CS440/ECE448 Lecture 37: Robots

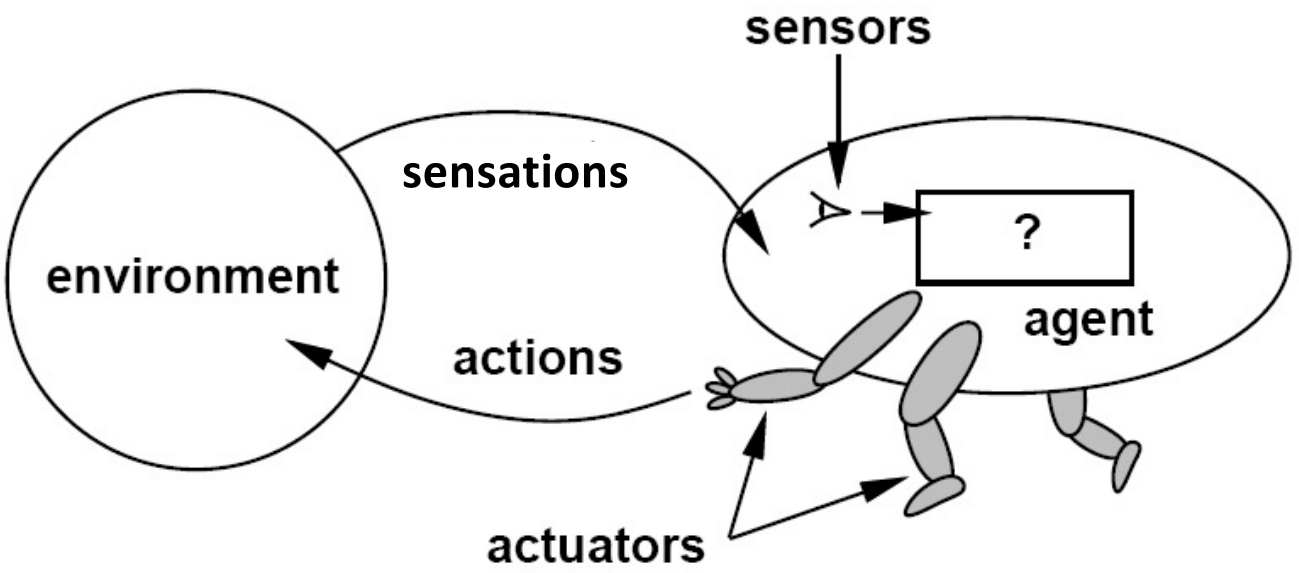
Mark Hasegawa-Johnson, 4/2022

Including slides by Svetlana Lazebnik and Margaret Fleck

CC-BY 4.0: You are free to: copy and redistribute the material in any medium or format, remix, transform, and build upon the material for any purpose, even commercially, if you give appropriate credit.

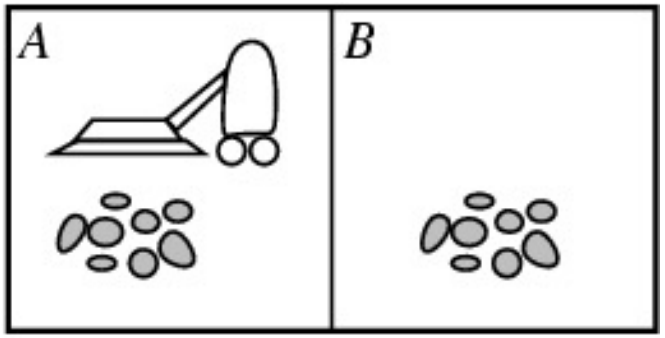
Agents (textbook chapter 2)

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators



Example: Vacuum-Agent

- **Environment = tuple of variables:**
  - Location, status of both rooms,
    e.g., S = { Loc=A, Status=(Dirty, Dirty) }
- **Action = variable drawn from a set:**
  A ∈ { Left, Right, Suck, NoOp }
- **Sensors = tuple of variables:**
  - Location, and status of Current Room Only
    e.g., S = { Loc=A, Status = Dirty }



function Vacuum-Agent([location,status]) returns an action

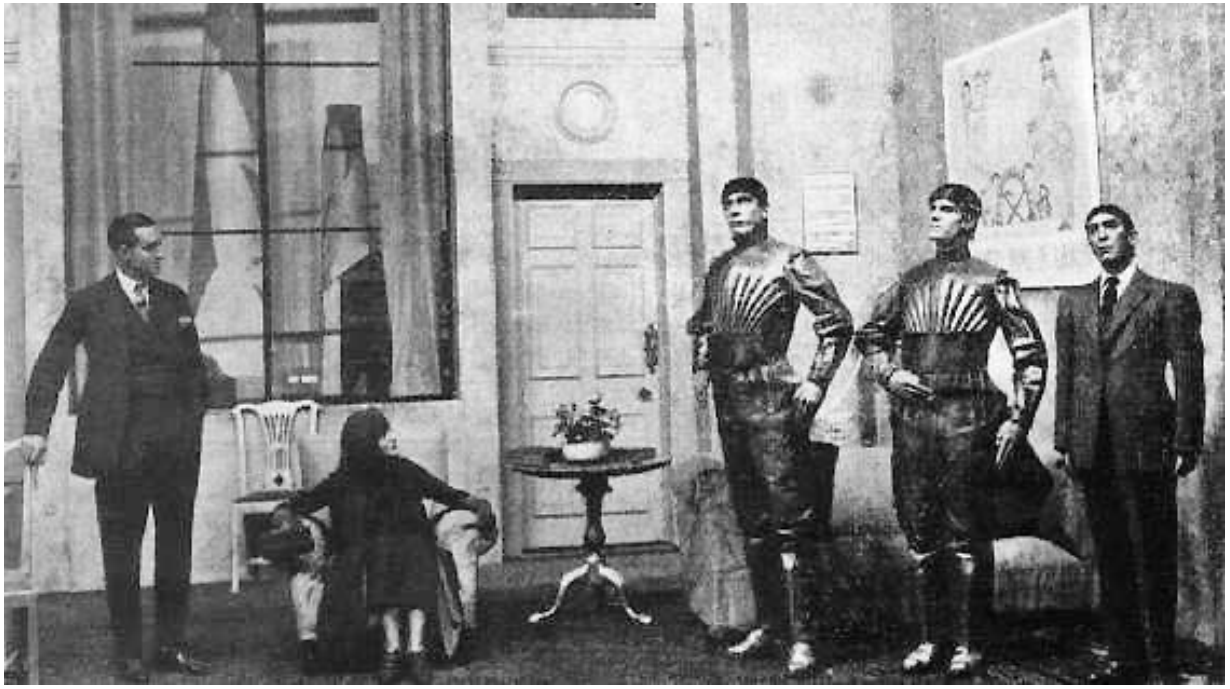
- *if* Loc=A
  - *if* Status=Dirty *then* return Suck
  - *else if I have never visited* B *then return* Right
  - *else return* NoOp
- *else*
  - *if* Status=Dirty *then* return Suck
  - *else if I have never visited* A *then return* Left
  - *else return* NoOp

Specifying the task environment

- **PEAS: Performance, Environment, Actions, Sensors**
- **P:** a function the agent is maximizing (or minimizing)
  - Assumed given
- **E:** a formal representation for *world states*
  - For concreteness, a tuple (var_1=val_1, var_2=val_2, … ,var_n=val_n)
- **A:** actions that change the state according to a *transition model*
  - Given a state and action, what is the successor state (or distribution over successor states)?
- **S:** observations that allow the agent to infer the world state
  - Often come in very different form than the state itself
  - E.g., in tracking, observations may be pixels and state variables 3D coordinates

What is a “Robot”?

A scene from “Rossum’s Universal Robots,” Karel Čapek, 1921
http://www.umich.edu/~engb415/literature/pontee/RUR/RURsmry.html

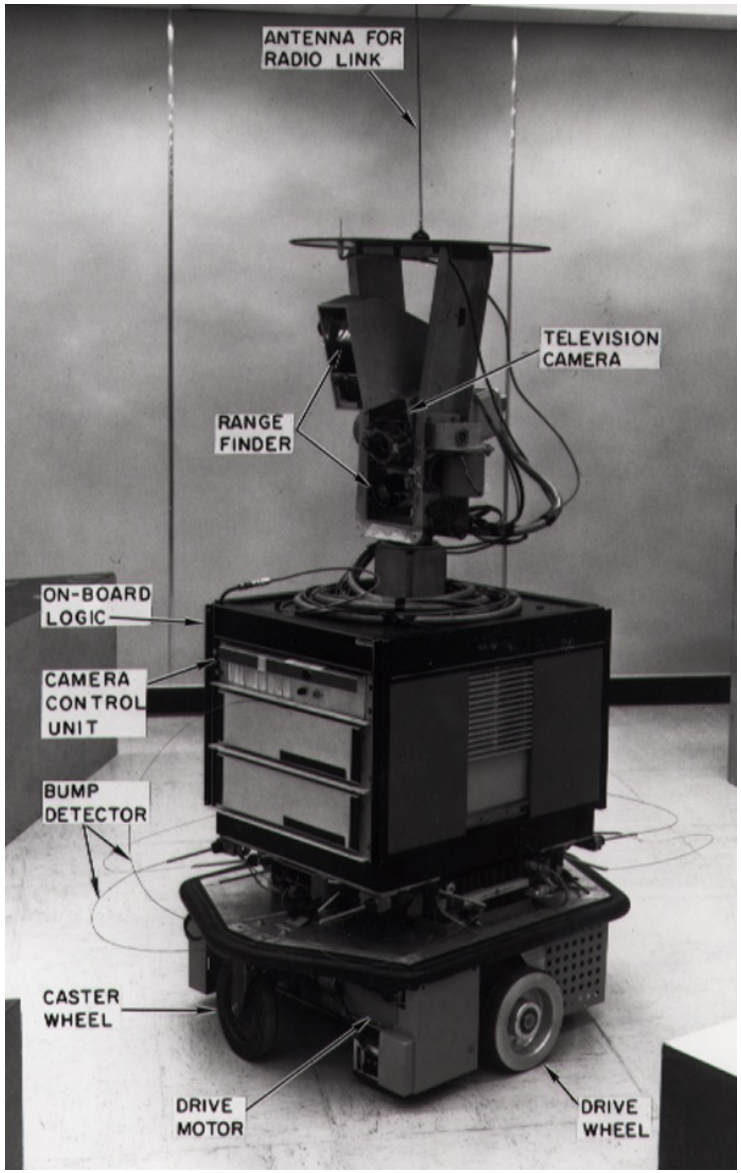


What is a “Robot”?

Example: Shaky the robot, 1972
https://en.wikipedia.org/wiki/Shakey_the_robot

PEAS:

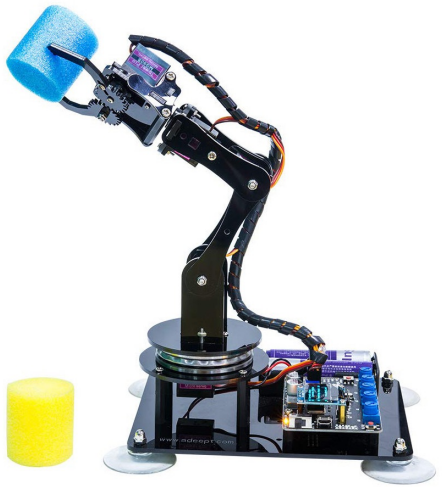
- Performance
  - Antenna for radio link
  - On-board logic
  - Camera control unit
- Environment
- Actuators
  - Caster wheel
  - Drive motor
  - Drive wheel
- Sensors
  - Range finder
  - Television camera
  - Bump detector



Performance

Adeept robot arm for Arduino (from Amazon)

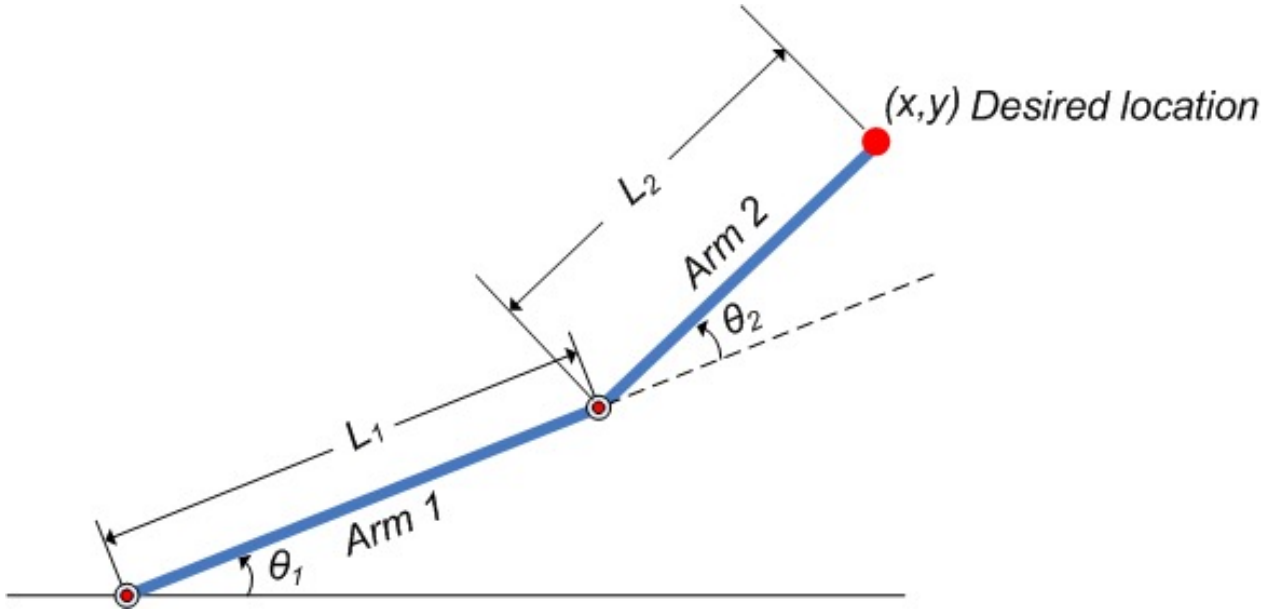
- How does the robot arm decide when it has successfully grasped a cup?
- How does it find the shortest path for its hand?



The Robot Arm Reaching Problem

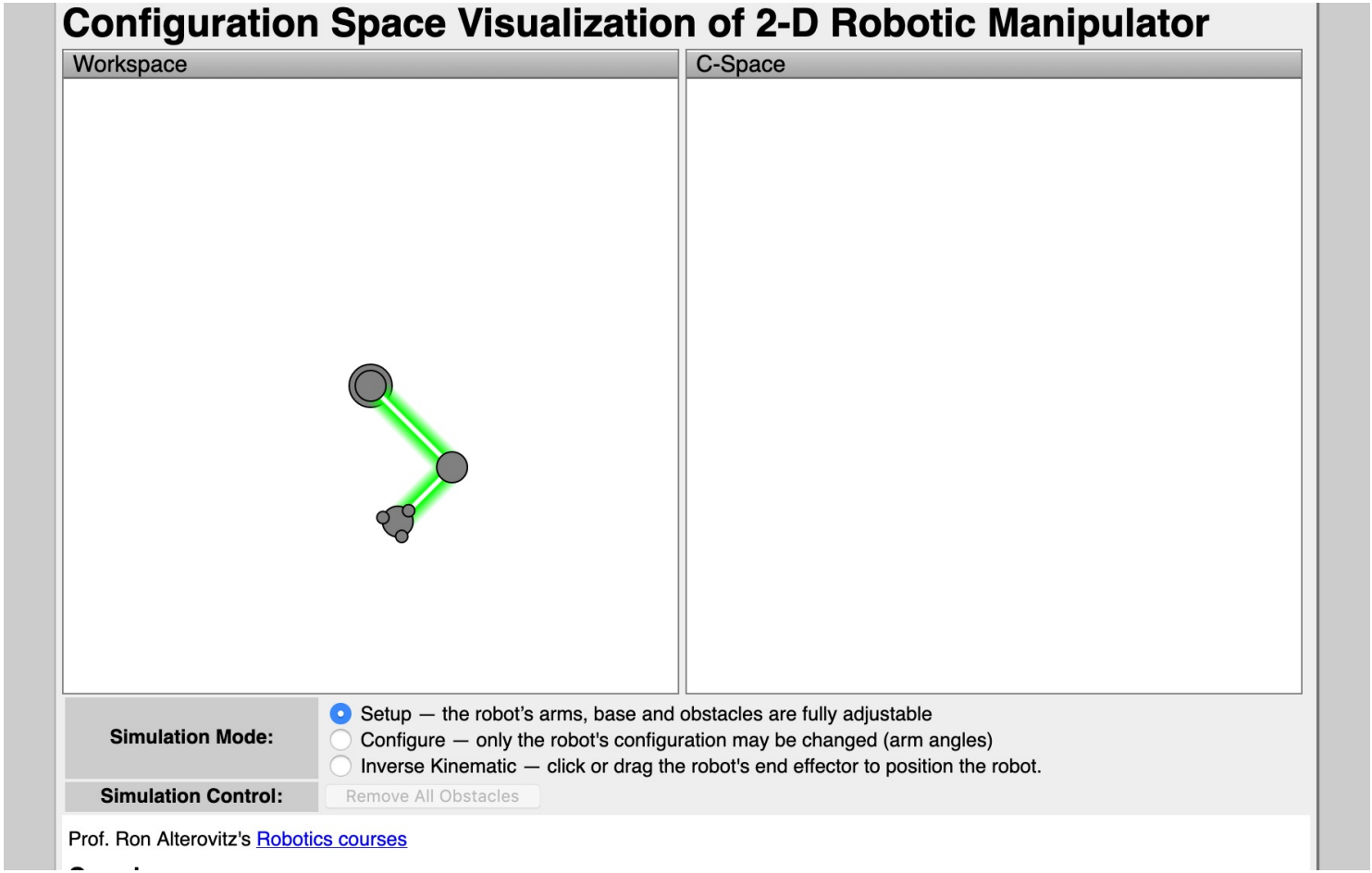
https://www.mathworks.com/help/fuzzy/modeling-inverse-kinematics-in-a-robotic-arm.html

- Our goal is to reach a particular location (x,y)
- But we can't control (x,y) directly! What we actually control is (θ_1, θ_2).



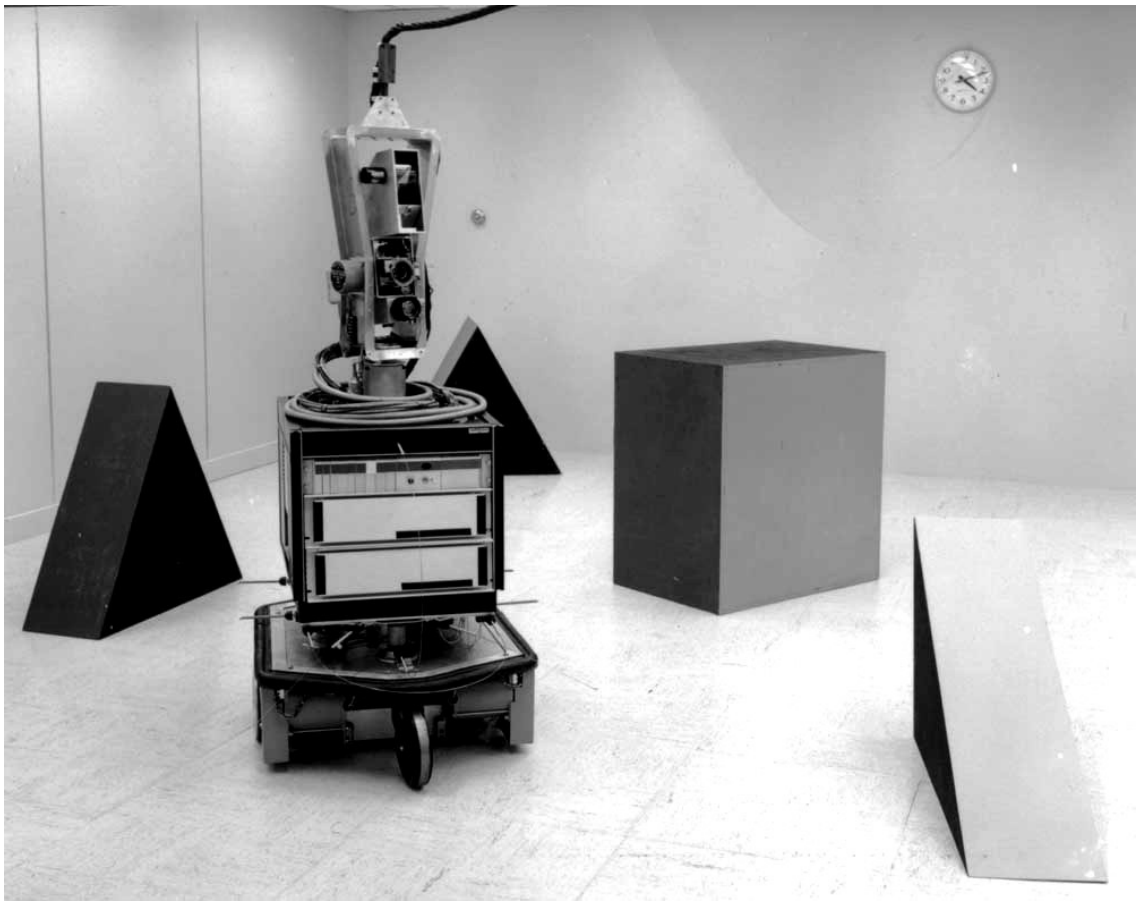
The Robot Arm Reaching Problem

Jeff Ichnowski, University of North Carolina, https://www.cs.unc.edu/~jeffi/c-space/robot.xhtml



The Environment

From https://newatlas.com/shakey-robot-sri-fiftieth-anniversary/37668/#gallery



The Environment

From https://newatlas.com/shakey-robot-sri-fiftieth-anniversary/37668/#gallery

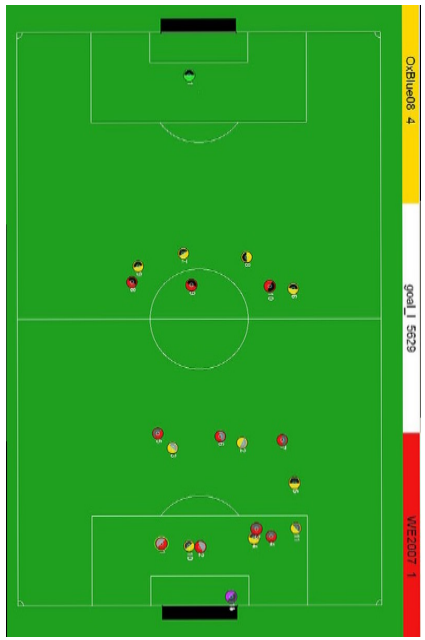
Properties of Environments

(Textbook, Chapter 2)

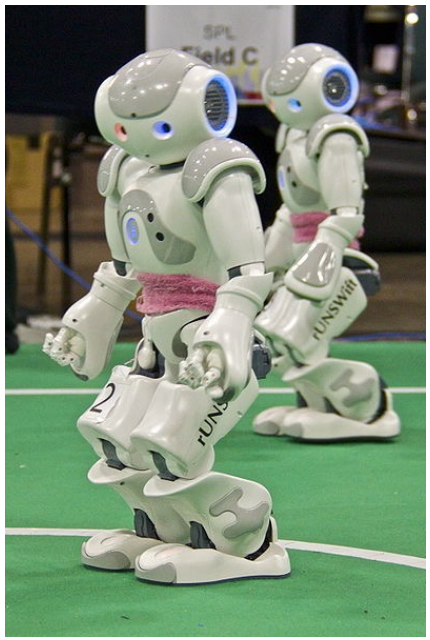
- Fully Observable vs. Partially Observable
- Deterministic vs. Stochastic
- Episodic vs. Sequential
- Static vs. Dynamic
- Discrete vs. Continuous
- Single agent vs. Multi-agent
- Known vs. Unknown

Fully observable vs. partially observable

- Do the agent's sensors give it access to the complete state of the environment?
  - For any given world state, are the values of all the variables known to the agent?



vs.



Source: L. Zettlemoyer

Deterministic vs. stochastic

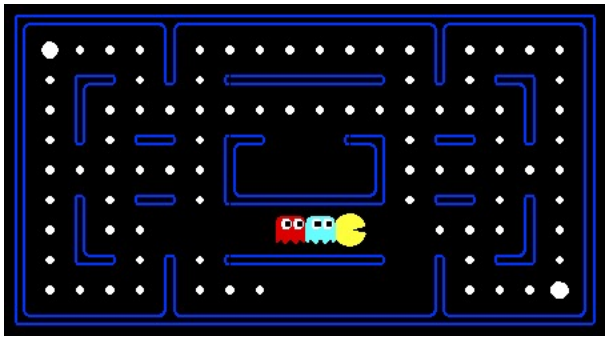
- Is the next state of the environment completely determined by the **current state** and the **agent's action**?
  - Is the transition model **deterministic** (unique successor state given current state and action) or **stochastic** (distribution over successor states given current state and action)?
  - **strategic:** the environment is deterministic except for the actions of other agents

vs.

Episodic vs. sequential

- Is the agent's experience divided into unconnected episodes, or is it a coherent sequence of observations and actions?
  - Does each problem instance involve just one action or a series of actions that change the world state according to the transition model?

vs.



Static vs. dynamic

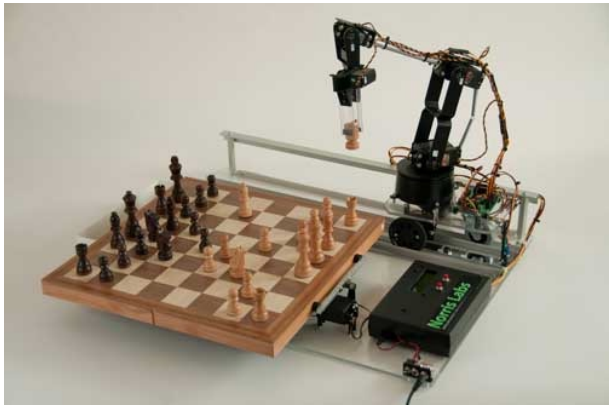
- Is the world changing while the agent is thinking?
  - **Semidynamic:** the environment does not change with the passage of time, but the agent's performance score does

vs.

Discrete vs. continuous

- Does the environment provide a countable (discrete) or uncountably infinite (continuous) number of distinct percepts, actions, and environment states?
  - Are the values of the state variables discrete or continuous?
  - Time can also evolve in a discrete or continuous fashion
  - "Distinct" = different values of utility

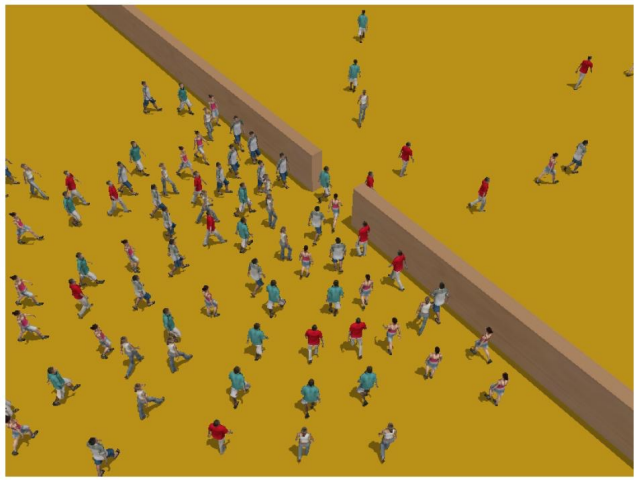
vs.



Single-agent vs. multiagent

- Is an agent operating by itself in the environment?

vs.

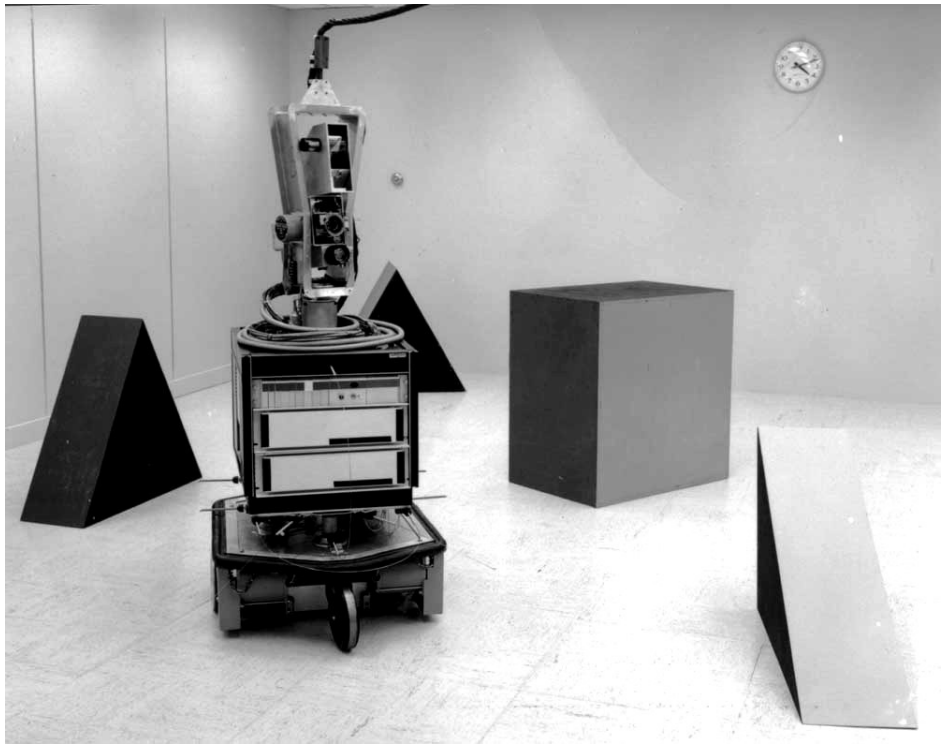


Known vs. unknown

- Are the rules of the environment (transition model and rewards associated with states) known to the agent?
  - Strictly speaking, not a property of the environment, but of the agent's state of knowledge

vs.

Types of Environments



Shakey's environment is:

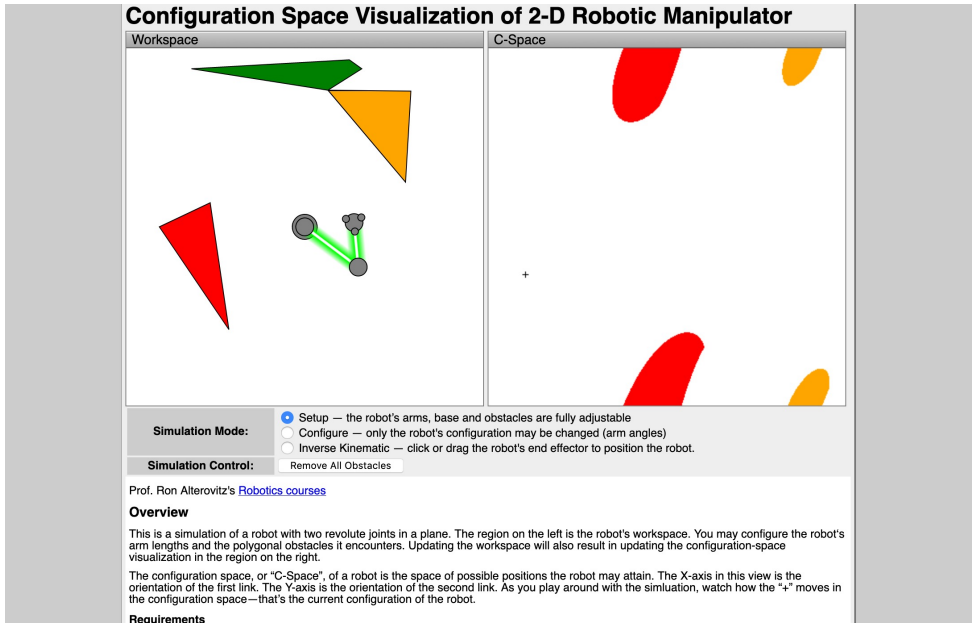
- Partially observable (not Fully)
- Deterministic (not Stochastic)
- Sequential (not Episodic)
- Static (not Dynamic)
- Continuous (not Discrete)
- Single-agent (not Multi-agent)
- Known (not Unknown)

Types of Environments

Shakey's environment is:

- Partially observable
- Deterministic
- Sequential
- ~~Static~~ Dynamic?
- Continuous
- Single-agent
- Known

Types of Environments

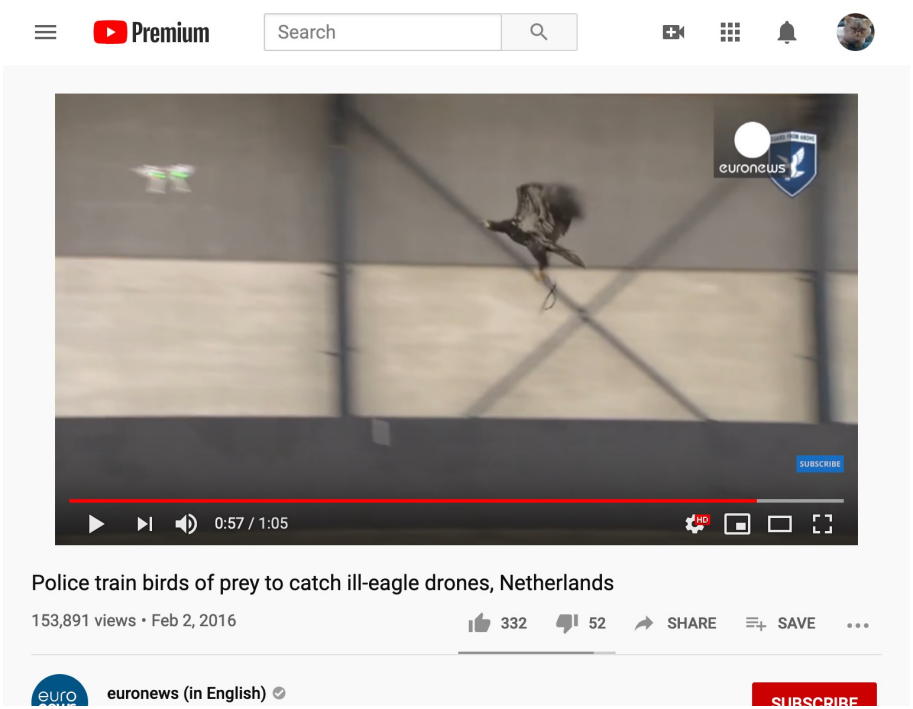


Jeff Ichnowski's environment is:

- ~~Partially~~ Fully observable
- Deterministic
- Sequential
- Static
- Continuous
- Single-agent
- Known

Types of Environments

Euronews, https://www.youtube.com/watch?v=b5DEg2qZzkU



The drone's environment is:

- Partially observable
- Deterministic
- Sequential
- ~~Static~~ Dynamic?
- Continuous
- ~~Single~~ Multi-agent
- Known (?)

Conclusions

- A robot, like any other agent, is characterized by its PEAS:
  - Performance
  - Environment
  - Actions
  - Sensors
- Environments are characterized as:
  - Fully Observable vs. Partially Observable
  - Deterministic vs. Stochastic
  - Episodic vs. Sequential
  - Static vs. Dynamic
  - Discrete vs. Continuous
  - Single agent vs. Multi-agent
  - Known vs. Unknown