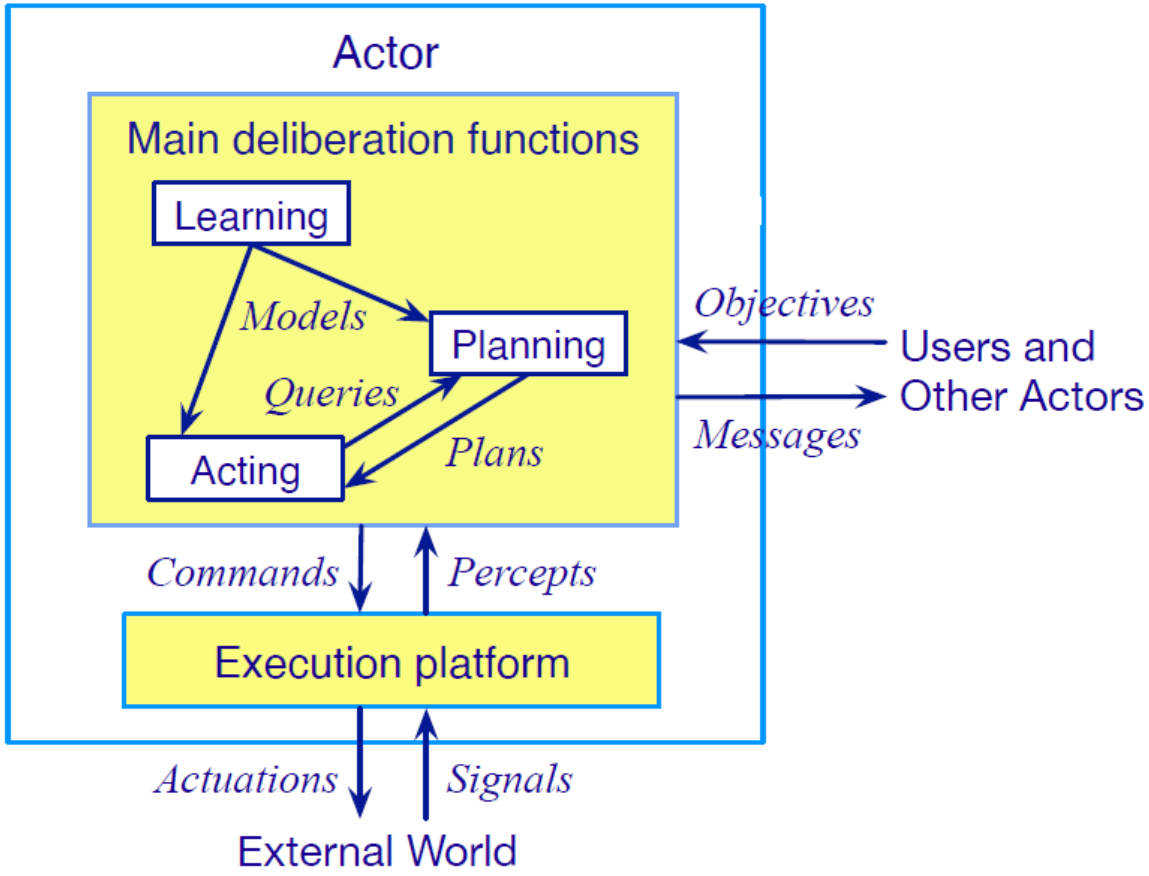
The Challenges of Using Models

- Models are often created and curated by humans, but this means they can be:
  - expensive to write and debug
  - sensitive to original assumptions
  - less adaptable to new environments
- Deployed systems may need to change models to account for
  - Adaptation to a new task or situation
  - The preferences of different humans
  - Failure to successfully complete an action
  - …
- Furthermore, acting systems often require multiple, simultaneous models at different levels of abstraction



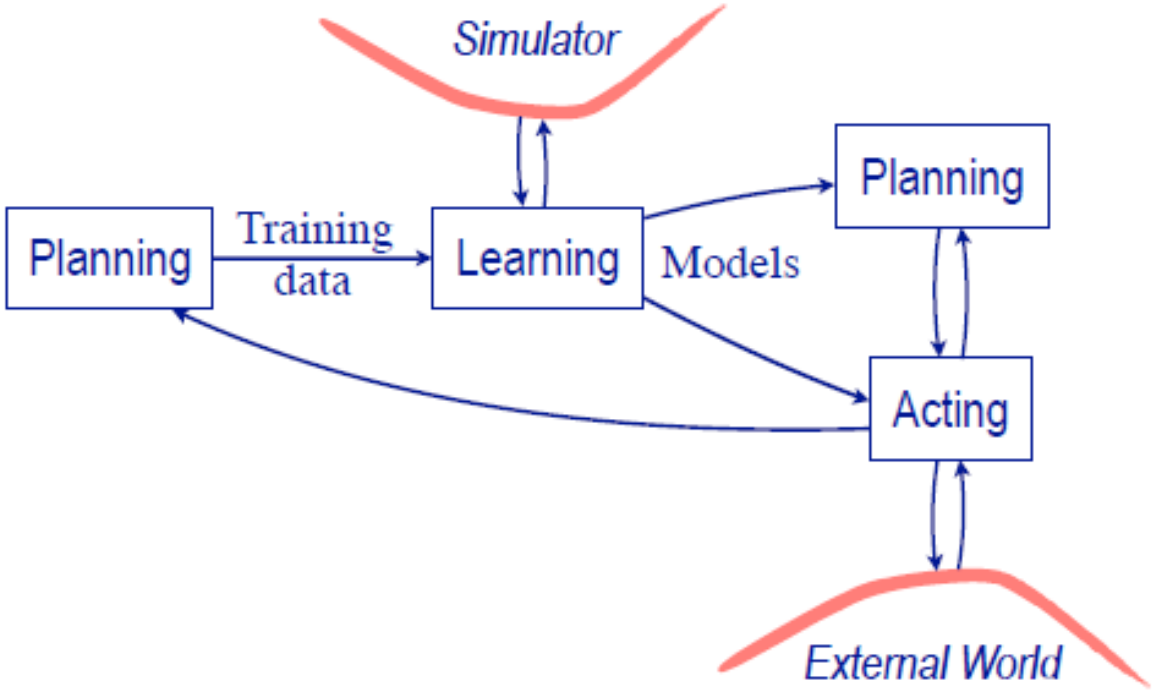
Learning

- Learning consolidates experience
- Learning can overcome some of the challenges of producing models
  - Automates model production
  - Provides mechanism to adapt models
- For acting, learning acquires or adapts knowledge about *how* to do something
- For planning, learning acquires or adapts the effect of *what* was done



Integrating Acting, Planning, and Learning

- Models can be learned:
  - Using planning to produce traces
  - By interacting with a simulator
- Learning might iterate with:
  - Planning: to determine what needs learn or how to invest learning effort
  - Acting: by sampling the simulator or external world to determine the preconditions or effects of actions



The Music Lesson. Johannes Vermeer (c. 1662–1665)

