

Architectures for Robot Control

Intelligent Robotics
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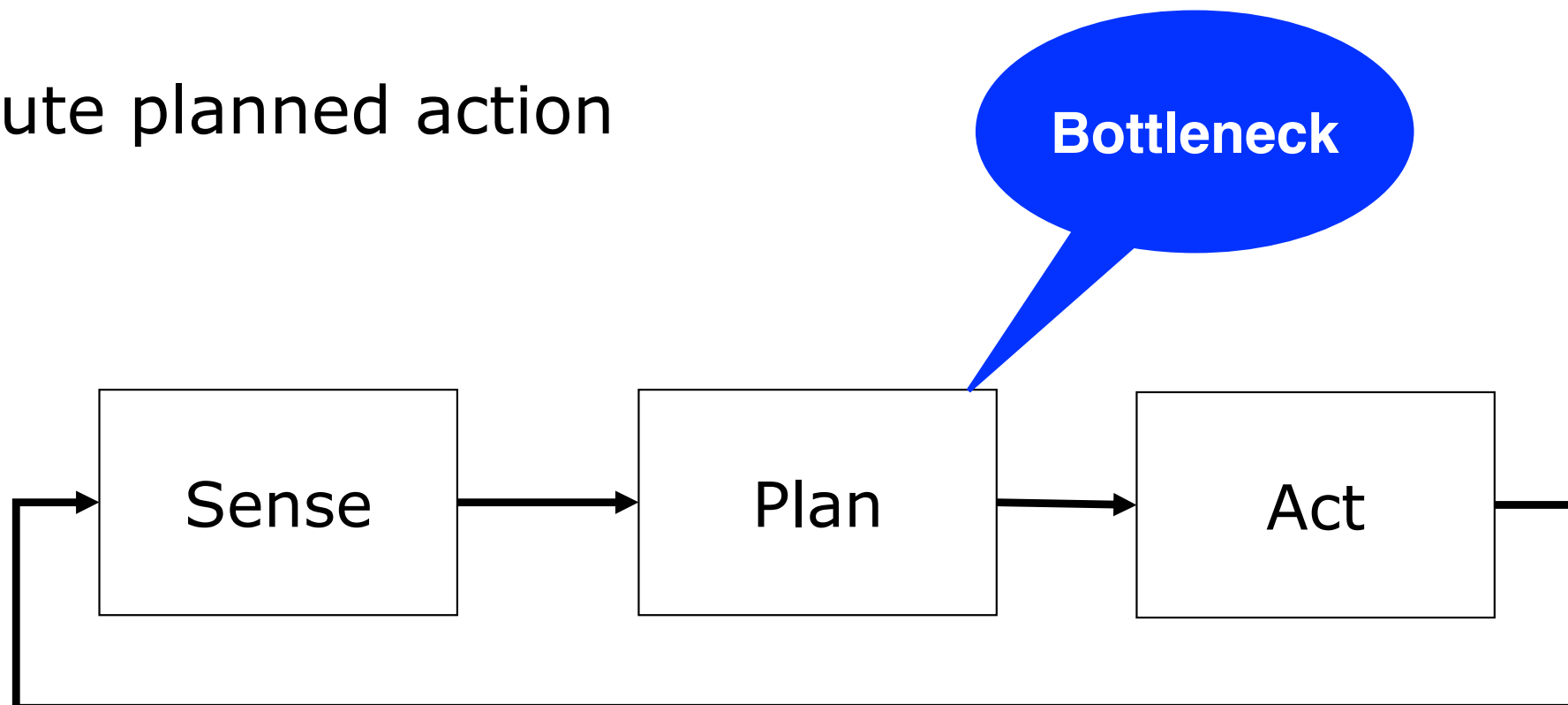
This Lecture

- Deliberative paradigm
 - STRIPS
- Reactive paradigm
 - Behaviour-based architectures
- Hybrid paradigm
- The SMACH package (ROS)

Architectures for Robot Control - Overview

Deliberative Paradigms

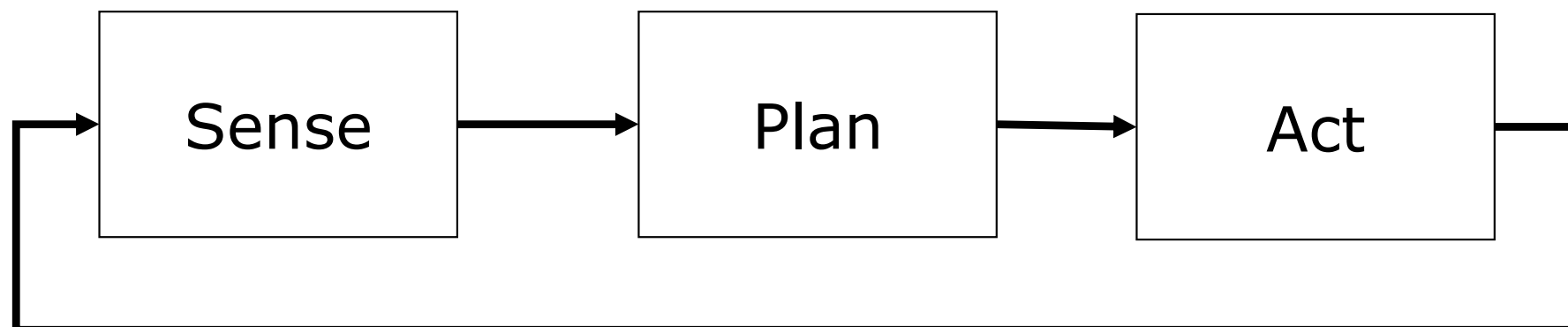
- Sense the world
- Update world model and generate plan
 - Knowledge representation + Automated reasoning
- Execute planned action



Deliberative Paradigms

- **Knowledge representation:**

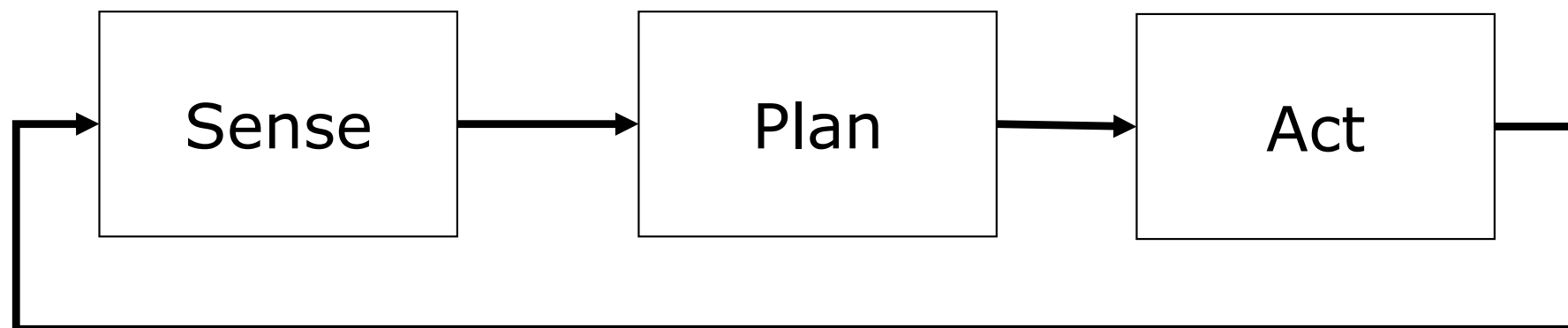
- *Closed world assumption*: World model contains everything the robot needs to know
- *Frame problem*: How to model everything the robot needs to know while keeping the size of the state space manageable?



Deliberative Paradigms

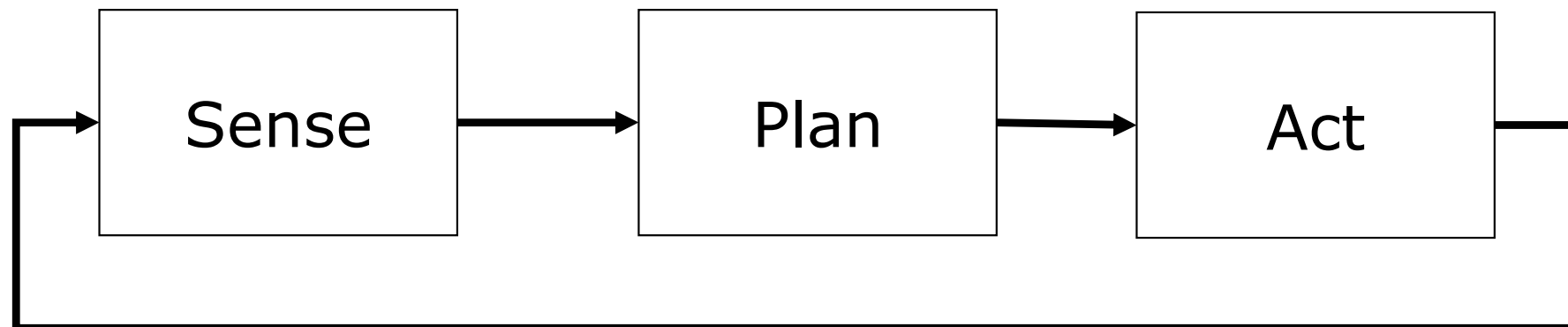
- **Planning:**

- Exploring the possible states of the world to find a plan is computationally expensive (e.g., STRIPS planning is NP-complete)



Deliberative Paradigms

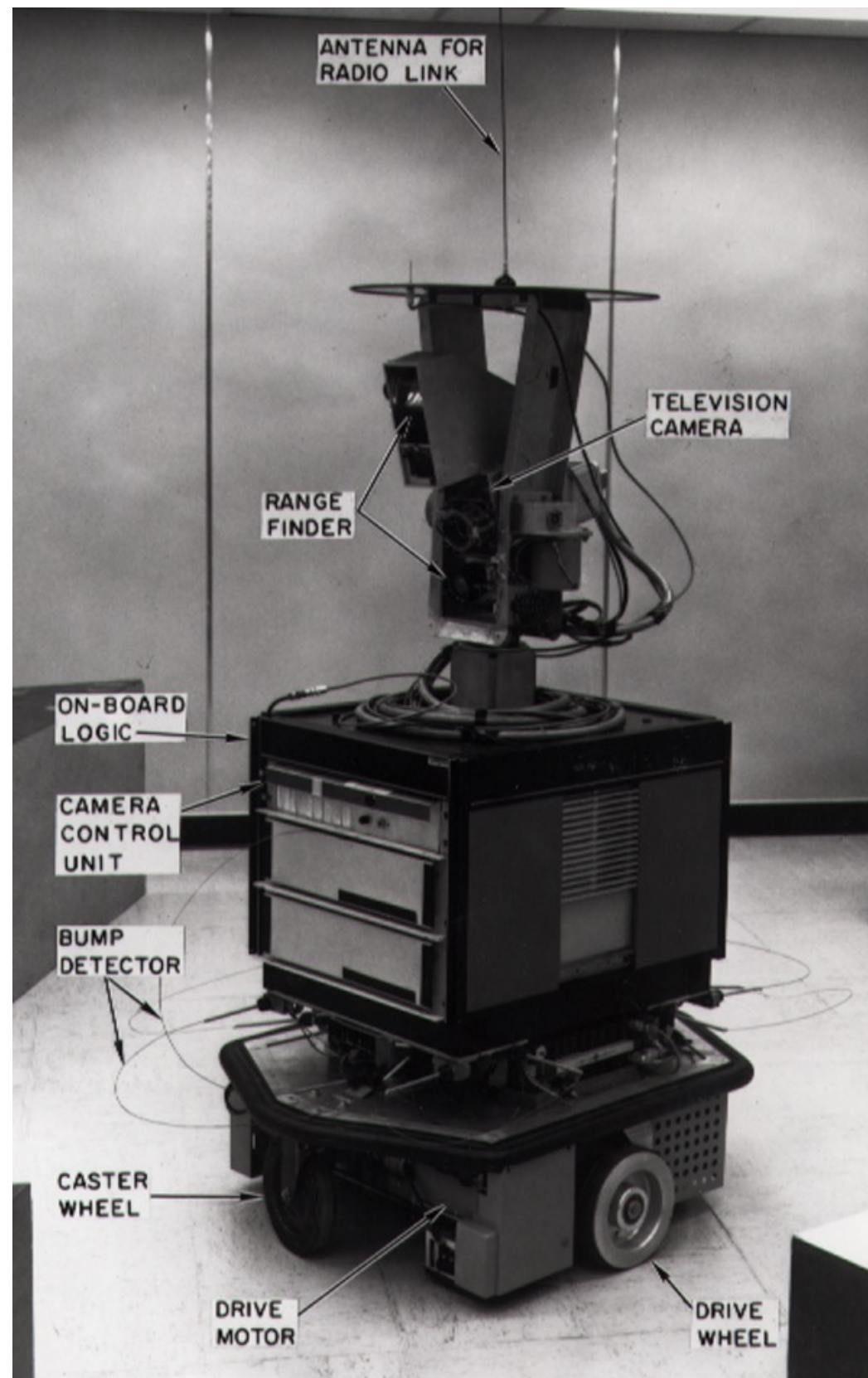
- Sensing and acting are disconnected:
 - After sensing we always need to update the world model and generate a plan
 - **No reactivity**



Shakey

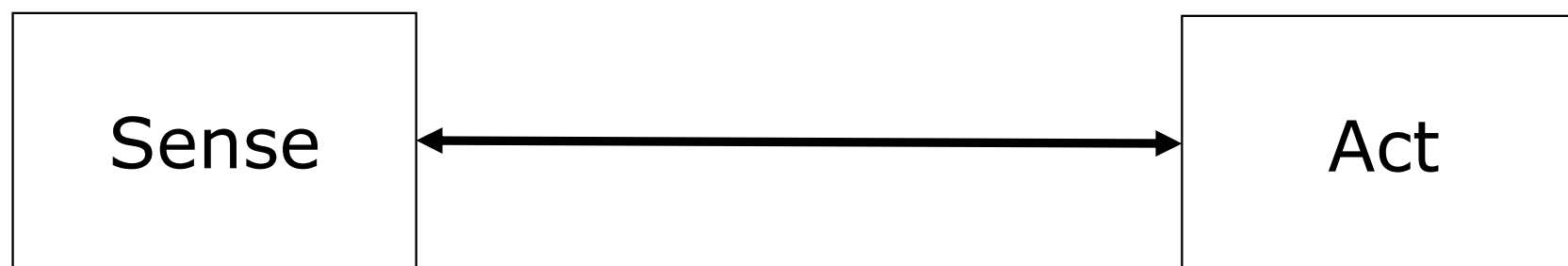
- Control architecture based on deliberative paradigm
- Plan step is based on STRIPS
 - *Knowledge representation*: First-order predicate logic
 - *Planning*: Logic based planning
 - Remember lectures on classical planning

Shakey



Reactive Paradigm

- *No* world model; no planning
- Direct mapping between sensor input and actuators output
- Very reactive to changes in sensor readings
- (Radical) answer to shortcomings of deliberative paradigm



Reactive Paradigm

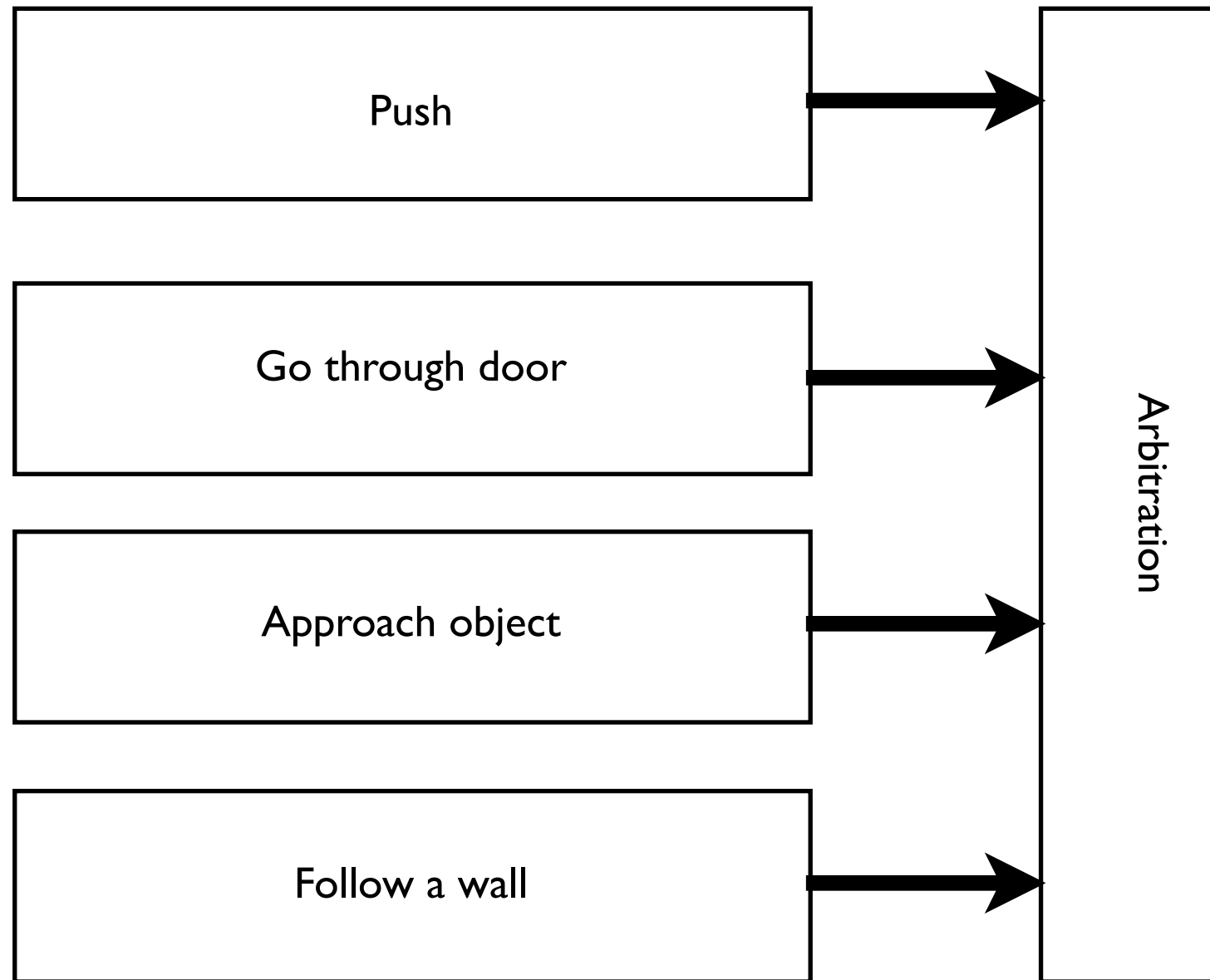
“ AI researchers ... partition the problems they work on into two components. The AI component, which they solve, and the non-AI component which they don't solve. Typically AI 'succeeds' by defining the parts of the problem that are unsolved as not AI. The principal mechanism for this partitioning is abstraction ... In AI, abstraction is usually used to factor out all aspects of perception and motor skills. I argue below that these are the hard problems solved by intelligent systems, and further that the shape of solutions to these problems constrains greatly the correct solutions of the small pieces of intelligence which remain.”

Rodney Brooks, *Intelligence without representation*, 1991,
Artificial Intelligence, Vol 47.

Behaviour-Based Architectures

- Overall controller composed of two parts
 - Task achieving controllers (e.g., simple state machines)
 - Arbitrating controller (also task specific)
- Controllers:
 - Are reactive (map perception to action)
 - Do not include world models, no planning
 - Are only capable of performing one task each
 - Should perform it very efficiently

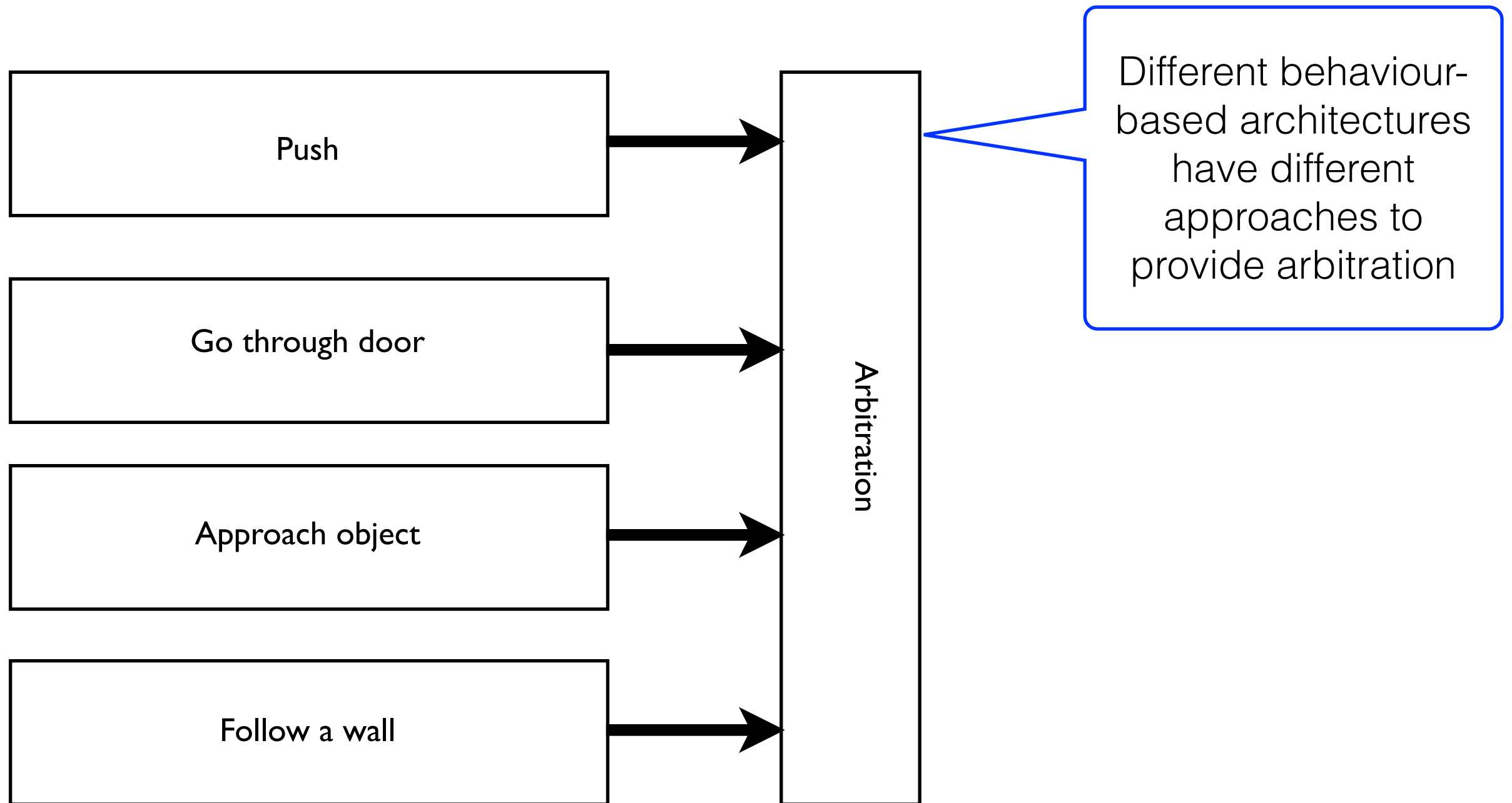
Behaviour-Based Architectures



Behaviour-Based Architectures

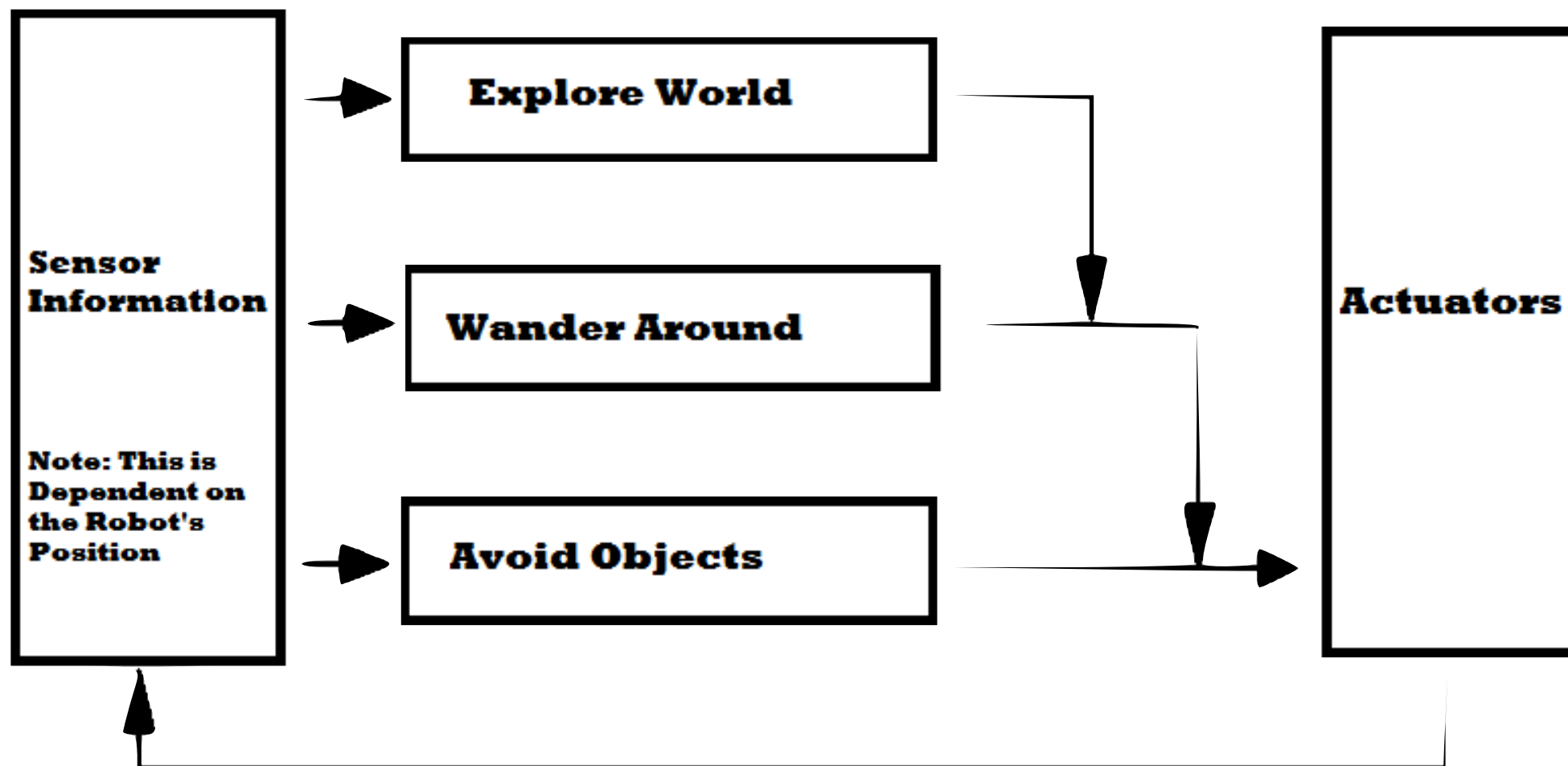
- Behaviours are the basic building block for robotics actions, with an overall *emergent* behaviour obtained from their arbitration
- Behaviours support good software design principles due to modularity
- However, we have some assumptions:
 - We need to be able to decompose the task into appropriate “primitive” behaviours
 - Each “primitive” behaviour requires only simple perceptual and physical talents

Behaviour-Based Architectures

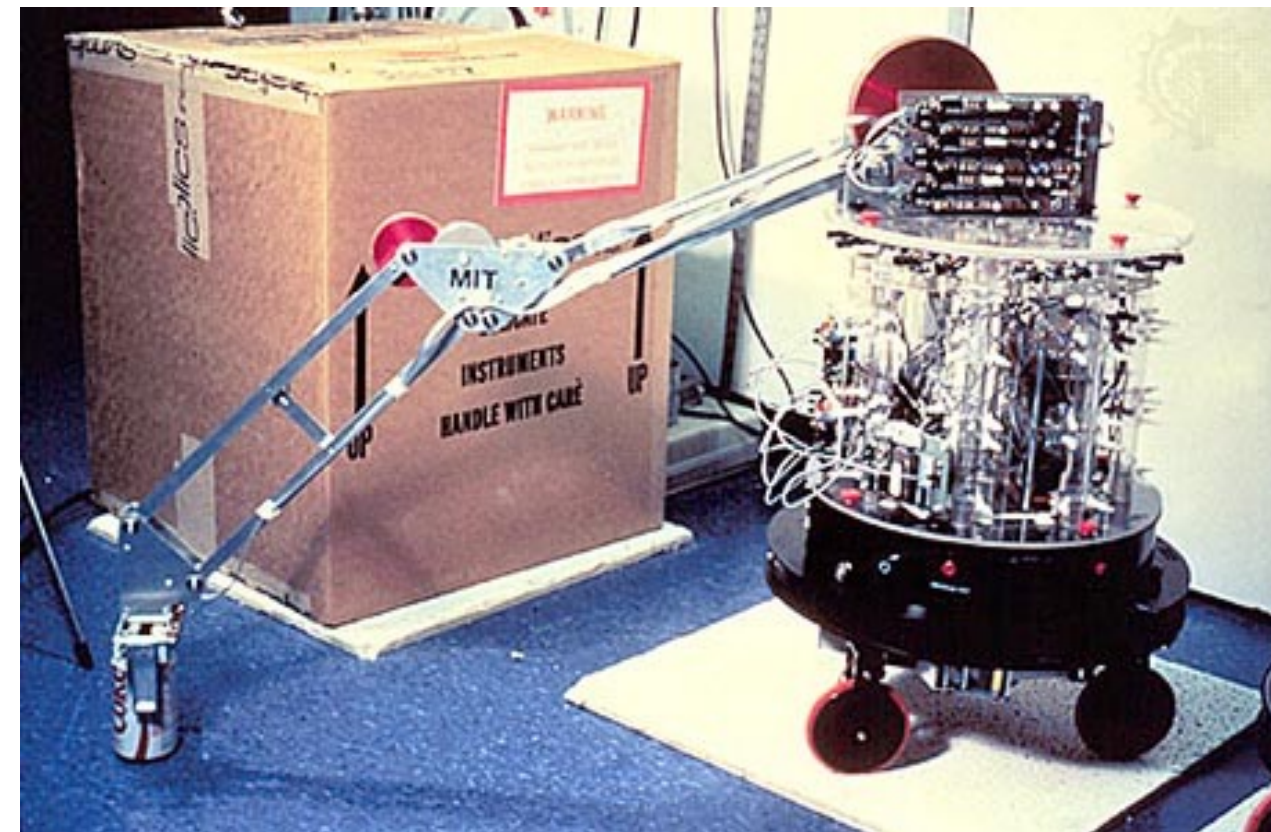
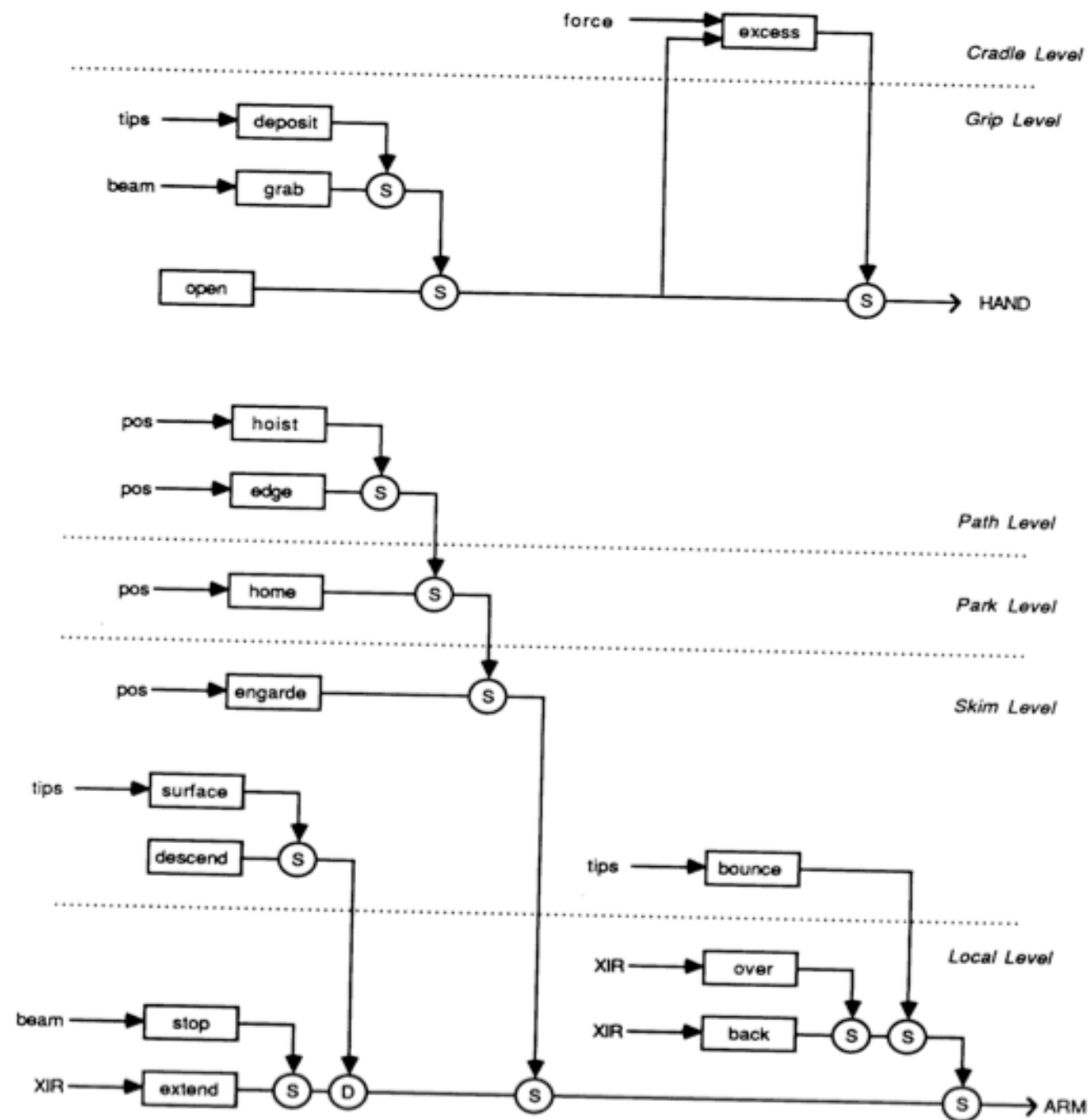


The Subsumption Architecture

- Behaviours are networks of sensing and acting modules (finite state machines)
- Modules are grouped into layers of competence
- Top layers can subsume lower layers



Herbert

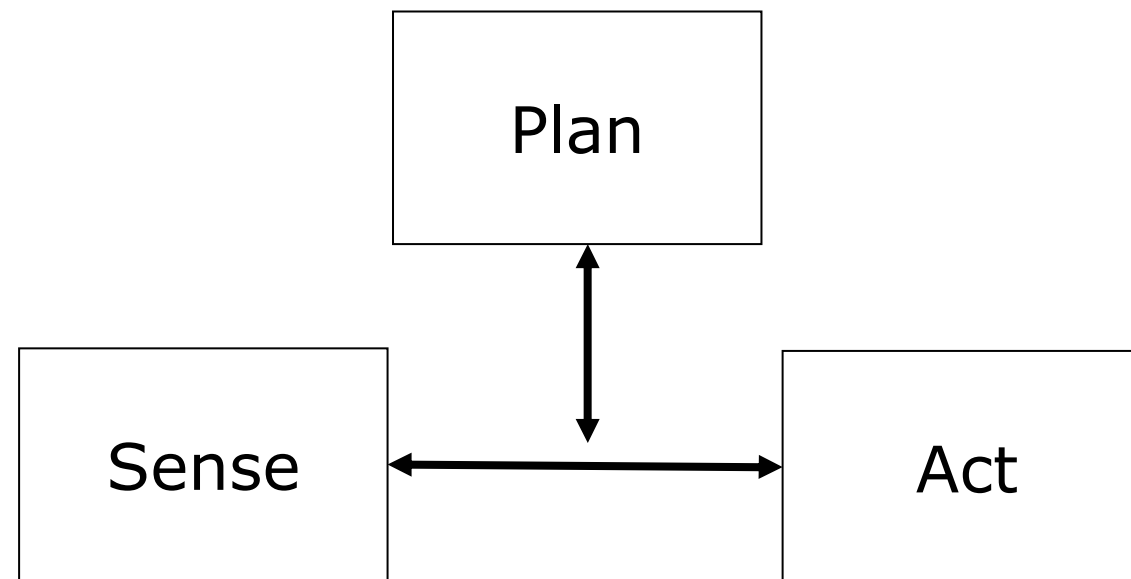


Shortcomings of Behaviour-Based Architectures

- Very task oriented - no flexibility
- No world model means no memory or ability to reason about optimal behaviours
- Arbitrating a large set of behaviours properly is a cumbersome and error-prone task
- Complex tasks *require* arbitration of a large set of behaviours

Hybrid Paradigm

- World model, used for planning
- Closed-loop, reactive control
- Many architectures of today follow this paradigm



Reading

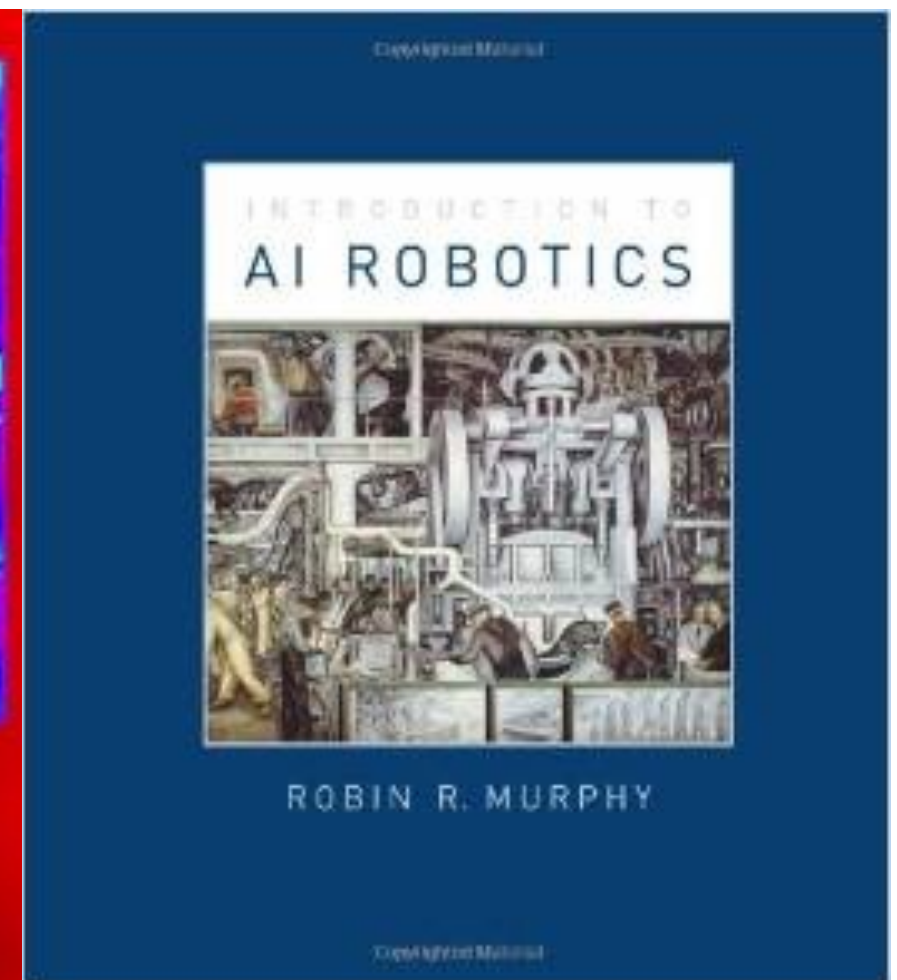
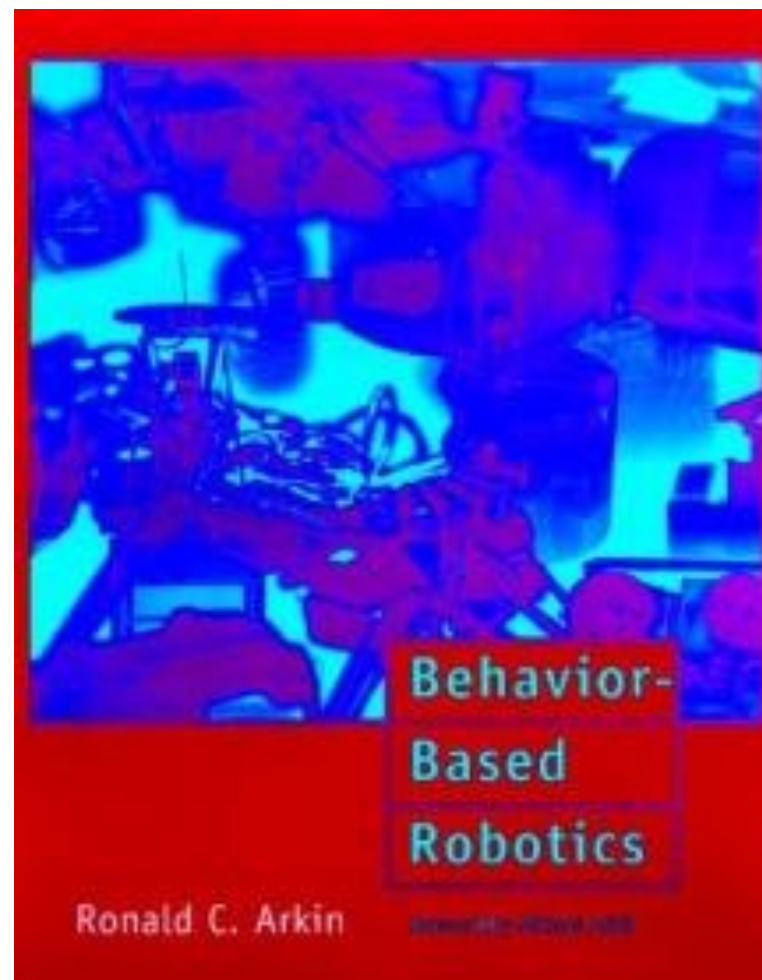
- Deliberative paradigm
 - [Fikes, Nilsson (1971)] STRIPS: a new approach to the application of theorem proving to problem solving. Artificial Intelligence, 2:189-208.
 - <http://www.sri.com/work/timeline-innovation/timeline.php?timeline=computing-digital#!&innovation=shakey-the-robot>

Reading

- Reactive paradigm
 - [R. A. Brooks]
 - (1986), "A Robust Layer Control System for a Mobile Robot", IEEE Journal of Robotics and Automation RA-2, 14-23.
 - (1987), "Planning is just a way of avoiding figuring out what to do next", Technical report, MIT Artificial Intelligence Laboratory.
 - (1991), "Intelligence Without Representation", Artificial Intelligence 47 (1991) 139-15

Reading

- General bibliography:
 - Behavior-based Robotics [Arkin]
 - Introduction to AI Robotics [Murphy]



The SMACH package

Overview

- Python implementation of robot executive based on hierarchical state machines
- Also provides concurrency
- See <http://wiki.ros.org/smach>

