Agent Architectures and Hierarchical Control

Overview:

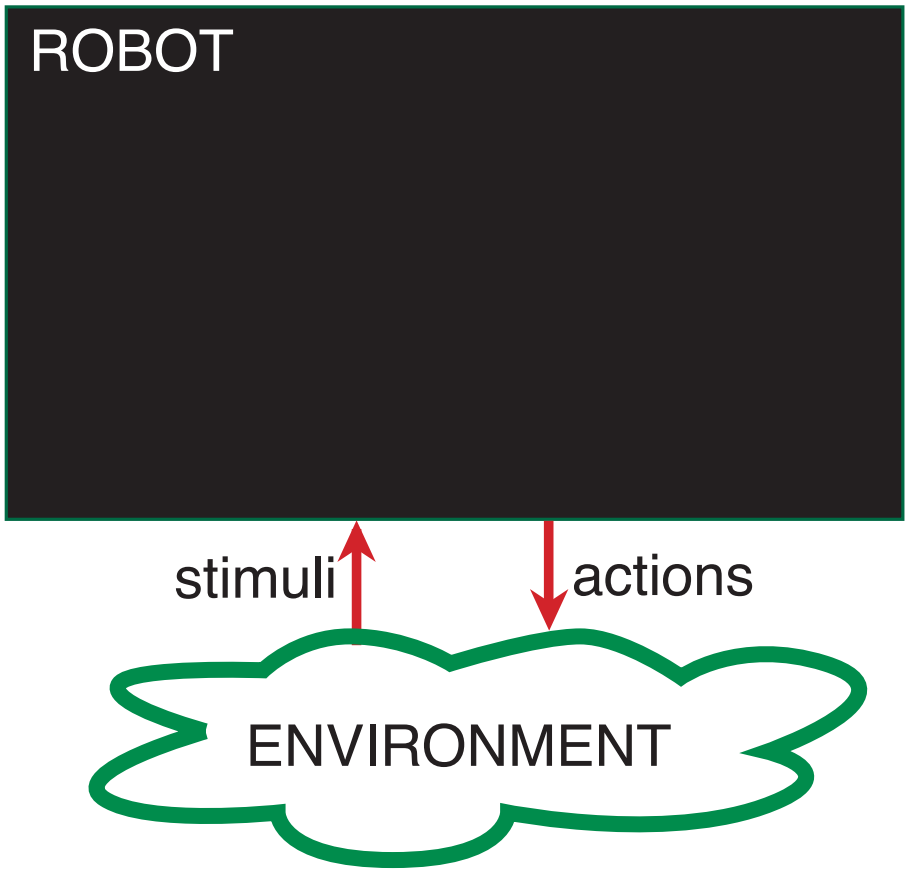
- Agents and Robots
- Agent systems and architectures
- Agent controllers
- Hierarchical controllers

Agents and Robots

A situated agent perceives, reasons, and acts in time in an environment.

- An **agent** is something that acts in the world.
- A **purposive agent** prefers some states of the world to other states, and acts to try to achieve worlds they prefer.
- Agents interact with the environment with a **body**.
- An **embodied** agent has a physical body.
- A **robot** is an artificial purposive embodied agent.

Agent Systems

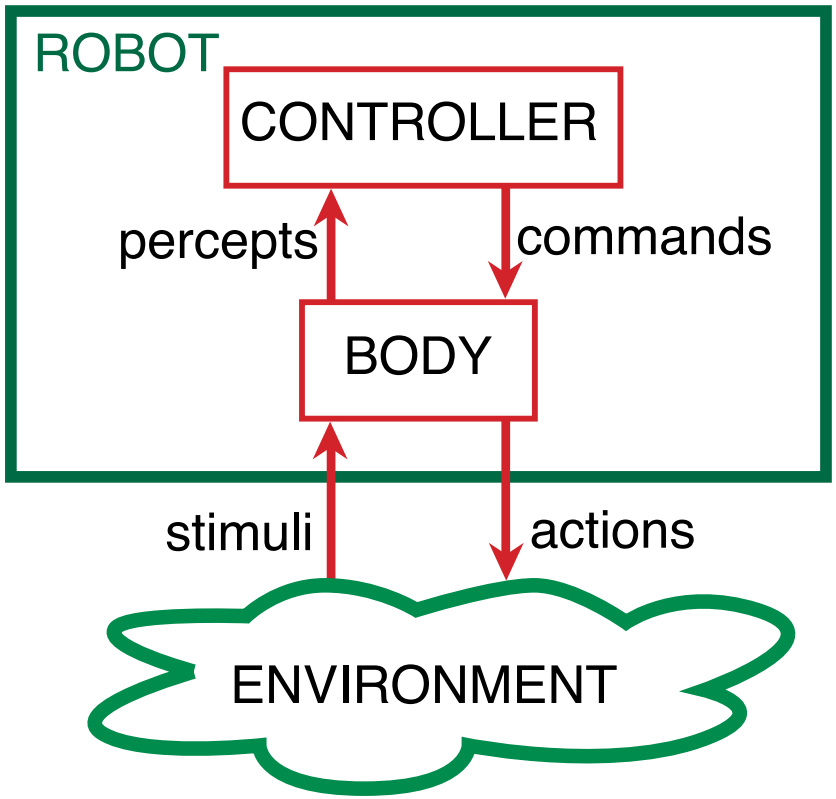


A agent system is made up of a agent and an environment.

- An agent receives stimuli from the environment
- An agent carries out actions in the environment.

Agent System Architecture

An agent is made up of a body and a controller.



- An agent interacts with the environment through its body.
- The body is made up of:
  - sensors that interpret stimuli
  - actuators that carry out actions
- The controller receives percepts from the body.
- The controller sends commands to the body.
- The body can also have reactions that are not controlled.

Implementing a controller

- A controller is the brains of the agent.
- Agents are situated in time, they receive sensory data in time, and do actions in time.
- Controllers have (limited) memory and (limited) computational capabilities.
- The controller specifies the command at every time.
- The command at any time can depend on the current and previous percepts.

Belief States

- An agent doesn't have access to its entire history. It only has access to what it has remembered.
- The memory or belief state of an agent at time t encodes all of the agent's history that it has access to.
- The memory of an agent encapsulates the information about its past that it can use for current and future actions.

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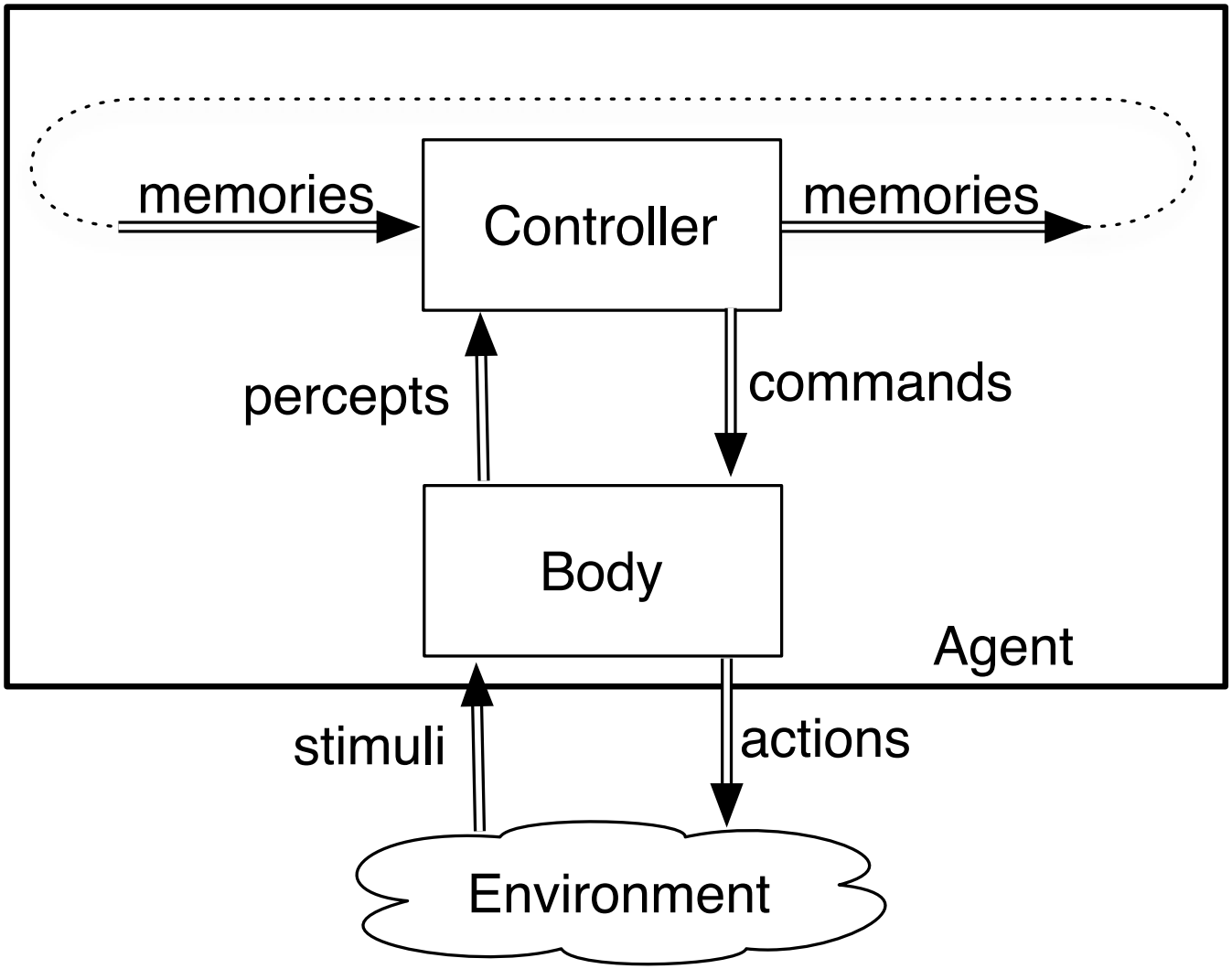
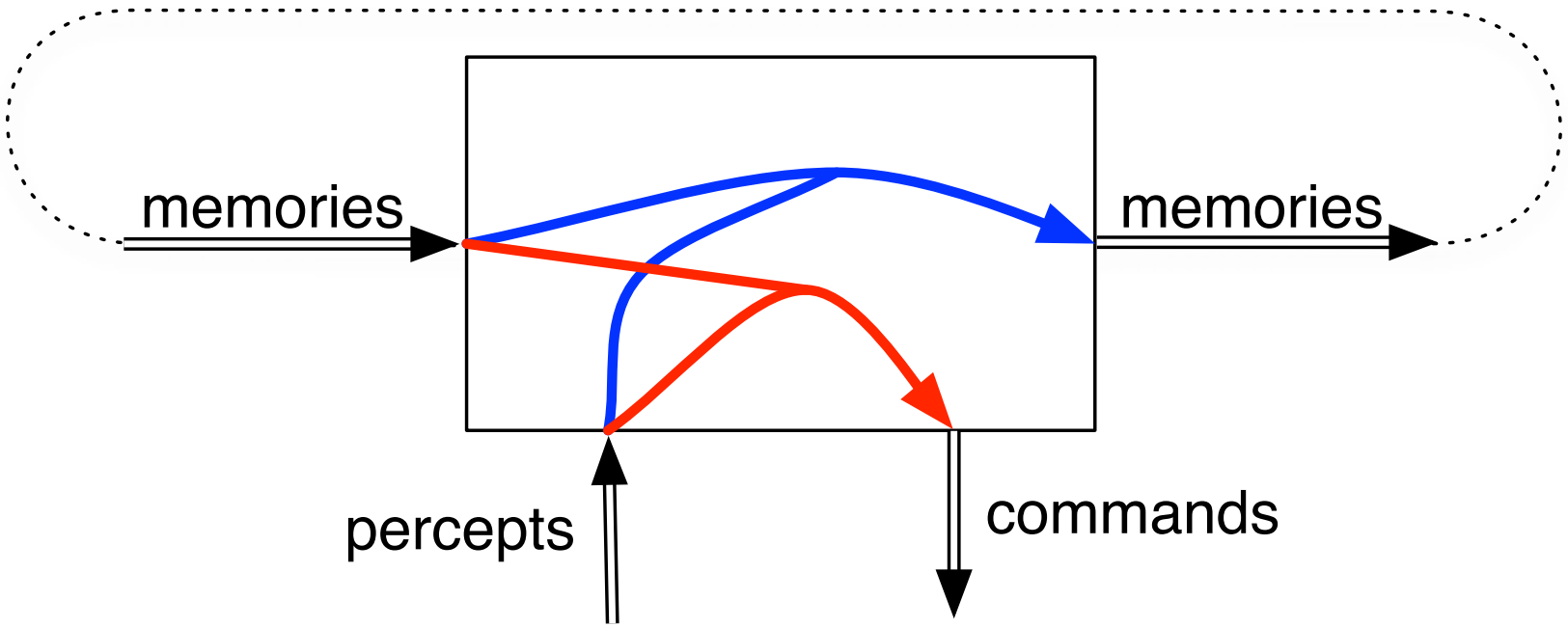
- At every time a controller has to decide on:
  - What should it do?
  - What should it remember?
    (How should it update its memory?)

  — as a function of its percepts and its memory.

Controller


memories
Controller
memories
percepts
commands
Body
Agent
stimuli
actions
Environment

Functions implemented in a controller



For discrete time, a controller implements:

- memory function *remember*(*memory*, *percept*), returns the next memory.
- command function *do*(*memory*, *percept*) returns the command for the agent.

Agent Architectures

You don't need to implement an intelligent agent as:

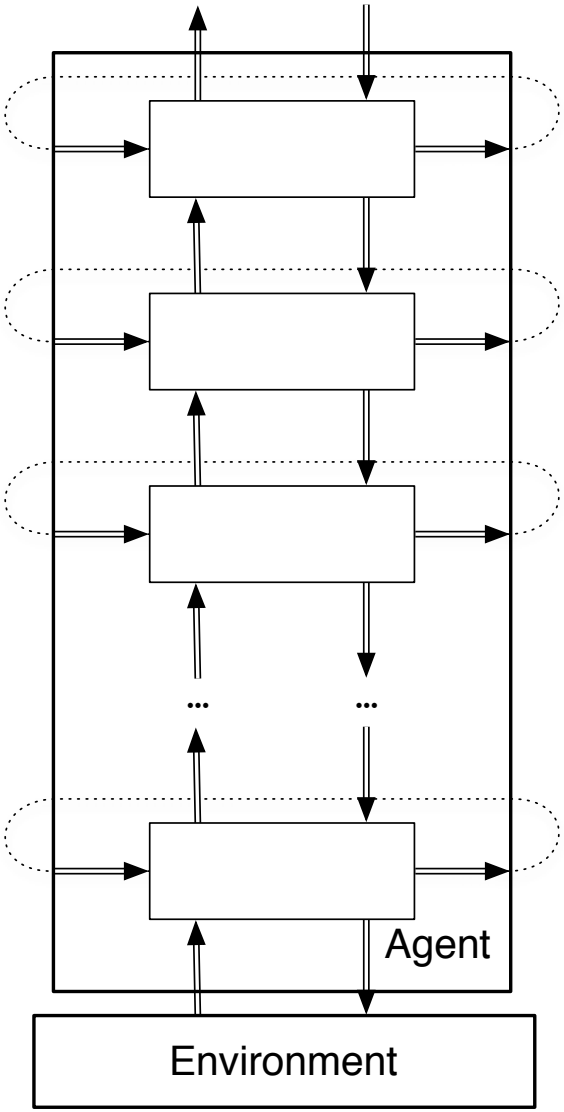
as three independent modules, each feeding into the the next.

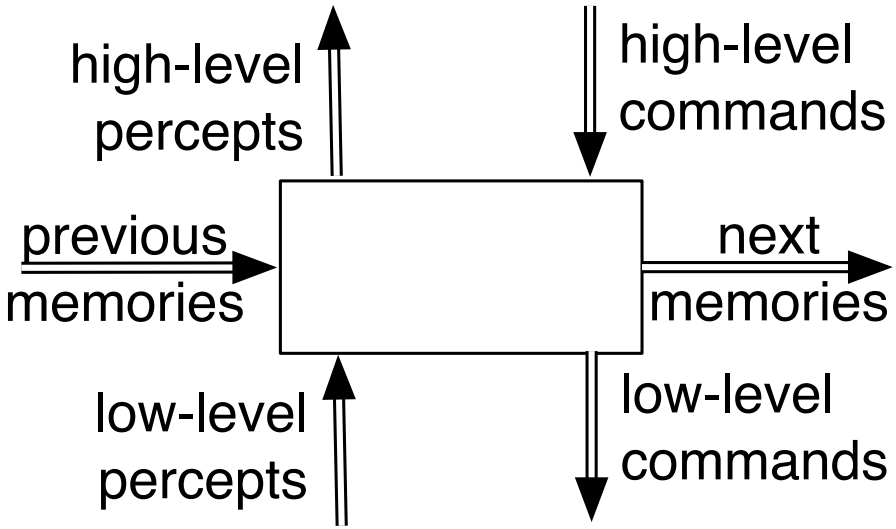
- It's too slow.
- High-level strategic reasoning takes more time than the reaction time needed to avoid obstacles.
- The output of the perception depends on what you will do with it.

Hierarchical Control

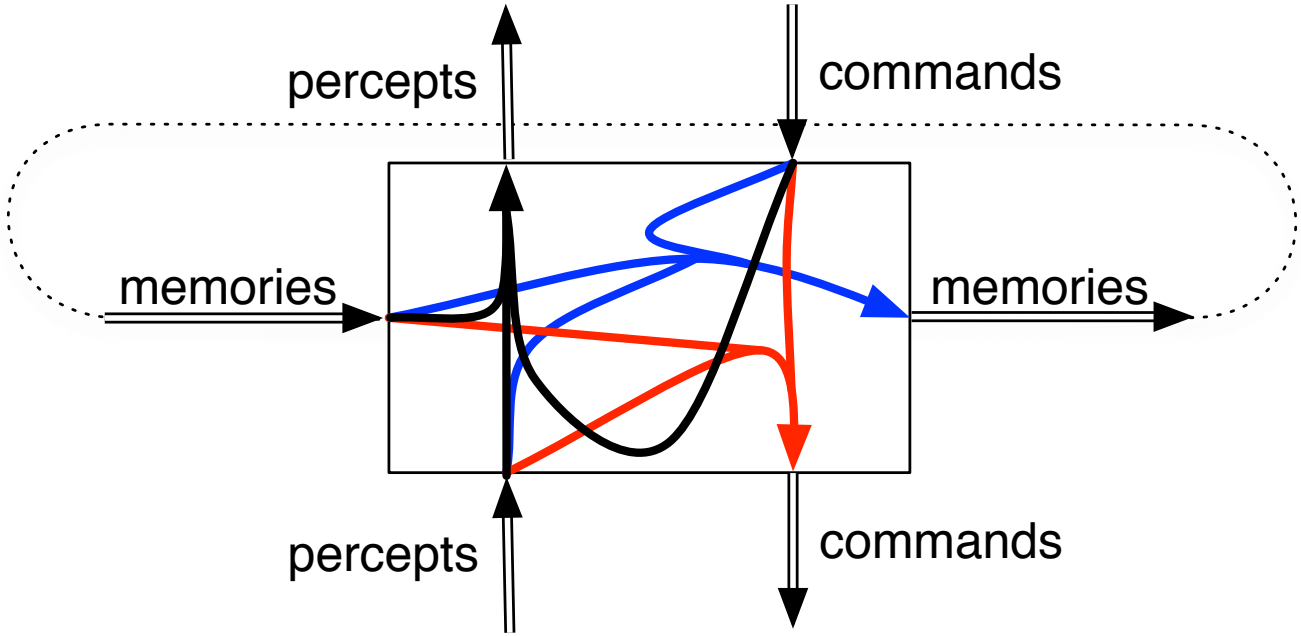
- A better architecture is a hierarchy of controllers.
- Each controller sees the controllers below it as a virtual body from which it gets percepts and sends commands.
- The lower-level controllers can
  - run much faster, and react to the world more quickly
  - deliver a simpler view of the world to the higher-level controllers.

Hierarchical Robotic System Architecture





Functions implemented in a layer

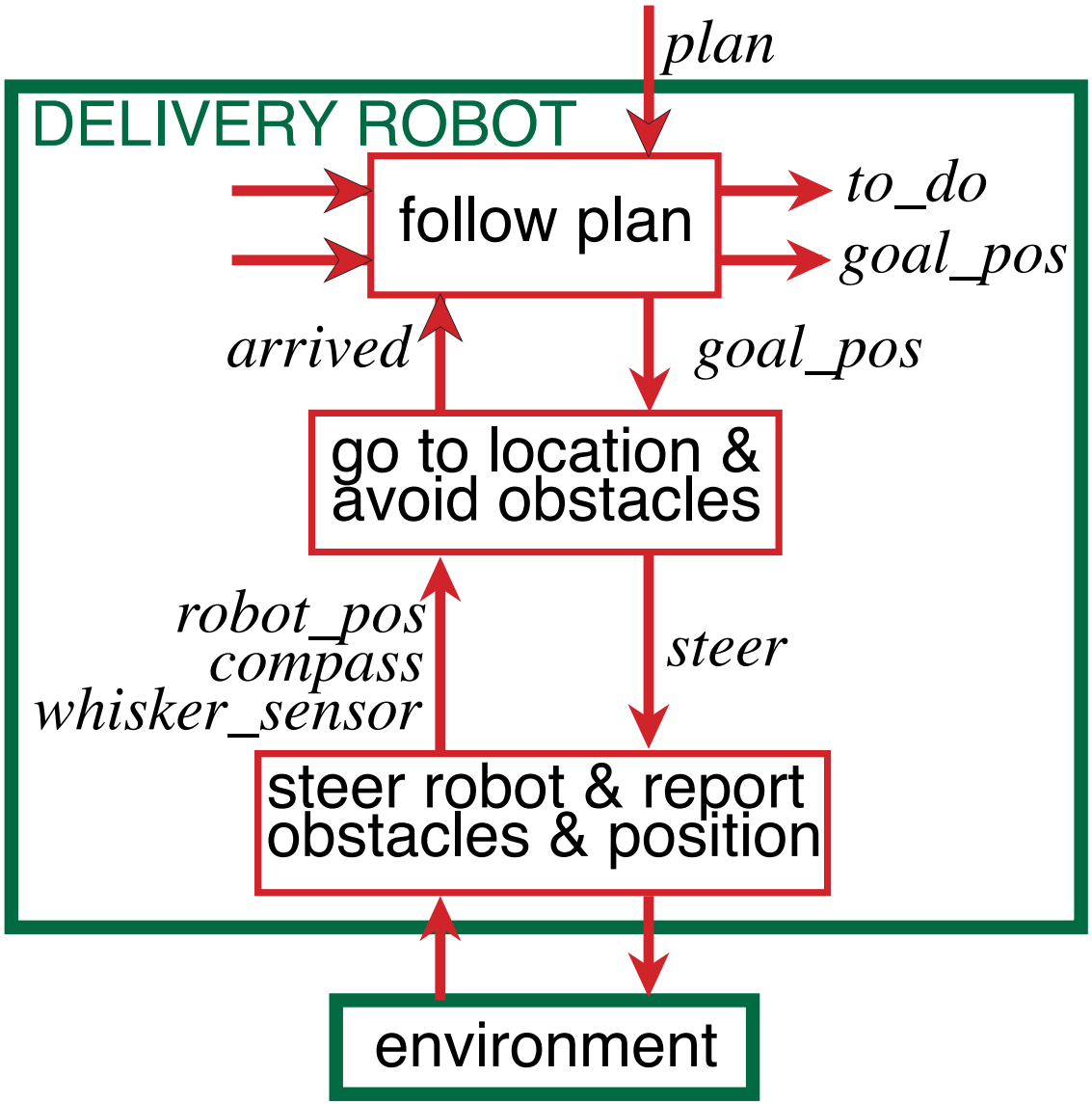


- memory function
  $remember(memory, percept, command)$
- command function
  $do(memory, percept, command)$
- percept function
  $higher\_percept(memory, percept, command)$

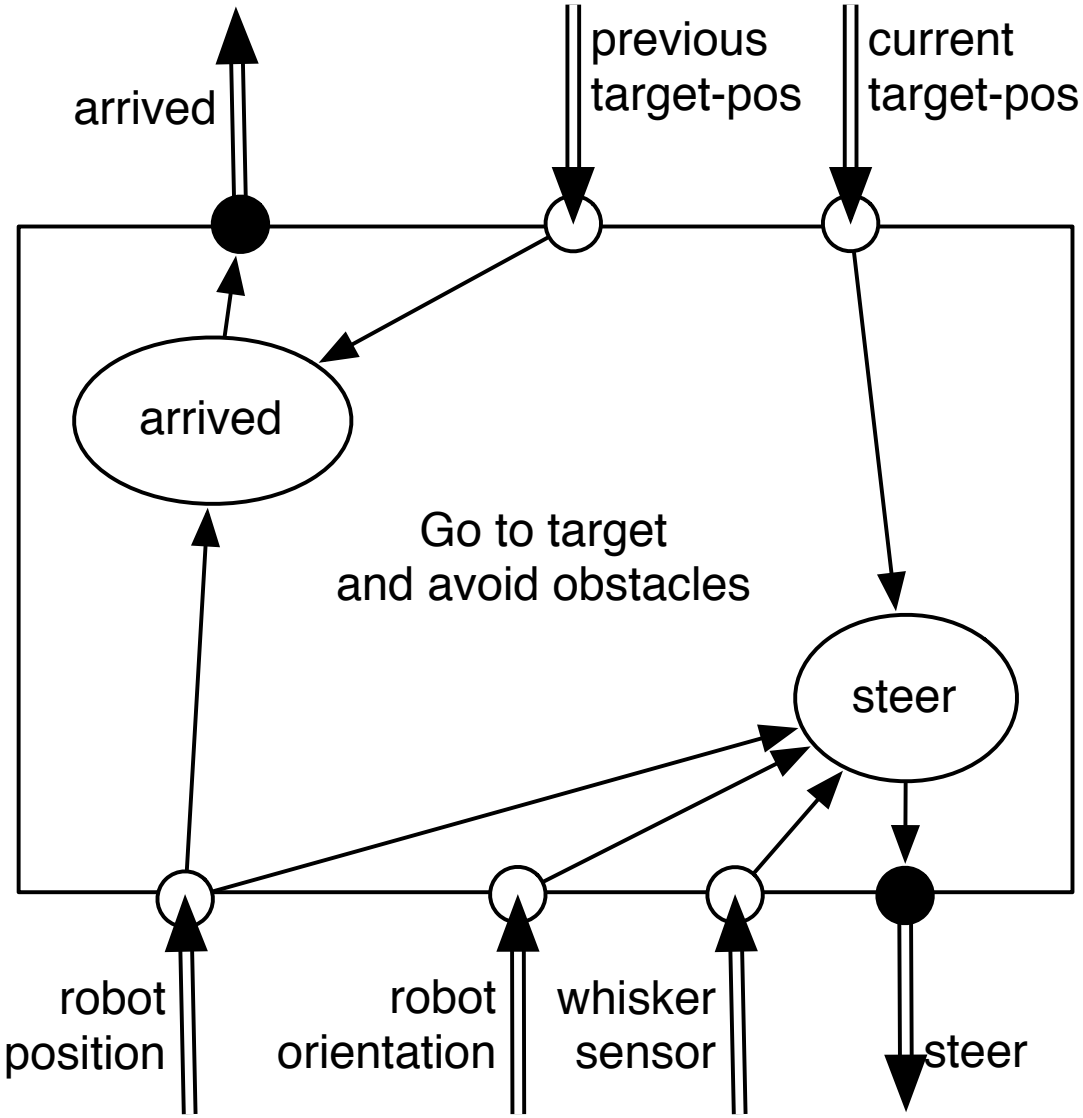
Example: delivery robot

- The robot has three actions: go straight, go right, go left. (Its velocity doesn't change).
- It can be given a plan consisting of sequence of named locations for the robot to go to in turn.
- The robot must avoid obstacles. 障碍物
- It has a single whisker sensor pointing forward and to the right. The robot can detect if the whisker hits an object. The robot knows where it is.
- The obstacles and locations can be moved dynamically. Obstacles and new locations can be created dynamically.

A Decomposition of the Delivery Robot



Middle Layer



Middle Layer of the Delivery Robot

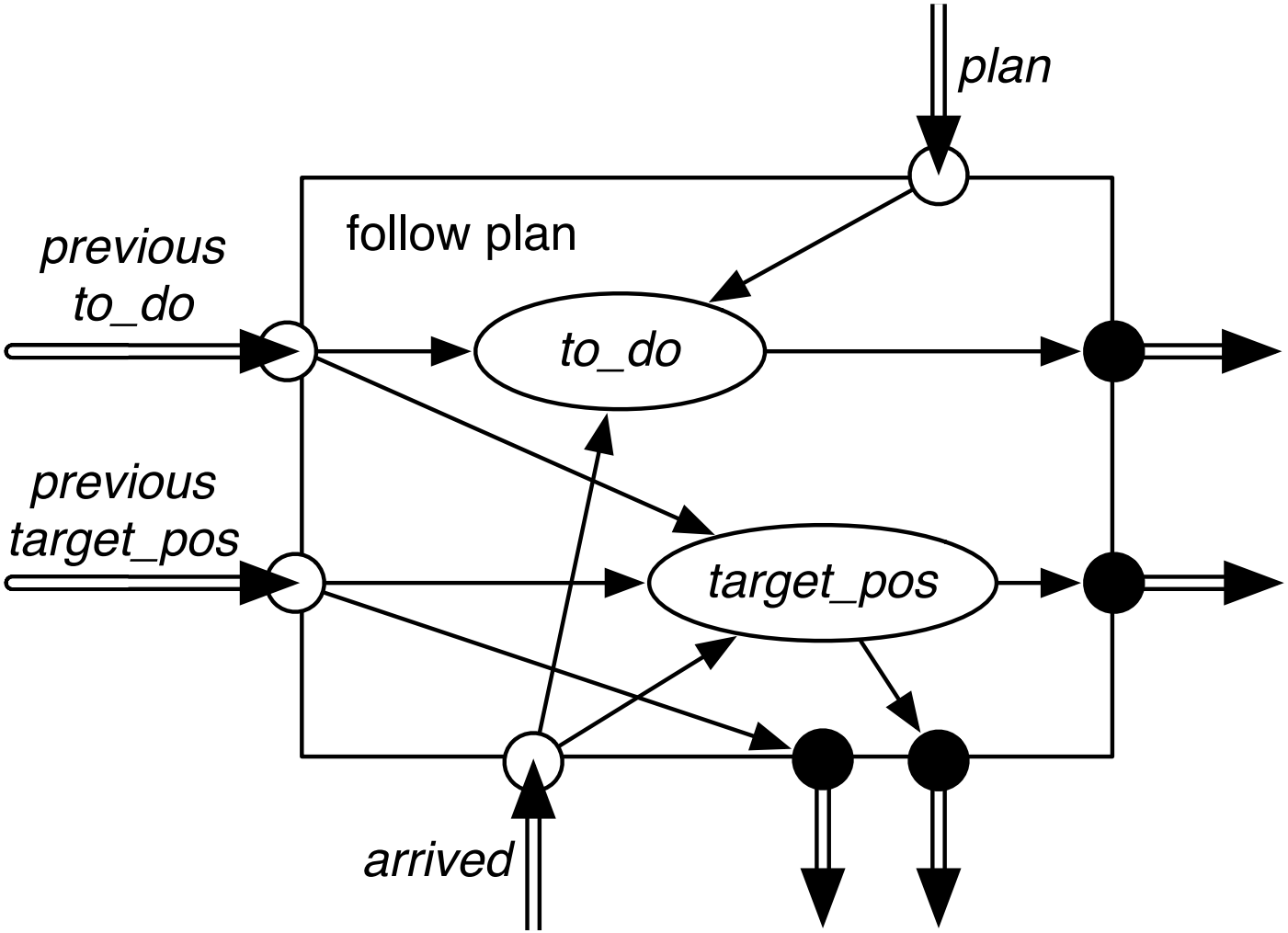
if $whisker\_sensor = on$
    then $steer = left$
else if $straight\_ahead(robot\_pos, robot\_dir, current\_goal\_pos)$
    then $steer = straight$
else if $left\_of(robot\_position, robot\_dir, current\_goal\_pos)$
    then $steer = left$
else $steer = right$

$$arrived = distance(previous\_goal\_pos, robot\_pos) < threshold$$

Top Layer of the Delivery Robot

- The top layer is given a plan which is a sequence of named locations.
- The top layer tells the middle layer the goal position of the current location.
- It has to remember the current goal position and the locations still to visit.
- When the middle layer reports the robot has arrived, the top layer takes the next location from the list of positions to visit, and there is a new goal position.

Top Layer


plan
follow plan
previous
to_do
to_do
previous
target_pos
target_pos
arrived

Code for the top layer

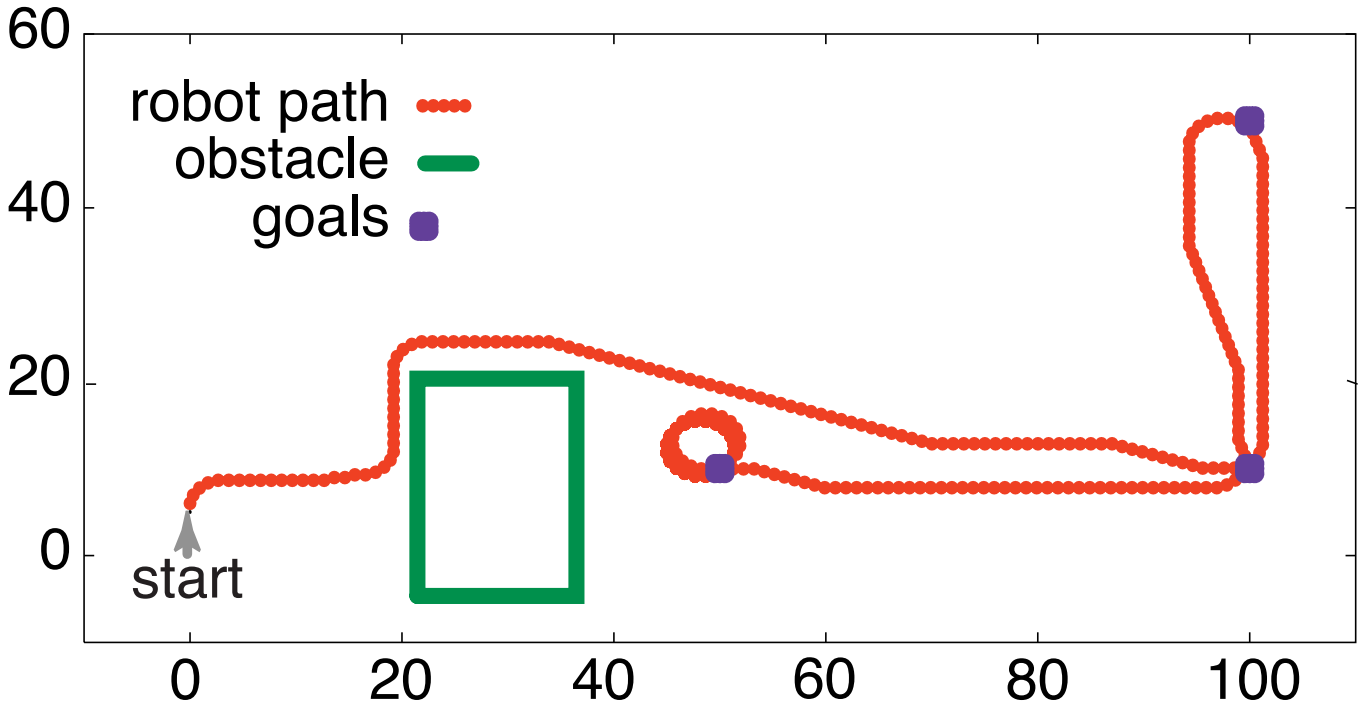
The top layer has two belief state variables:

- *to_do* is the list of all pending locations
- *goal_pos* is the current goal position

if *arrived*
    then $goal\_pos = coordinates(head(to\_do'))$.
if *arrived*
    then $to\_do = tail(to\_do')$.

Here to_do' is the previous value for the *to_do* feature.

Simulation of the Robot



$$to\_do = [goto(o109), goto(storage), goto(o109), goto(o103)]$$

$$arrived = true$$

What should be in an agent's belief state?

- An agent decides what to do based on its belief state and what it observes.
- A purely reactive agent doesn't have a belief state.
  A dead reckoning agent doesn't perceive the world.
  — neither work very well in complicated domains.
- It is often useful for the agent's belief state to be a model of the world (itself and the environment).