

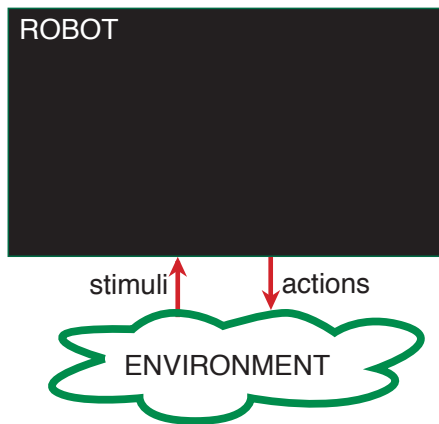
Overview:

- 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.

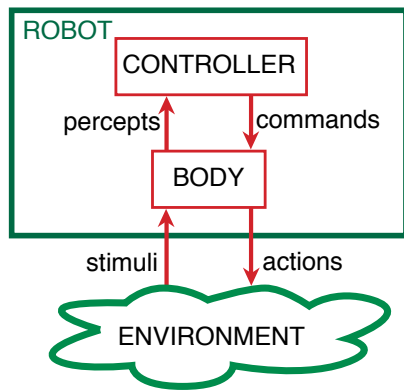


A **agent system** is made up of a **agent** and an **environment**.

- 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.

The Agent Functions

- Let T be the set of time points.
- A **percept trace** is a sequence of all past, present, and future percepts received by the controller.
- A **command trace** is a sequence of all past, present, and future commands output by the controller.
- A **transduction** is a function from percept traces into command traces.
- A transduction is **causal** if the command trace up to time t depends only on percepts up to t .
- A **controller** is an implementation of a causal transduction.
- A causal transduction specifies a function from an agent's history at time t into its action at time t .

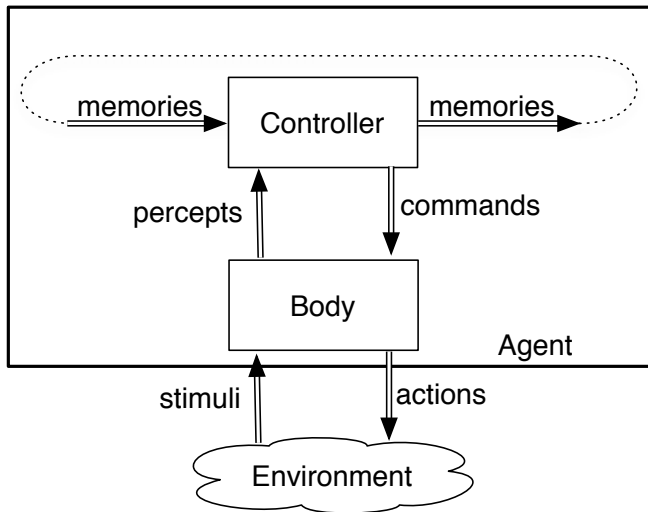
Belief States

- 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.

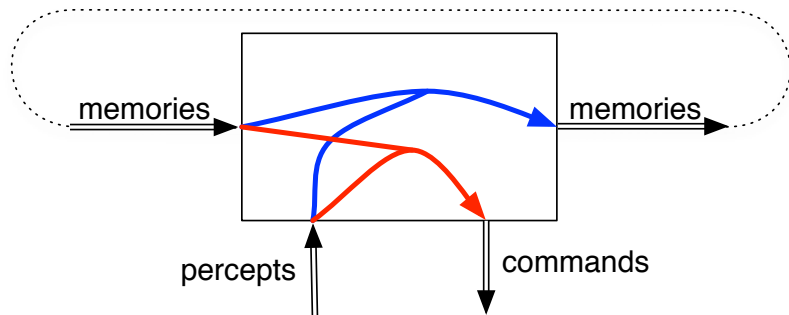
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- At every time a controller has to decide on:
 - ▶ What should it do?
 - ▶ What should it remember?
(How should it update its memory?)— as a function of its percepts and its memory.

Controller



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:



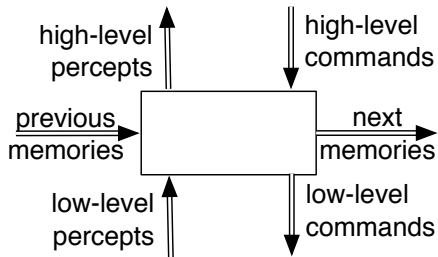
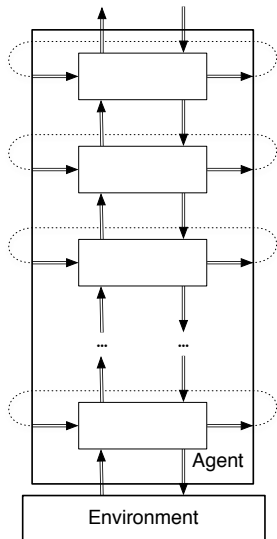
as three independent modules, each feeding into the the next.

- 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.

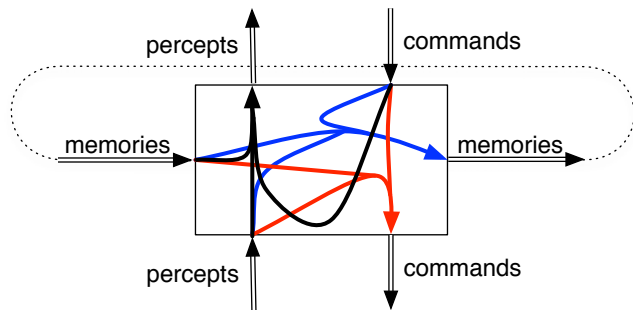
Hierarchical Control

- 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

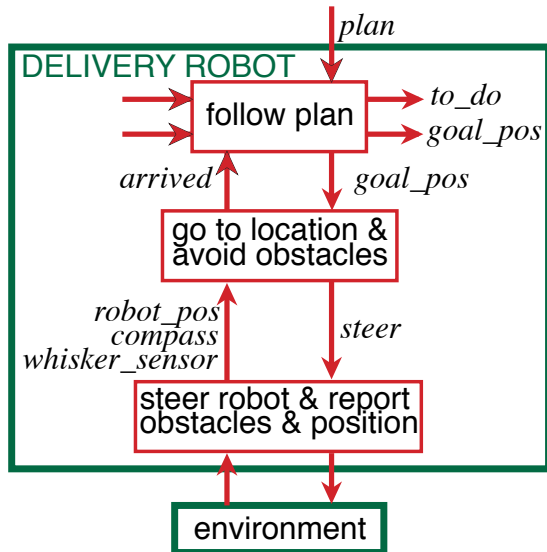


- **memory function**
remember(memory, percept, command)
- **command function**
do(memory, percept, command)
- **percept function**
higher_percept(memory, percept, command)

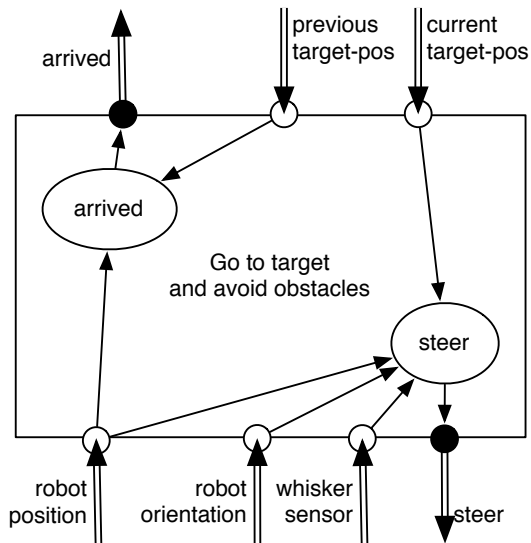
Example: delivery robot

- 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.
- 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

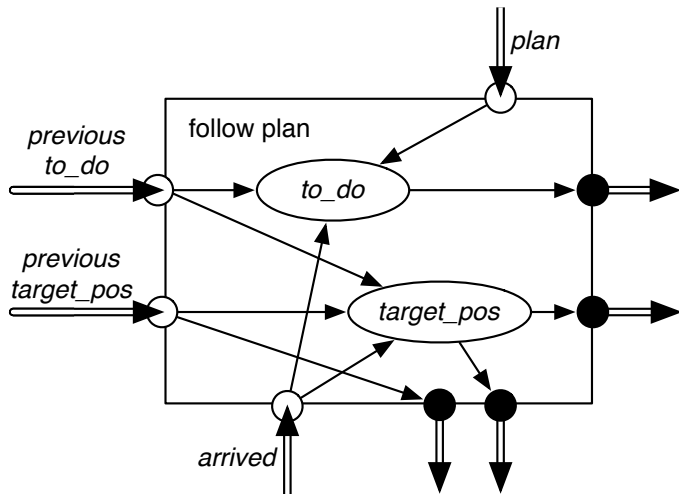
```
if whisker_sensor = on
    then steer = left
else if straight_ahead(robot_pos, robot_dir, current_goal_pos)
    then steer = straight
else if left_of(robot_position, robot_dir, current_goal_pos)
    then steer = left
else steer = right
```

```
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



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*

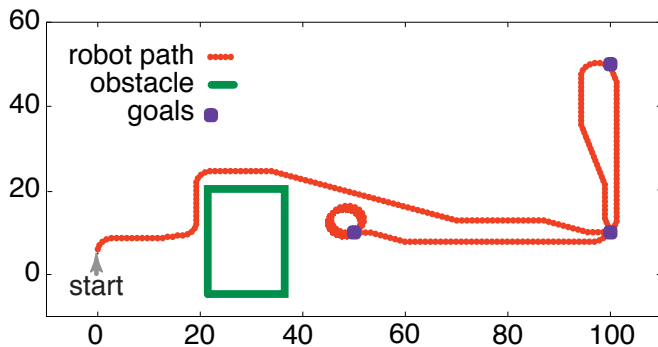
then *goal_pos* = *coordinates(head(to_do'))*.

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).