1.2 Intelligent Agents:

Agents, Rationality & PEAS

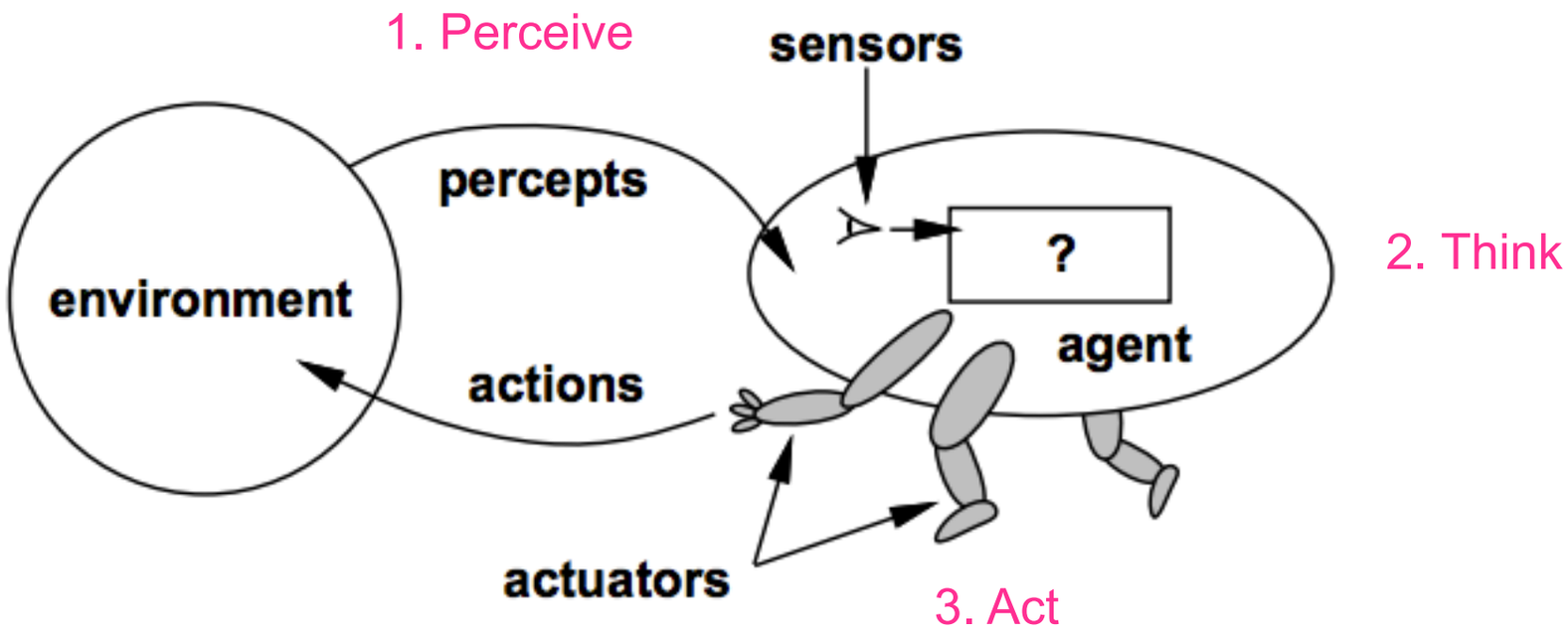
Recap: AI Definitions

Human	Ideal
Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)
"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998)
"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 1.1 Some definitions of artificial intelligence, organized into four categories.

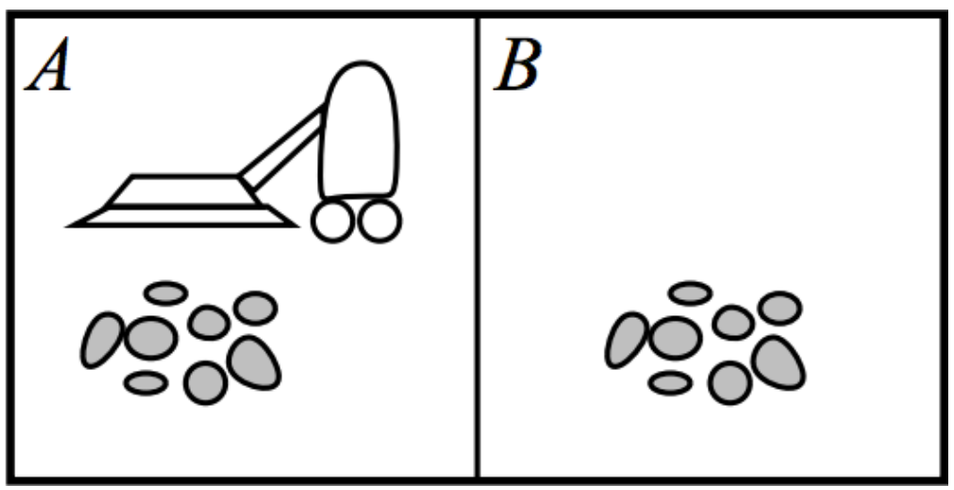
An Agent

- An agent is something that perceives its environment through sensors and acts upon that environment through actuators



- Agents include human, robots, chatbots, digital assistants (e.g. Siri), smart phones, self-driving cars, etc. (agent = architecture + program)
- Agent's behaviour is described by the agent function that maps any given percept (input) sequence to an action

Vacuum Cleaner World



- Percepts: Location and content (e.g. *[A, Dirty]*)
- Actions: *Suck, Move Left, Move Right, NoOp*

A vacuum cleaner with just two locations

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

Simple agent function for vacuum cleaner world above

Rationality

- A rational agent is one that does the *right* thing – that has good behaviour
- Consider the *consequences* of the agent's behaviour – if agent's sequence of actions is desirable, then it has performed well
- Performance measure evaluates any given sequence of environment states
  - Amount of dirt cleaned up in X hours *vs.* number of clean square on floor at each time step in vacuum cleaner world
  - Mediocre working cleaner *vs.* efficient cleaner that takes long breaks
- Russell (2019) argues that there could be a mismatch between human's preferences and the machine's understanding of those human preferences (performance measures)

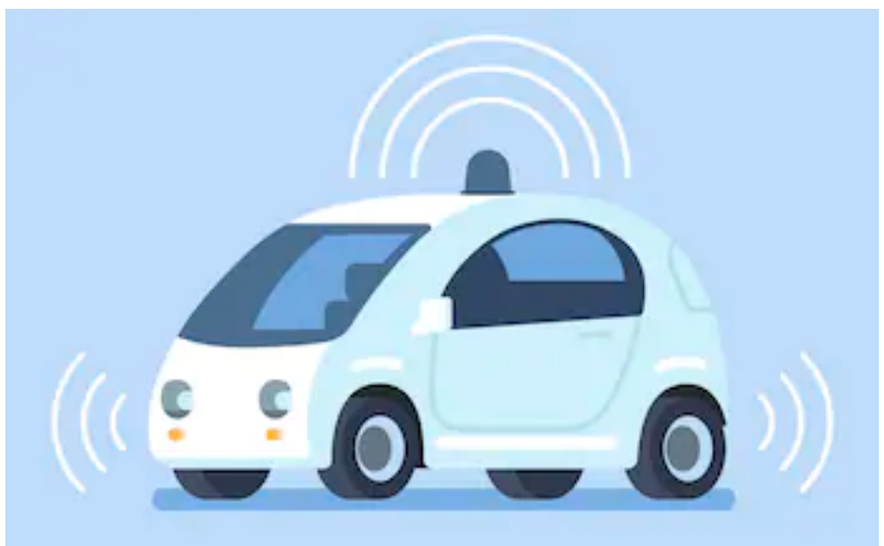
Rationality II

- A rational agent should choose an action that maximises the expected value of its performance measure given the percept sequence and whatever built-in knowledge the agent has
- Rationality ≠ Omniscience (≈ knows the actual outcome)
- Rationality maximises expected outcome, perfection maximises actual performance
- *"Not to be absolutely certain is, I think, one of the essential things in rationality."* – Bertrand Russell
- Rational agent should perform exploration/information gathering and learn
- Rational agent should be autonomous – it should learn what it can to compensate for partial or incorrect prior knowledge (independence over time)

PEAS – Task Environment

- Performance measure
- Environment
- Actuators
- Sensors

Automated Taxi



Agent Type	Performance Measure	Environment	Actuators	Sensors
Taxi driver	Safe, fast, legal, comfortable trip, maximize profits	Roads, other traffic, pedestrians, customers	Steering, accelerator, brake, signal, horn, display	Cameras, sonar, speedometer, GPS, odometer, accelerometer, engine sensors, keyboard

Figure 2.4 PEAS description of the task environment for an automated taxi.

Agent Type	Performance Measure	Environment	Actuators	Sensors
Medical diagnosis system	Healthy patient, reduced costs	Patient, hospital, staff	Display of questions, tests, diagnoses, treatments, referrals	Keyboard entry of symptoms, findings, patient's answers
Satellite image analysis system	Correct image categorization	Downlink from orbiting satellite	Display of scene categorization	Color pixel arrays
Part-picking robot	Percentage of parts in correct bins	Conveyor belt with parts; bins	Jointed arm and hand	Camera, joint angle sensors
Refinery controller	Purity, yield, safety	Refinery, operators	Valves, pumps, heaters, displays	Temperature, pressure, chemical sensors
Interactive English tutor	Student's score on test	Set of students, testing agency	Display of exercises, suggestions, corrections	Keyboard entry

Figure 2.5 Examples of agent types and their PEAS descriptions.

Task environment properties

- Fully *vs.* partially observable: agent's sensors give it access to complete or partial state of the environment at each point in time, e.g. noisy sensors
- Single agent vs. multi-agent: one and many
- Deterministic vs. stochastic: next state of the environment is completely determined by the current state and the action executed by the agent (taxi driving is stochastic because traffic behaviour can't be predicted)
- Episodic vs. sequential: divided into atomic episodes, in each episode percepts and action are not influenced by actions taken in previous episodes, e.g. spotting defects on an assembly line
- Dynamic vs. static: The environment can change while agent is deliberating, e.g. taxi driving
- Discrete vs. continuous: There is a finite number of distinct states, e.g. chess, vacuum cleaner world

Environments Types I

1. OBSERVABILITY

This refers to the possibility for an agent to obtain complete and accurate information about the environment's state. Has all the information required to complete the goal.

Examples

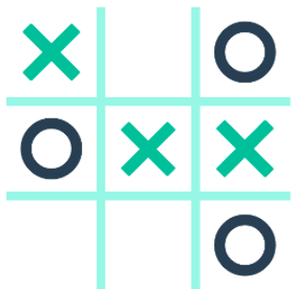
- *Partially-observable environment:* physical world: information about any event on earth, self-driving vehicles
- *Observable environment*: Chess. If you look at a chess board, all information required to make an optimal decision is available. It doesn't matter what happened in the past. Image analysis.

2. DETERMINISTIC vs STOCHASTIC/PROBABILISTIC (NON-DETERMINISTIC)

In a deterministic environment, any action has a single guaranteed effect, and no failure or uncertainty. On the contrary is a non-deterministic (stochastic) environment. In this environment, the same task performed twice may produce different results or may even fail completely (i.e. includes some randomness).

Examples

- *Non-deterministic environment*: physical world: Robot on Mars, self-driving vehicles
- *Deterministic environment*: Tic-Tac-Toe



3. STATIC vs DYNAMIC

An environment is static if only the actions of an agent modify it. It is dynamic on the other hand if other processes are operating on it.

Examples

- *Dynamic environment:* physical world, drones's vision system
- *Static environment:* empty office with no moving objects, speech analysis

Environment Types II

4. EPISODIC vs SEQUENTIAL (NON-EPISODIC)

In an episodic environment, each agent's performance is the result of a series of independent tasks performed. There is no link between the agent's performance and other different scenarios. In other words, the agent decides which action is best to take, it will only consider the task at hand and doesn't have to consider the effect it may have on future tasks.

Examples

- *Episodic environment:* mail sorting system
- *Non-episodic environment:* chess game

5. DISCRETE vs CONTINUOUS

An environment is said to be discrete if there are a finite number of actions (but can be large) that can be performed within it.

Examples

- *Discrete environment:* A game of chess or checkers where there are a set number of moves.
- *Continuous environment:* Taxi driving: there could be a route from to anywhere to anywhere else, drone's vision system

The more complex an environment is, the harder it is to decide which action to perform. The most complex environment is one that is unobservable, non-deterministic, non-episodic, dynamic and continuous

Environment Types

Task environment	Observable?	Agent?	Deterministic?	Episodic?	Static?	Discrete?
Crossword puzzle	Fully	Single	Deterministic	Sequential	Static	Discrete
Chess with clock	Fully	Multi	Deterministic	Sequential	Semi	Discrete
Poker	Partially	Multi	Stochastic	Sequential	Static	Discrete
Backgammon	Fully	Multi	Stochastic	Sequential	Static	Discrete
Taxi driving	Partially	Multi	Stochastic	Sequential	Dynamic	Continuous
Medical diagnosis	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Image analysis	Fully	Single	Deterministic	Episodic	Static	Continuous
Part-picking robot	Partially	Single	Stochastic	Episodic	Dynamic	Continuous
Refinery controller	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
Interactive tutor	Partially	Multi	Stochastic	Sequential	Dynamic	Discrete

- What are the task environments for an internet shopping agent?
- What about an agent navigating in the real world?

Agent Types

- Simple reflex agents select actions on the basis of the *current* percept, ignoring the percept history (e.g. vacuum cleaner, braking, blinking)
- Model-based reflex agents use knowledge about how the world evolves independent of agent and how agent's actions affect the world to select action (partial visibility, keeps track of percept history)
- Goal-based agents aim for final state that needs to be reached, e.g. reach destination, happy (current state, goal)
- Utility-based agents *maximise* the expected utility of the action outcomes. Utility function is an internal form of the *performance measure*
- Learning agents can adapt to the environment by learning new tasks and hence new actions to take. Has a more complex mechanism than all the agents above (more on this when we look at *Machine Learning*)

Summary

- An agent is something that perceives and acts in an environment
- A rational agent acts so as to maximise the expected value of the performance measure, given the percept sequence and its built-in knowledge
- A task environment specification includes **P**erformance measure, **E**nvironment, **A**ctuators and **S**ensors
- Task environment can have properties such as fully or partially observable, single- or multi-agent, deterministic ot stochastic, static or dynamic, episodic or sequential, discrete or continuous
- Four types of agents are simple reflex agents, model-based reflex agents, goal-based agents and utility-based agents
- They can all improve their performance through learning

References

- Russel and Norvig, Chapter 2
- M. Saint-Antoine. Deterministic vs Stochastic Modelling [Video]
- Fanuc Pick and Place Robot [Link]
- How AI is trying to help fight COVID-19 disease [Link]
- S. Russell (2019) Human Compatible [Book]

Questionnaire

- Please fill out a short course questionnaire by clicking HERE or accessing the QR code