Deliberative Planning and Acting

Tutorial based on new book

IJCAI Tutorial
NY, July 2016

Introduction

Automated Planning and Acting

Malik Ghallab, Dana Nau
and Paolo Traverso

IJCAI Tutorial
NY, July 2016

Deliberative Planning and Acting

- Acting deliberately
  - Motivated by some intended objectives
  - Consists of choosing and performing actions justifiable by sound reasons with respect to intended objective
- Deliberation
  - *What* to do to achieve objectives
  - *How* to do it
- Relies on
  - *Innate behavior* preprogrammed or evolved
  - *Learned behavior*
  - *Model-based behavior*

Focus

[Greenpower Science]

[Weir 2002]

[Bird 2009]

[Bosch, c.1502]

Motivation

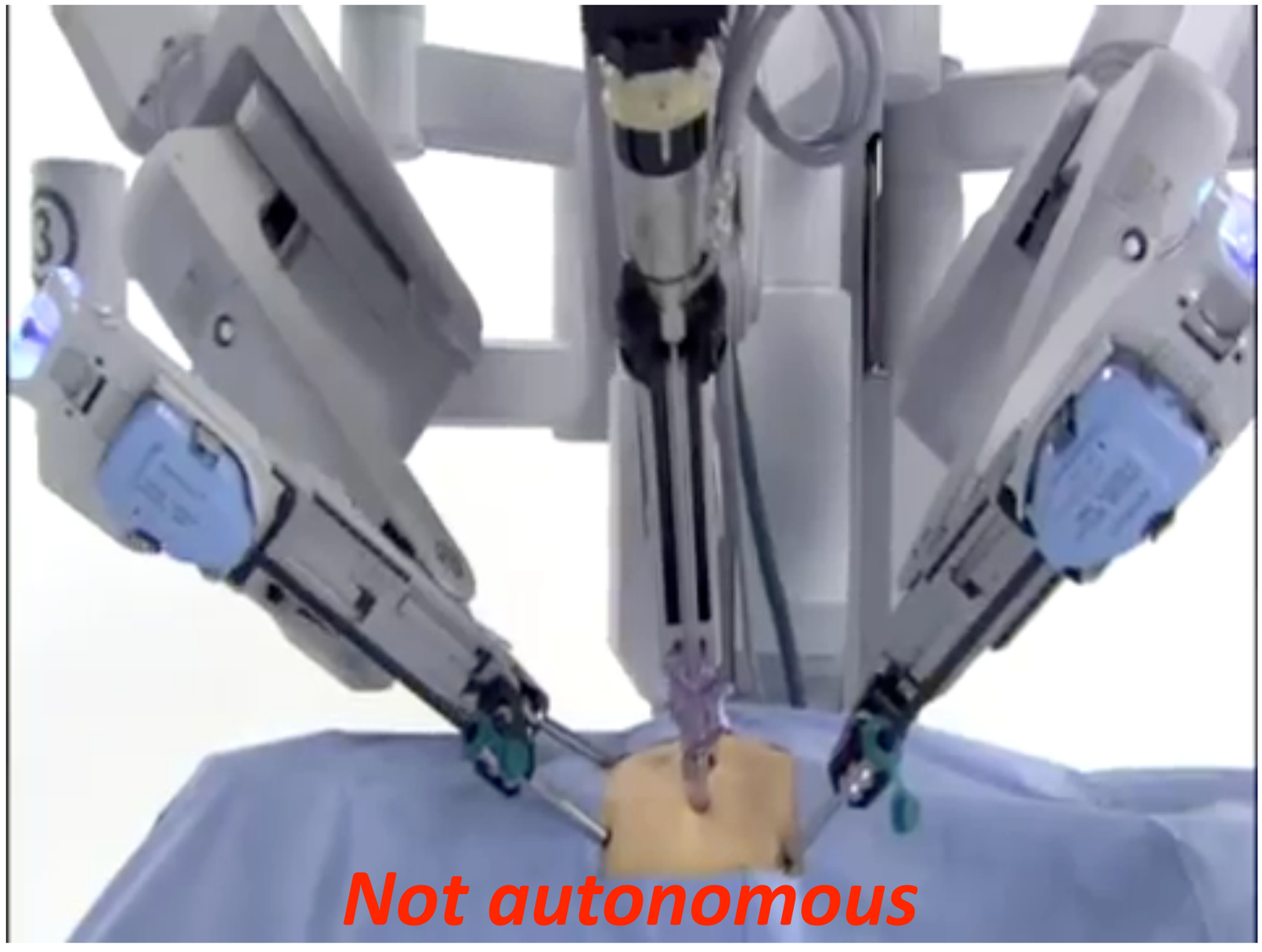
Study computational models and principles which permit

an artificial *actor* to act deliberately

- *Understand* deliberative acting
- *Experiment* with deliberative actors
- *Develop* socially useful technologies

Motivation

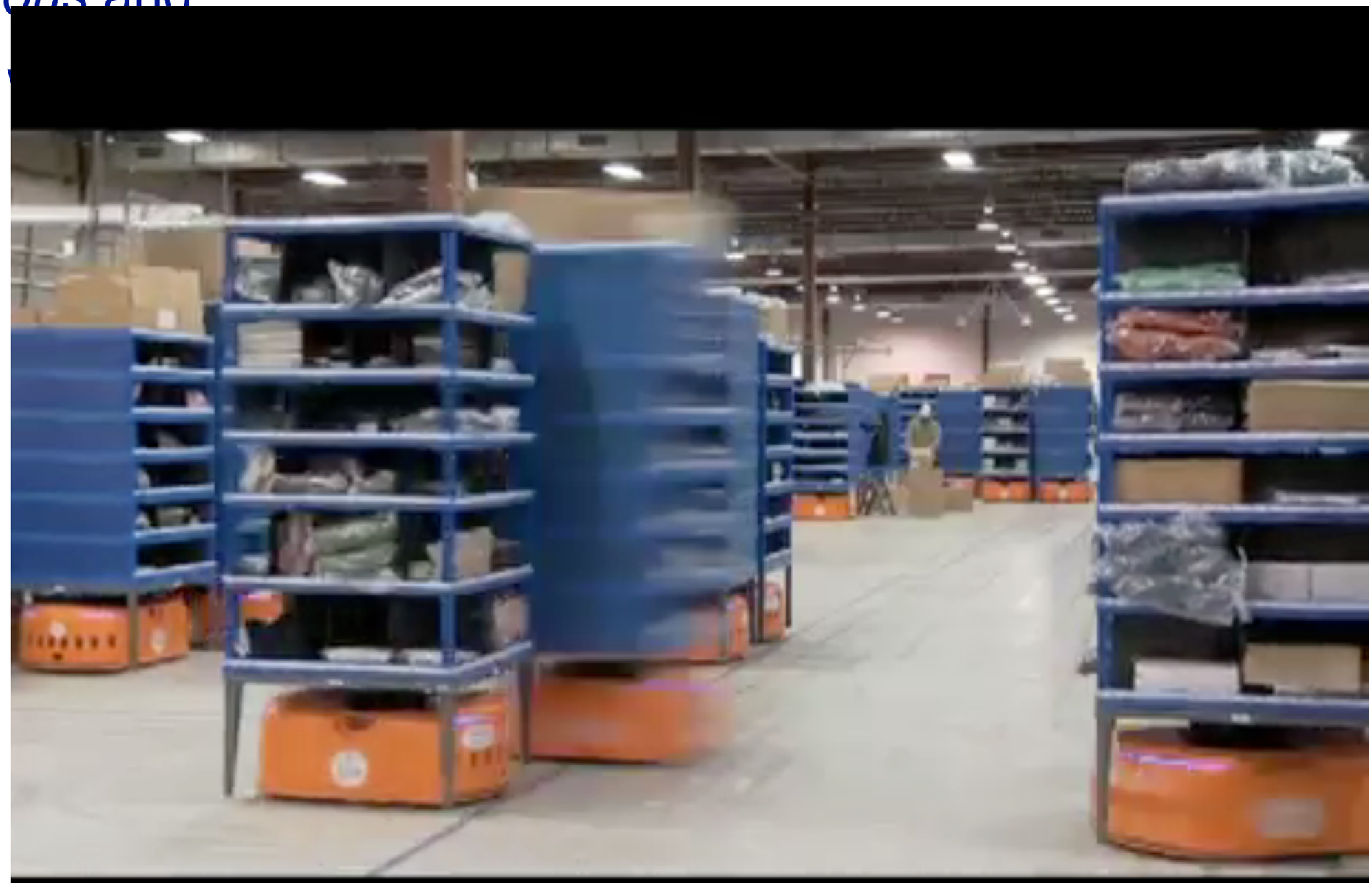
- Deliberation: required for an actor that is
  - *autonomous*



[Intuitive Surgical]

Motivation

- Deliberation: required for an actor that is
  - *autonomous* and
  - *versatile*

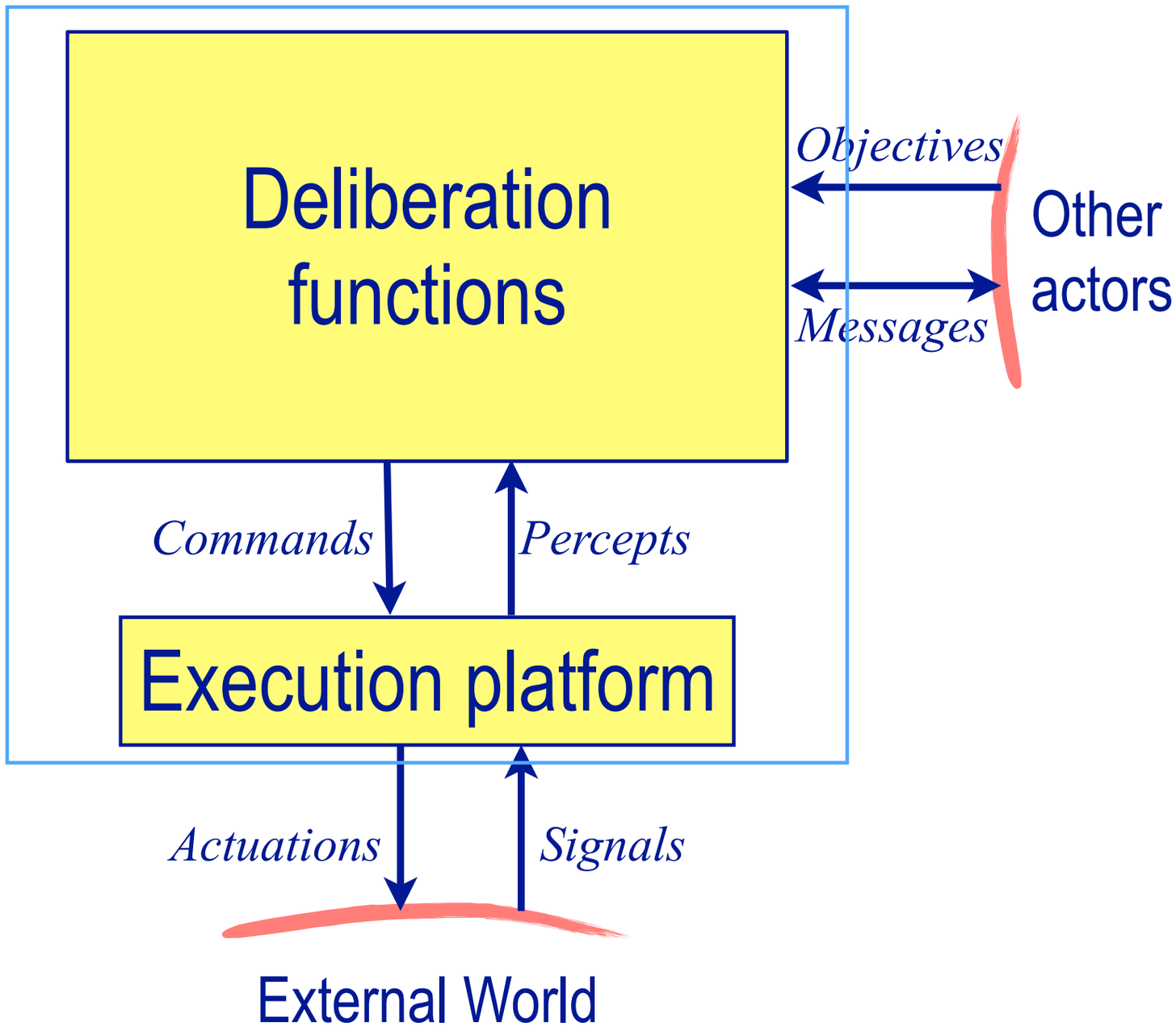


Not versatile

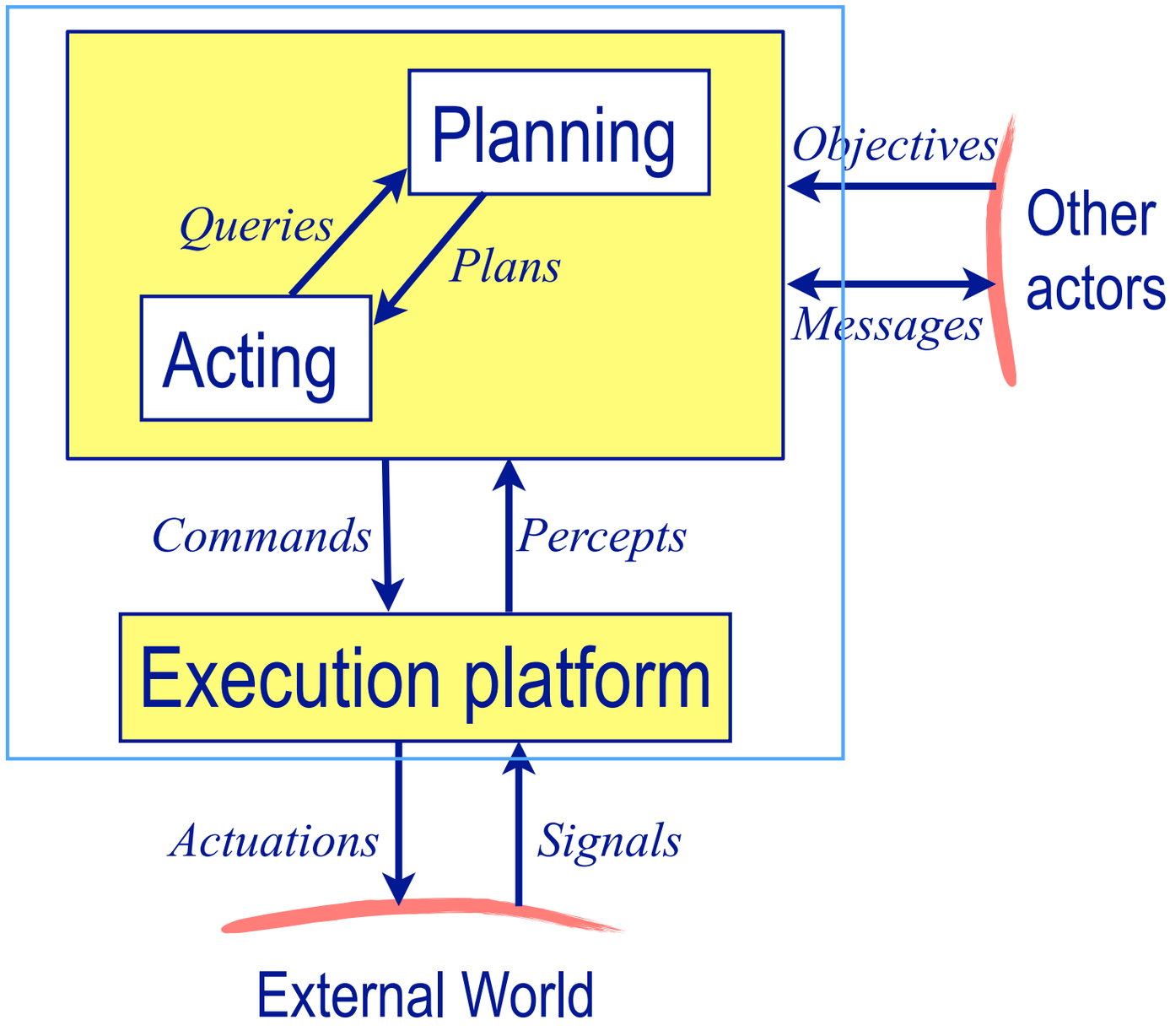
[Kiva Systems]


Coca-Cola
Coca-Cola
Refreshing & Uplifting

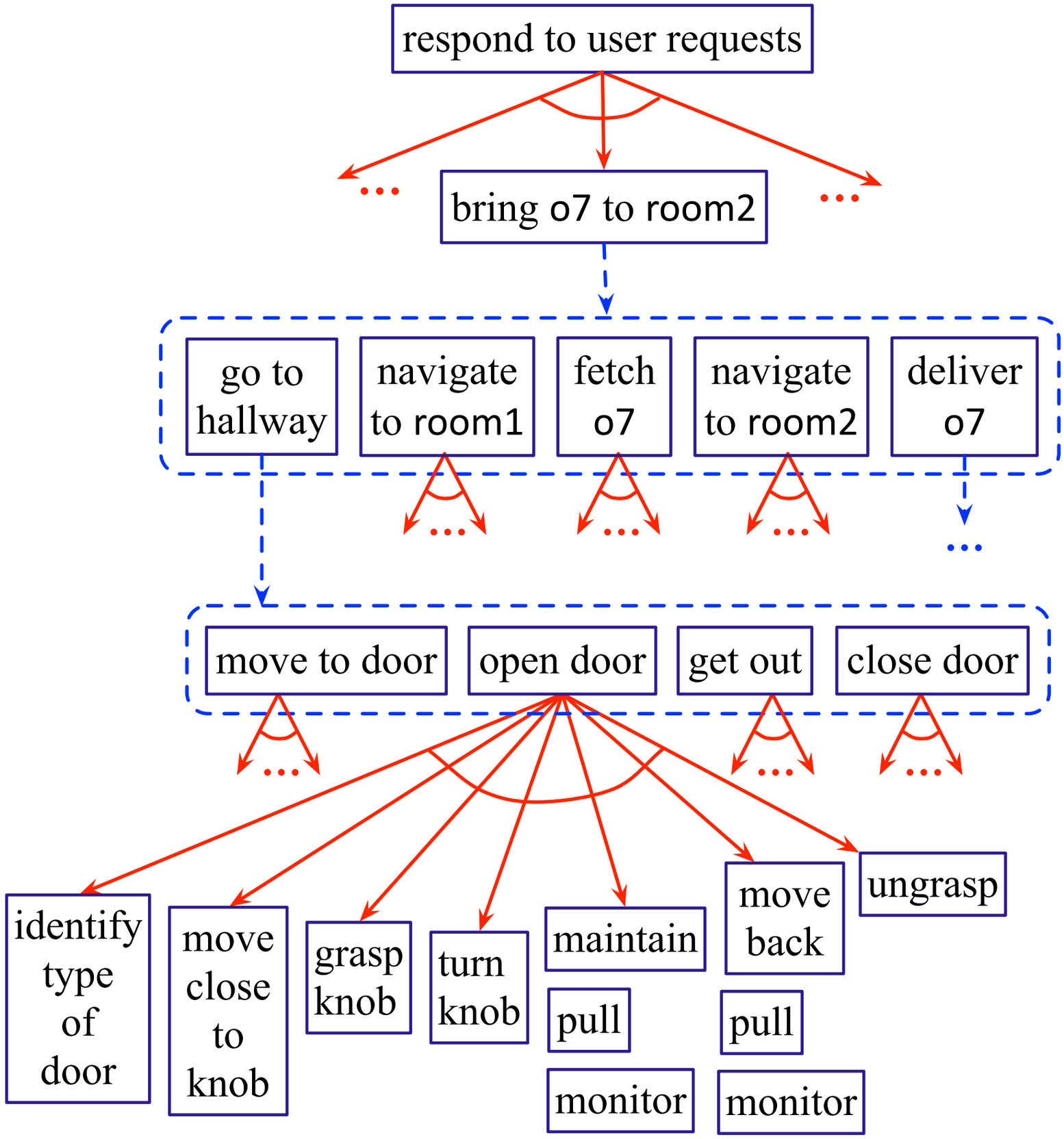
Conceptual View of an Actor

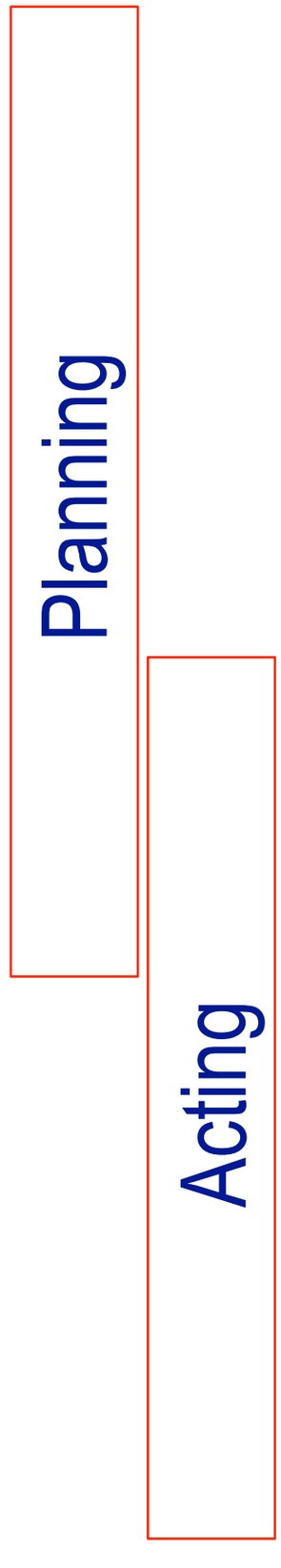


Conceptual View of an Actor



Conceptual View of an Actor





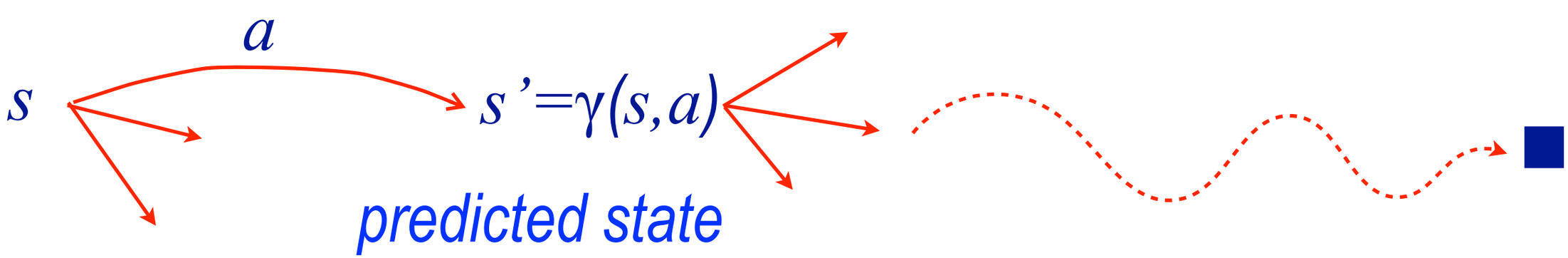
Planning

- *What* set of actions can achieve some purpose

  Synthesis of an organized set of actions

- Relies on *Simulation* + *Search*

  - *Simulation* of the effects of an action with a *descriptive model*
  - *Search* over *predicted states* and possible organizations of feasible actions to achieve intended purpose



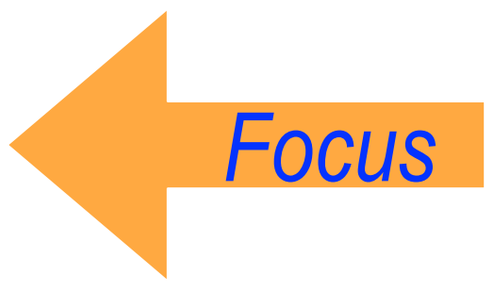
Planning

- *Different types of actions*

  => Different predictive models

    => Different planning problems and techniques

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



Acting

- *How* to perform chosen actions while reacting to the context in which the activity takes place
  - Refining actions into commands w.r.t. current context
  - Reacting to events
- Relies on *operational models* of actions
- Focuses on *current observed state*
- Acting ≠ Execution
  ≠ Planning

What are the specifics of acting as a deliberation function?

How to address *jointly* planning and acting?

Acting vs Planning

- Planning
  - Models × Problems ⟶ Plans

Function

- Acting
  - *Situated interaction* with dynamic unpredictable environment
    - Adapt actions to context
    - React to context

Transduction
closed loop on streams I/O

Is Acting ≠ Planning?

- Planning
  - Models × Problems ⟶ Plans

- Acting
  - Situated interaction with dynamic unpredictable environment

Synthesize a plan that is a situated automata

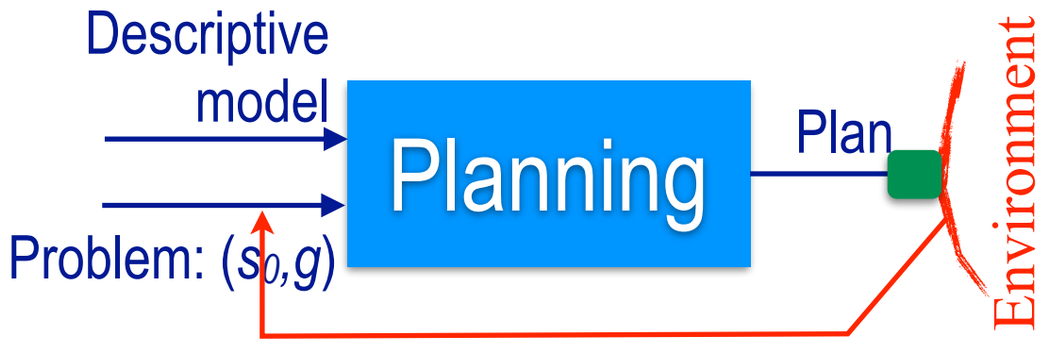
Yes: MDP, Nondeterministic planning

But: Modeling effort: exponential in #effects(a) × #events(s)

Adaptation of automata execution to diversity

Is Acting ≠ Planning?

- Planning:
  - Models × Problems ⟶ Plans



- Acting:
  - Situated interaction with dynamic unpredictable environment

Close the loop on a planner

Yes: Receding horizon, interleaved planning and execution

But: Type of input: not always (s,g)

Type of models needed

Is Acting ≠ Planning?

- Planning:
  - Models × Problems ⟶ Plans

- Acting:
  - Situated interaction with a dynamic unpredictable environment

Design Acting as a flexible embedded system

Yes: Control theory, Automata theory, state charts

Real-time reactive systems, synchronous languages

But: Seldom adequate for diversity of tasks and environments

Planning & Acting

- *Hierarchically organized deliberation*
  - Combine tasks with/without planning actions with/without online refinement
  - Heterogeneous representations and models

  ➡Hierarchy of representations, tools, and techniques

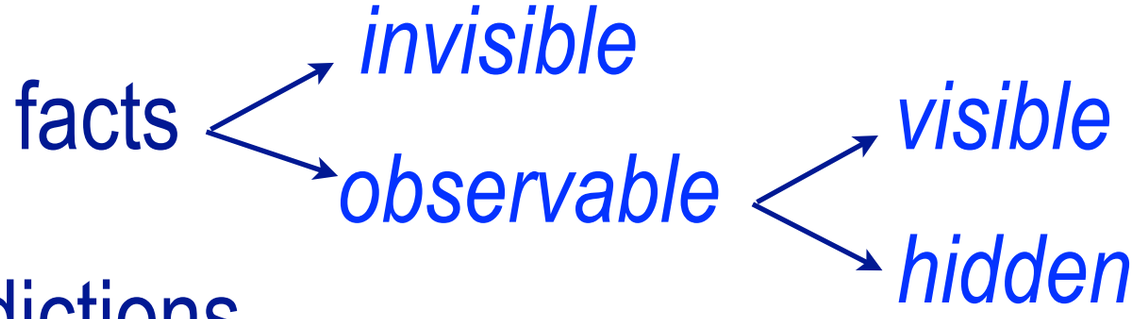
- *Continual online deliberation*
  - Limited predictive models and knowledge of the environment
  - Cost of minor mistakes and retrials < cost of modeling, information gathering, and deliberation

  ➡Deliberation remains partial until objectives achieved, including through flexible modification of its plans and retrials

  ➡While acting: focused perception to refine and monitor actions, react to events, update and repair plans

Simplifying assumptions

- *Dynamics of the environment*
  - Exogenous events, changes that are expected and/or observed
  - Dynamics described with discrete, continuous or hybrid models
- *Observability* of the environment



- *Uncertainty* in knowledge and predictions
  - Abstracting away uncertainty at high level deliberation
  - Reasoning with explicit models of uncertainty
- *Time* and concurrency
  - Discrete transitions
  - Handling durations, deadlines, concurrent activity synchronization

Tutorial Outline

- *Deterministic models*
  - Refinement methods for acting
  - Refinement methods for planning
- *Temporal models*
  - Timelines and temporal refinement methods
  - Chronicles for planning and acting
- *Nondeterministic models*
  - Offline and online nondeterministic planning
  - I/O automata and refinement methods for planning and acting