COMP3411/9814: Artificial Intelligence

Intelligent Agents - Classifying AI Tasks

Lecture Overview

- Agents
- Agents and environments - Examples of AI tasks
- Rationality
- PEAS model of an Agent
- Environment types - Classifying Tasks
- Agents acting in an environment
- Agent Types

Three Definitions of *Agent*

- Agent as actor
  - Acts autonomously in the world to achieve goals
  - Rational – may have beliefs, desires and intentions

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Textbooks combine the first two types, then say AI is about “agents”

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- An entity that perceives its environment through sensors and acts on its environment through effectors
- Example — human agent

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  - sensors – eyes, ears, touch, etc.
  - effectors – hands, legs, etc.
- Example – Delivery Robot

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- Example — human agent
  - sensors – eyes, ears, touch, etc.
- Example – Delivery Robot
  - sensors – ultrasonic, infrared range finder, video input, etc.
  - effectors – effectors – motors, manipulators, etc.

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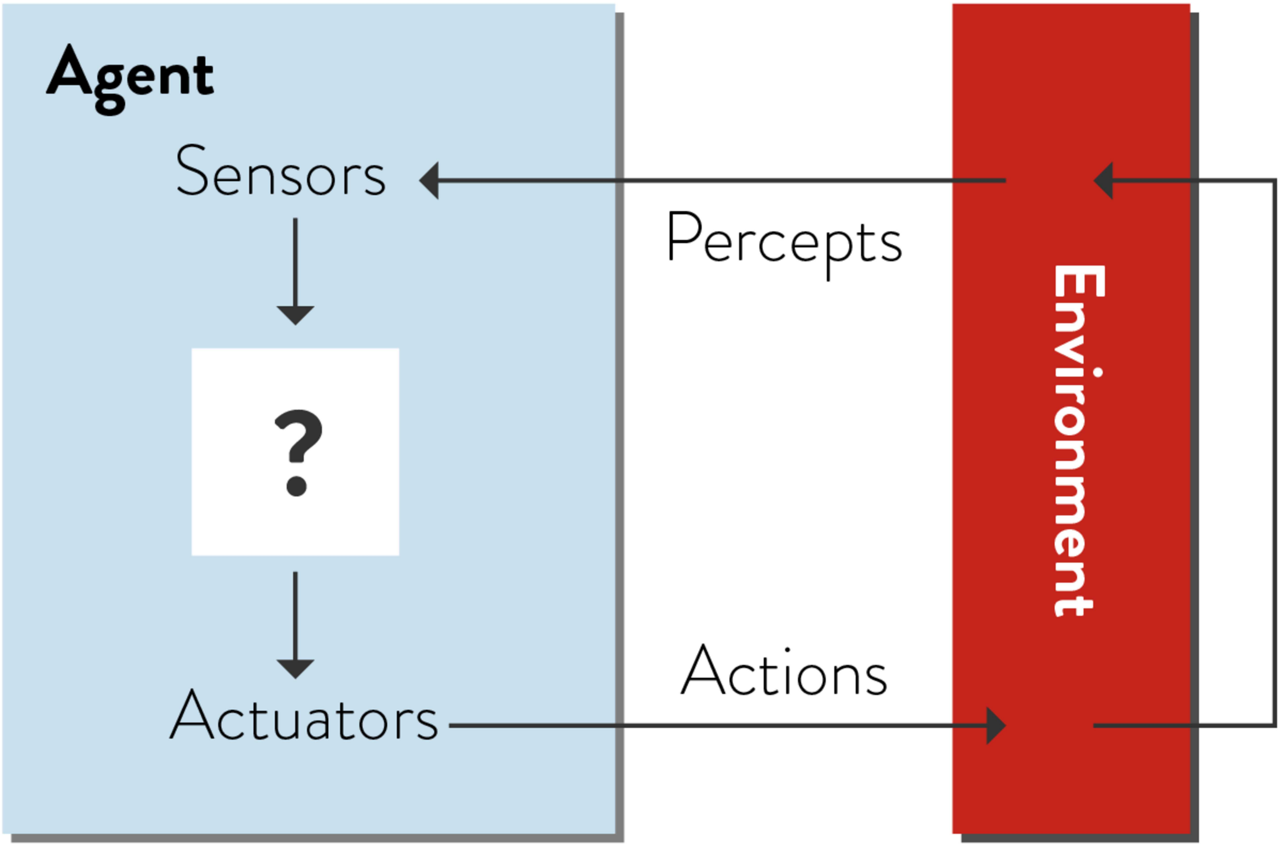
Agents according to Poole and Mackworth : person, robot, dog, worm, lamp, computer program that buys and sells, corporation?

An Agent

- An agent is a system that perceives its environment through sensors and acts upon that environment through effectors.
- A rational agent is an agent whose acts try to maximize some performance measure.

Agent Model



Agents include humans, robots, softbots, thermostats, etc.

Agents as Mappings

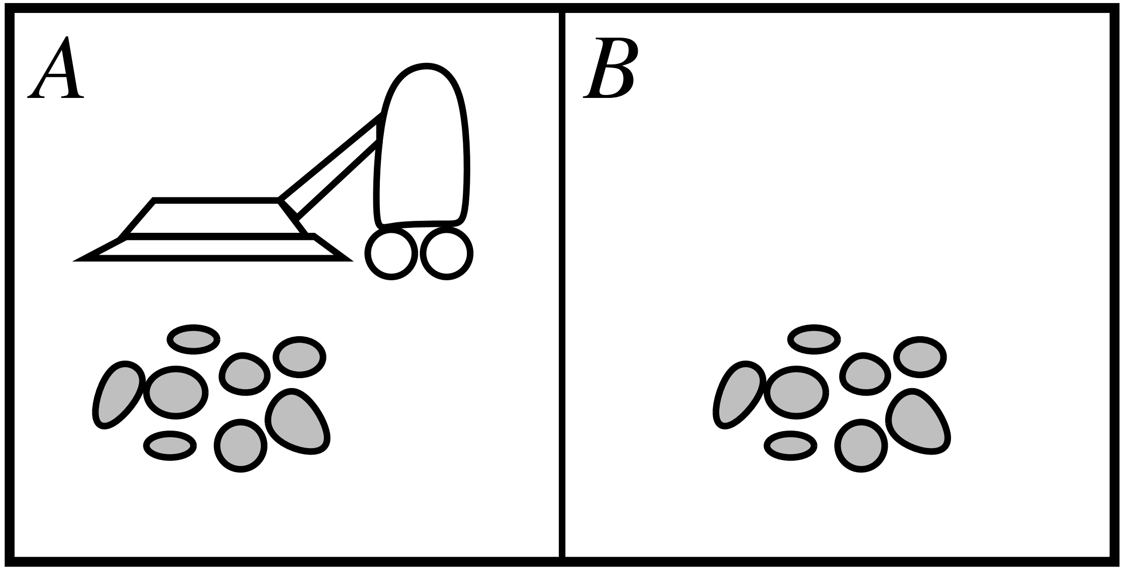
- An agent can be seen as a mapping between percept sequences and actions.

$$f : Percept^{*} \rightarrow Action$$

  - The agent program runs on a physical architecture to produce f

- The less an agents relies on its built-in knowledge, as opposed to the current percept sequence, the more autonomous it is

Vacuum-cleaner world



Percepts: location and contents, e.g., [*A*, *Dirty*]

Actions: *Left*, *Right*, *Suck*, *NoOp*

A vacuum-cleaner agent

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean]$, $[A, Clean]$	$Right$
$[A, Clean]$, $[A, Dirty]$	$Suck$
$\vdots$	$\vdots$

function REFLEX-VACUUM-AGENT([*location*,*status*]) **returns** an action

  if *status* = *Dirty* **then return** *Suck*
  else if *location* = *A* **then return** *Right*
  else if *location* = *B* **then return** *Left*

What is the right function?
Can it be implemented in a small agent program?

Agents in the environment

- Before we design an agent program, we must have a pretty good idea of the possible percepts and actions, what goals or performance measure the agent is supposed to achieve, and what sort of environment it will operate in.
  - These come in a wide variety.
- There a few basic elements for a selection of agent types.

Agents in the environment

- Before we design an agent program, we must have a pretty good idea of the possible percepts and actions, what goals or performance measure the agent is supposed to achieve, and what sort of environment it will operate in.
  - These come in a wide variety.
- There a few basic elements for a selection of agent types.
- For example, we can use PAGE (Percepts, Actions, Goals, Environment) description
  - Note that the goals do *not* necessarily have to be represented within the agent; they simply describe the performance measure by which the agent design will be judged.

Examples of Artificial Agents and PAGE description

Agent Type	Percepts	Actions	Goals	Environment
Medical diagnosis system	Symptoms, findings, patient's answers	Questions, tests, treatments	Healthy patient, minimize costs	Patient, hospital
Satellite image analysis system	Pixels of varying intensity, color	Print a categorization of scene	Correct categorization	Images from orbiting satellite
Part-picking robot	Pixels of varying intensity	Pick up parts and sort into bins	Place parts in correct bins	Conveyor belt with parts
Refinery controller	Temperature, pressure readings	Open, close valves; adjust temperature	Maximize purity, yield, safety	Refinery
Interactive English tutor	Typed words	Print exercises, suggestions, corrections	Maximize student's score on test	Set of students

Rational Agents

- The rationality of an agent depends on
  - the performance measure defining the agent's degree of success
  - the percept sequence, the sequence of all the things perceived by the agent
  - the agent's knowledge of the environment
  - the actions that the agent can perform

For each possible percept sequence, an ideal rational agent does whatever possible to maximize its performance, based on the percept sequence and its built-in knowledge.

Rationality

- What is the right function?
- Can it be implemented in a small agent program?
- Fixed performance measure evaluates the environment sequence
  - one point per square cleaned up in time T?
  - one point per clean square per time step, minus one per move?
  - penalize for > k dirty squares?

Rationality

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Rational $\neq$ omniscient

– percepts may not supply all relevant information

Rational $\neq$ clairvoyant

– action outcomes may not be as expected

Hence, rational $\neq$ successful

Rational $\Rightarrow$ exploration, learning, autonomy

Agents as functions

- Agents can be evaluated empirically, sometimes analysed mathematically
- Agent is a function from percept sequences to actions
- Ideal rational agent would pick actions which are expected to maximise the performance measure.

Specifying and Classifying Tasks

We want a unified framework that can be used to

- specify
- characterize
- compare
- contrast

different AI tasks.

How to Define a Task

Tasks are the problems to which rational agents are the solutions.

To design a rational agent, we must specify the task environment

We need to specify four things:

- Performance measure
- Environment
- Actuators
- Sensors

Task and PEAS Model

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The PEAS Model (Russell & Norvig 2.3.1)

The PEAS model of an Agent

- Performance measure
  - How can we tell if an agent is doing a good or bad job? What are the qualities of performance that we would like to measure?
- Environment
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- Actuators
  - What are the outputs that enable action upon an environment?
- Sensors
  - What are the inputs that sense and provide data for the agent?

Example: Playing Chess

Performance measure ?

Environment?

Actuators?

Sensors?

Example: Playing Chess

Performance measure: +1 for a Win, + 1/2 for a Draw, 0 for a Loss.
Environment: board, pieces
Actuators: move piece to new square

Sensors: which piece is on which square

Example: Internet shopping agent

Performance measure ?

Environment?

Actuators?

Sensors?

Example: Internet shopping agent

Performance measure ?

price, quality, appropriateness, efficiency

Environment?

current and future WWW sites, vendors, shippers

Actuators?

display to user, follow URL, fill in form

Sensors?

HTML pages and data (text, graphics, scripts)

Example: Automated Taxi

Performance measure:

Environment:

Actuators:

Sensors:

Example: Automated Taxi

Performance measure: safety, reach destination, maximize profits, obey laws, passenger comfort, ...

Environment: city streets, freeways, traffic, pedestrians, weather, customers, ...

Actuators: steer, accelerate, brake, horn, speak/display, ...

Sensors: video, accelerometers, gauges, engine sensors, keyboard, GPS, ...

Robots



DARPA Grand Challenge

DARPA Grand Challenge

Classifying Tasks and Environment Types

Simulated vs. Situated or Embodied

Static vs. Dynamic

Discrete vs. Continuous

Fully Observable vs. Partially Observable

Deterministic vs. Stochastic

Episodic vs. Sequential

Known vs. Unknown

Single-Agent vs. Multi-Agent

Environment Types

Simulated: a separate program is used to simulate an environment, feed percepts to agents, evaluate performance, etc.

Static: environment doesn’t change while the agent is deliberating

Discrete: finite (or countable) number of possible percepts/actions

Fully Observable: percept contains all relevant information about the world

Deterministic: current state of world uniquely determines the next

Episodic: every action by the agent is evaluated independently

Known: the rules of the game, or physics/dynamics of the environment are known to the agent

Single-Agent: only one agent acting in the environment

Environment Types

Chess

Robocup Soccer

Simulated vs. Situated or Embodied

- Chess is Simulated, Robocup is Situated and Embodied

Simulated: a separate program is used to simulate an environment, feed percepts to agents, evaluate performance, etc. Situated: the agent acts directly on the actual environment the agent has a physical body in the world

Embodied: the agent has a physical body in the world

Question: If Chess is played on a physical board with actual pieces, would it become embodied?

Static vs. Dynamic

- Chess is Simulated, Robocup is Situated and Embodied
- Chess is Static, Robocup is Dynamic

Static: the environment does not change while the agent is thinking

Dynamic: the environment may change while the agent is thinking e.g. if the ball is in front of you but you take too long to act, another player may come in and kick it away

Notes:

- 1. In a multi-player game, Static environment will obviously change when the opponent moves, but cannot change once it is "our turn".
- 2. In tournament Chess, the clock will tick down while the player is thinking (thus making it slightly non-static).

Discrete vs. Continuous

- Chess is Simulated, Robocup is Situated and Embodied
- Chess is Static, Robocup is Dynamic
- Chess is Discrete, Robocup is Continuous

Discrete: only a finite (or countable) number of discrete percepts/actions

Continuous: states, percepts or actions can vary continuously

e.g. each piece must be on one square or the other, not half way in between.

Fully Observable vs. Partially Observable

- Chess is Simulated, Robocup is Situated and Embodied
- Chess is Static, Robocup is Dynamic
- Chess is Discrete, Robocup is Continuous
- Chess is Fully Observable, Robocup (Legged) is Partially Observable

Fully Observable: agent percept contains all relevant information about the world

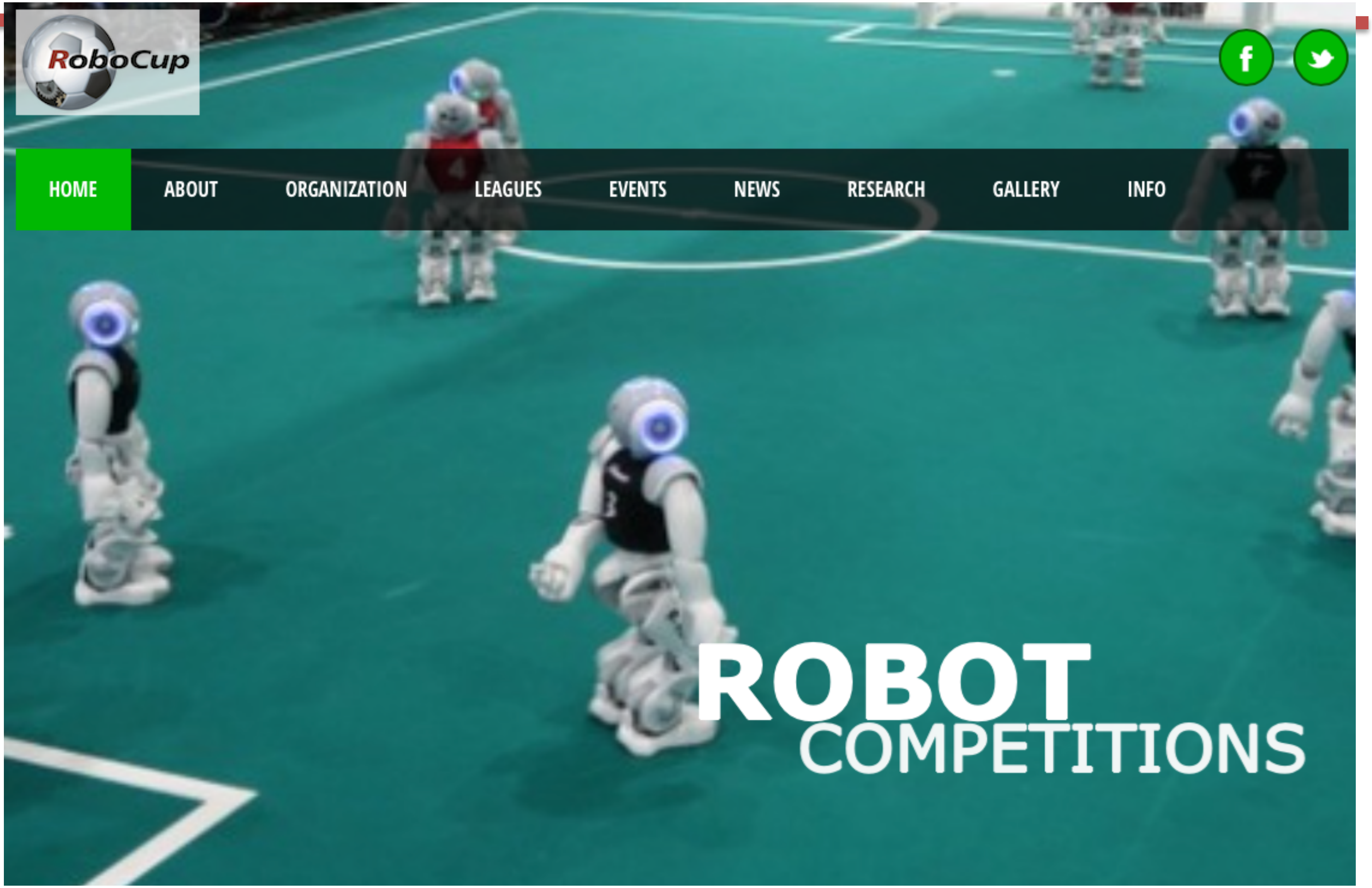
Partially Observable: some relevant information is hidden from the agent

[watch Dog’s Eye View video] [watch Melbourne vs. Cornell video]

Note:

The Robocup F180 League is close to fully observable, because the robots have access to an external computer connected to an overhead camera.

http://www.robocup.org



Robocup videos

The goal of the annual RoboCup competitions, which have been in existence since 1997, is to produce a team of soccer-playing robots that can beat the human world champion soccer team by the year 2050.

- Official website: http://www.robocup.org
- 1999-2011 UNSW RoboCup Evolution

https://www.youtube.com/watch?v=Rs8SJuM7dBI (4min)

Four-Legged League

- Northern Bites vs. Microsoft Hellhounds -- Four-Legged League, RoboCup 2007

https://www.youtube.com/watch?v=MLybmZ6OW5I

- Robocup Part 2 - rUNSWift vs Germany Uploaded on Jan 31, 2008 - Robocup Part 3 - Game 6

https://www.youtube.com/watch?v=Cv7333wHFMM

Deterministic vs. Stochastic

- Chess is Simulated, Robocup is Situated and Embodied ?
- Chess is Static, Robocup is Dynamic
- Chess is Discrete, Robocup is Continuous
- Chess is Fully observable, Robocup (Legged) is Partially Observable ?
- Chess is Deterministic, Robocup is Stochastic

Deterministic: the current state uniquely determines the next state

Stochastic: there is some random element involved

Note:

The non-determinisim partly arises because the physics can only be modeled with limited precision. But, even if it could be modeled perfectly, there would still be randomness due to quantum mechanical effects.

Episodic vs. Sequential

- Chess is Simulated, Robocup is Situated and Embodied
- Chess is Static, Robocup is Dynamic
- Chess is Discrete, Robocup is Continuous
- Chess is Fully observable, Robocup (Legged) is Partially Observable
- Chess is Deterministic, Robocup is Stochastic
- Both Chess and Robocup are Sequential

Episodic: every action by the agent is evaluated independently
Sequential: the agent is evaluated based on a long sequence of actions

Both Chess and Robocup are considered Sequential, because evaluation only happens at the end of a game, and it is necessary to plan several steps ahead in order to play the game well.

Known vs. Unknown

- Chess is Simulated, Robocup is Situated and Embodied ⍰
- Chess is Static, Robocup is Dynamic
- Chess is Discrete, Robocup is Continuous
- Chess is Fully observable, Robocup (Legged) is Partially Observable ⍰
- Chess is Deterministic, Robocup is Stochastic
- Both Chess and Robocup are Sequential
- Both Chess and Robocup are Known

Known: the rules of the game, or physics/dynamics of the environment, are known to the agent.

Note:

Video Games like Infinite Mario are sometimes set up in such a way that the dynamics of the environment are Unknown to the agent.

Single-Agent vs. Multi-Agent

- Chess is Simulated, Robocup is Situated and Embodied ?
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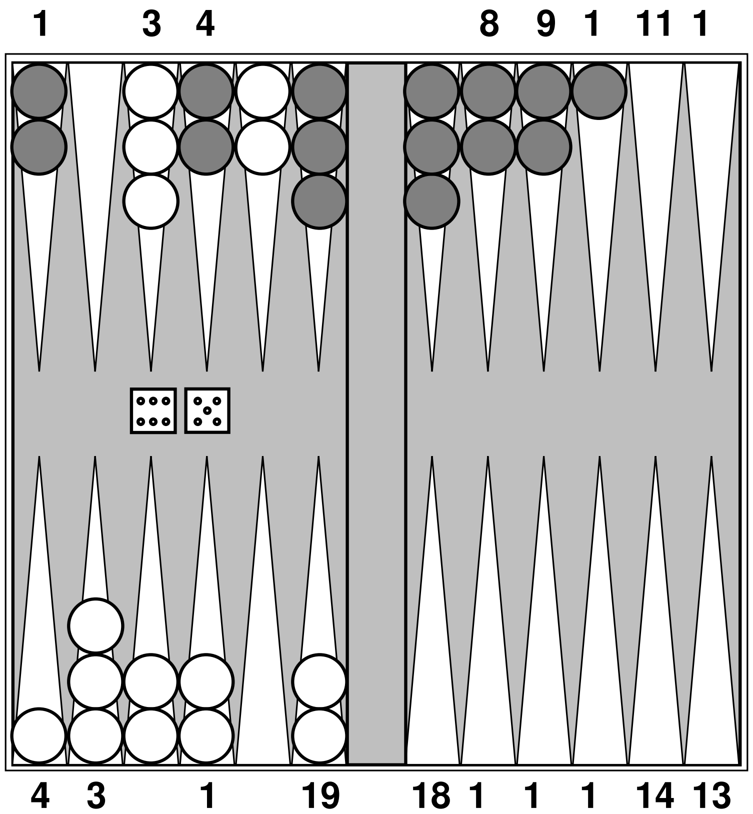
- Chess is Discrete, Robocup is Continuous
- Chess is Fully observable, Robocup (Legged) is Partially Observable ?
- Chess is Deterministic, Robocup is Stochastic
- Both Chess and Robocup are Sequential
- Both Chess and Robocup are Known
- Both Chess and Robocup are Multi-Agent

- Examples of Single-Agent tasks include:
  - solving puzzles like Sudoku, or Rubik's cube
  - Solitaire card games

Dice Games (Backgammon)



Simulated ?

Static ?

Discrete ?

Fully Observable ?

Deterministic ?

Episodic ?

Known ?

Single-Agent ?

Dice Games (Backgammon)

- Like Chess, Backgammon is Simulated, Static, Discrete, Sequential and Known and Multi-Agent.
- Normally, we consider Backgammon to be Fully Observable and Stochastic. The dice rolls are random, but all players can see them.

- If instead the dice rolls are generated by a computer using a pseudo- random number generator, with a specified seed, the game could be considered Deterministic but Partially Observable. In this case, the sequence of dice rolls is fully determined by the seed, but future dice rolls are not observable by the players.

Card Games (Poker, Rummy, Mahjong)

Simulated ?

Static ?

Discrete ?

Fully Observable ?

Deterministic ?

Episodic ?

Known ?

Single-Agent ?

Card Games (Poker, Rummy, Mahjong)

- Card Games like Poker, Rummy or Mahjong are Simulated, Static, Discrete, Sequential, Known and Multi-Agent.
- Card Games are Stochastic if the cards are shuffled during the game, but can be considered Deterministic if the cards are shuffled only once, before the game begins.
- Card Games are Partially Observable and involve Asymmetric Information in the sense that each player can see their own cards but not those of other players.

Robots

Situated and Embodied Cognition

- Rodney Brooks 1991:

• Situatedness: The robots are situated in the world – they do not deal with abstract descriptions, but with the "here" and "now" of the environment which directly influences the behaviour of the system.

• Embodiment: The robots have bodies and experience the world directly – their actions are part of a dynamics with the world, and actions have immediate feedback on the robot's own sensations.

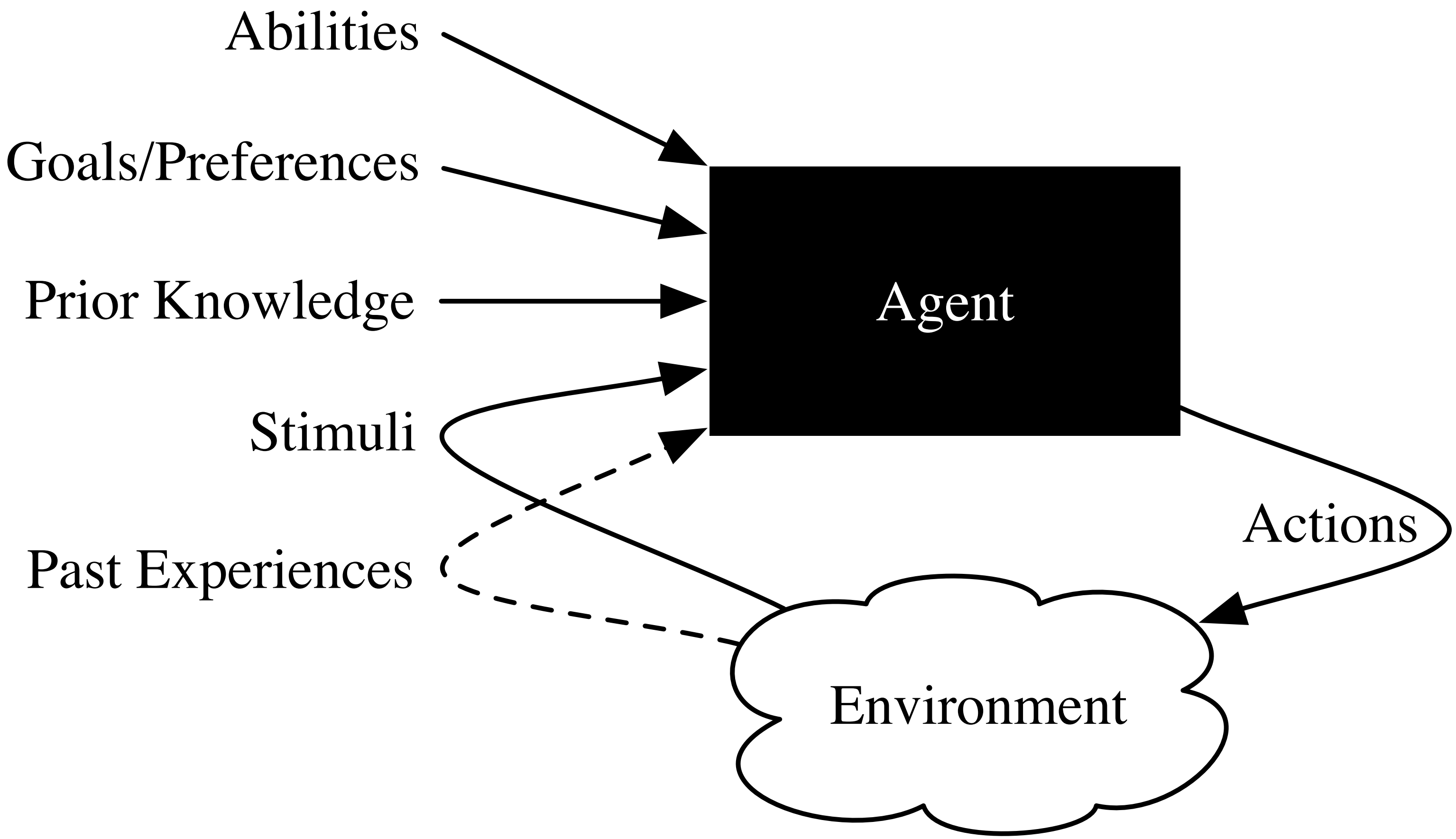
Situated vs. Embodied

- Situated but not Embodied: High frequency stock trading system:
  - it deals with thousands of buy/sell bids per second and its responses vary as its database changes.
  - but it interacts with the world only through sending and receiving messages.
- Embodied but not Situated: an industrial spray painting robot:
  - does not perceive any aspects of the shape of an object presented to it for painting; simply goes through a pre-programmed series of actions
  - but it has physical extent and its servo routines must correct for its interactions with gravity and noise present in the system.

Agents Situated in Environment

- AI is about practical reasoning: reasoning in order to do something.
- A coupling of perception, reasoning, and acting comprises an **agent**.
- An agent acts in an **environment**.
  - An agent's environment may well include other agents.
- An agent together with its environment is called a **world**.

Agents acting in an environment



An agent is something that acts in an environment.

An agent interacting with an environment

An Agent - a black box in terms of its inputs and outputs.

- At any time, what an agent does depends on:
  - **prior knowledge** about the agent and the environment
  - **history** of interaction with the environment, which is composed of
    - **stimuli** received from the current environment, which can include **observations** about the environment, as well as actions that the environment imposes on the agent and
    - **past experiences** of previous actions and stimuli, or other data, from which it can learn
  - **goals** that it must try to achieve or **preferences** over states of the world
  - **abilities**, the primitive actions the agent is capable of carrying out.

Inputs to an agent

- Abilities — the set of possible actions it can perform
- Goals/Preferences — what it wants, its desires, its values,...
- Prior Knowledge — what it comes into being knowing, what it doesn't get from experience,...
- History of stimuli
  - (current) stimuli — what it receives from environment now (observations, percepts)
  - past experiences — what it has received in the past

Example agent: autonomous car

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Example agent: autonomous car

- abilities: steer, accelerate, brake
- goals: safety, get to destination, timeliness,. . .
- prior knowledge: what signs mean, what to stop for
  stimuli: vision, laser, GPS. . .
- stimuli: vision, laser, GPS. . .
- past experiences: street maps, how breaking, steering affects direction..

Example agent: robot

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Example agent: robot

- abilities: movement, grippers, speech, facial expressions,. . .
- goals: deliver food, rescue people, score goals, explore,. . .
- prior knowledge: what is important feature, categories of objects, what a sensor tell us,. . .
- stimuli: vision, sonar, sound, speech recognition, gesture recognition,. . .
- past experiences: effect of steering, slipperiness, how people move,. . .

Example agent: teacher

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Example agent: teacher

- abilities: present new concept, drill, give test, explain concept,. . .
- goals: particular knowledge, skills, inquisitiveness, social skills,. . .
- prior knowledge: subject material, teaching strategies,. . .
- stimuli: test results, facial expressions, errors, focus,. . . .
- past experiences: prior test results, effects of teaching strategies, . . .

Example agent: thermostat for heater

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Example agent: thermostat for heater

- abilities: turn heater on or off
- goals: conformable temperature, save fuel, save money
- prior knowledge: 24 hour cycle, weekends
- stimuli: temperature, set temperature, who is home, outside temperature
- past experiences: when people come and go, who likes what temperature

Example agent: medical doctor

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Other Agents

- user interface
- Bee
- smart home
- ...

- abilities:
- goals:
- prior knowledge:
- stimuli:
- past experiences:

Environment types

- The environment type largely determines the agent design
- The real world is (of course)
  - partially observable,
  - stochastic (instead of deterministic),
  - sequential (instead of episodic),
  - dynamic (instead of static),
  - continuous (instead of discrete),
  - multi-agent (instead of single-agent).

Summary

- AI tasks or environments can be classified in terms of whether they are simulated, static, discrete, fully observable, deterministic, episodic, known, single- or multi- agent.
- The environment type strongly influences the agent design (discussed in the next section..)

Summary

- Assumptions made about environment dictate nature of agent
  - Capabilities those needed to survive in the environment
  - Need not be “over-engineered” to handle more complexity
  - Agent + Environment can be thought of as a coupled system

References

- Poole &Mackworth, Artificial Intelligence: Foundations of Computational Agents, Chapter 1
- Russell & Norvig, *Artificial Intelligence: a Modern Approach*, Chapter 2.