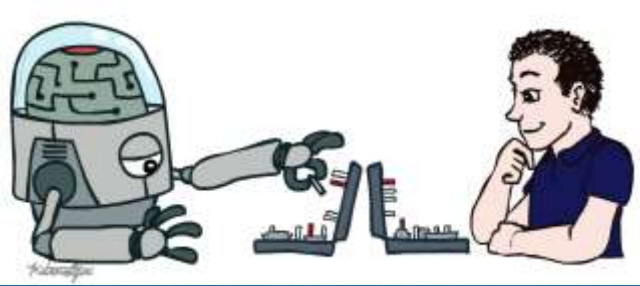

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DSE CL 557 - Artificial and Computational Intelligence

#2. Intelligent Agents

Sunday, September 6, 2020

Dr. Saikishor Jangiti

Agenda

#1 Introduction

- Foundations of AI
- Brief Overview of Modern AI & Application Domains.

#2 Intelligent Agents

- Agents and environments
- Rationality
- PEAS

  (Performance measure, Environment, Actuators, Sensors)
- Environment types
- Agent types

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

- Can formal rules be used to draw valid conclusions?
- How does the mind arise from a physical brain?
- Where does knowledge come from?
- How does knowledge lead to action?

Areas Contributing to AI

Philosophy
Mathematics
Economics
Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

Aristotle (384-322 B . C .) : first to formulate precise set of laws to govern rational part of brain

Ramon Lull (d. 1315) : useful reasoning could actually be carried out by a mechanical artifact

Hobbes (1588-1679) : "we add and subtract in our silent thoughts."

Leibniz (1646-1716) : Built a mechanical device intended to carry out operations on concepts rather than numbers

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Linguistics

Some '*isms* on the working of minds :

Rationalism - Correct Reasonings (Aristotle, Descartes …)

Dualism - A part of the human mind (or soul or spirit) that is outside of nature

Materialism - Alternative to dualism - holds that the brain's operation according to the laws of physics constitutes the mind

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Linguistics

Obtaining Knowledge

David Hume's (1711–1776) : First principles of induction

Logical positivism- Rudolf Carnap : Every knowledge obtained has a logical connection

Carnap (1905–1997) : A book "*The Logical Structure of the World*" (1928) defined an explicit computational procedure for extracting knowledge from elementary experiences

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Linguistics

Connection between knowledge and action:

Aristotle - (in *De Motu Animalium*) that actions are justified by a logical connection between goals and knowledge of the action's outcome

I need covering;

a cloak is a covering.

I need a cloak.

What I need, I have to make;

I need a cloak.

I have to make a cloak.

And the conclusion, "***I have to make a cloak***" is an action

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Control theory, Cybernetics
Linguistics

- What are the formal rules to draw valid conclusions?
- What can be computed?
- How do we reason with uncertain information?

Areas Contributing to AI

Philosophy
Mathematics
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Neuroscience
Psychology
Computer Engineering
Control theory, Cybernetics
Linguistics

- What are the formal rules to draw valid conclusions?

George Boole (1815–1864) : Propositional Logic

Gottlob Frege (1848–1925): First order logic

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Linguistics

- What can be computed?

Kurt Gödel (1906–1978) : In any formal theory as strong as Peano arithmetic #(the elementary theory of natural numbers), there are true statements that are undecidable in the sense that they have no proof within the theory

Computability, tractability, NP-completeness

Probability theory & inference mechanisms

- https://en.wikipedia.org/wiki/Peano_axioms

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Linguistics

- How should we make decisions so as to maximize payoff?

Utility / preferred outcomes

Decision theory -Probability & utility theory

Game theory

- How to make decisions when payoffs are not immediate?
    - Markov Decision Process

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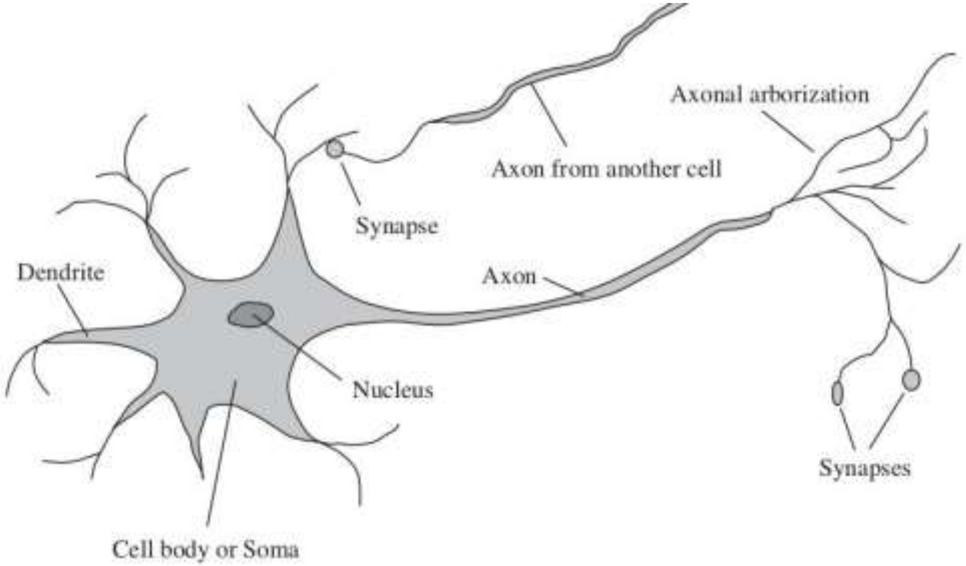
Linguistics

How do brains process information?

- Study of the nervous system / brain
- How does brain enables thoughts - Mystery Still

Aristotle , "*Of all the animals, man has the largest brain in proportion to his size*"



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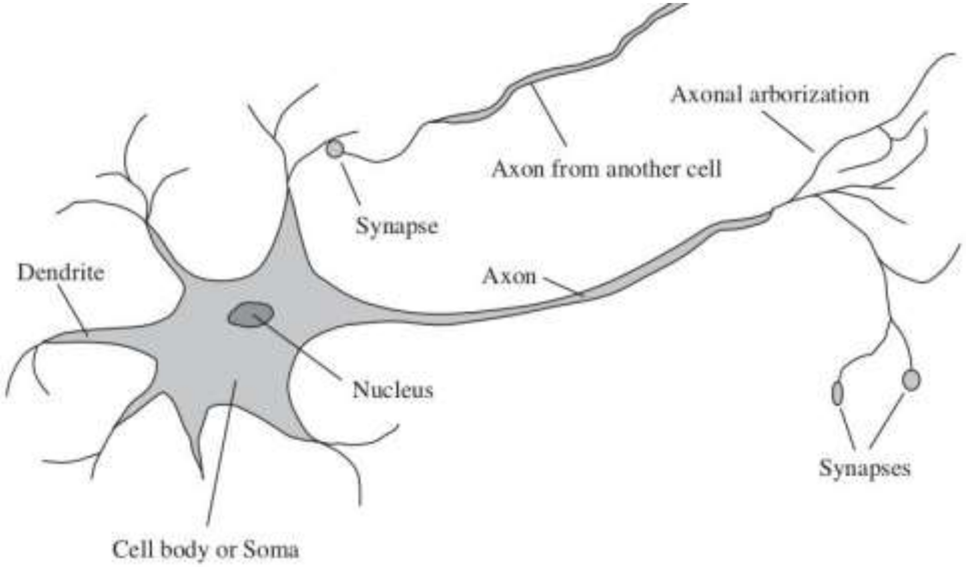
	Supercomputer	Personal Computer	Human Brain
Computational units	10^4 CPUs, 10^{12} transistors	4 CPUs, 10^9 transistors	10^{11} neurons
Storage units	10^{14} bits RAM 10^{15} bits disk	10^{11} bits RAM 10^{13} bits disk	10^{11} neurons 10^{14} synapses
Cycle time	10^{-9} sec	10^{-9} sec	10^{-3} sec
Operations/sec	10^{15}	10^{10}	10^{17}
Memory updates/sec	10^{14}	10^{10}	10^{14}



Areas Contributing to AI

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How do humans and animals think and act?

- *Cognitive Psychology* - Brain as an information-processing device
- Two months after the dartmouth workshop, a workshop in MIT gave birth to *Cognitive Science*
  - George Miller, Noam Chomsky, Allen Newell and Herbert Simon - roles of computer models to address the psychology of memory, language, and logical thinking, issues..

"*a cognitive theory should be like a computer program*" (Anderson, 1980);

Areas Contributing to AI

Philosophy
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Psychology
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Control theory, Cybernetics
Linguistics

Computers & Programming Languages

Areas Contributing to AI

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Control theory

- Deals with the behaviour of dynamic systems
  - behaviour must ensure the error between the current state and goal state is minimized
- Cybernetics - Book by Wiener
  - (Norbert Wiener, 1948) : Scientific study of control and communication in the animal and the machine
- Ashby's Design for a Brain (1948, 1952):
  - Intelligence could be created by the use of homeostatic devices containing appropriate feedback loops to achieve stable adaptive behavior
  - Led to the idea of *design of systems that maximize an objective function over time*

Areas Contributing to AI

Philosophy
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Linguistics

- How does language relate to thought?
- Verbal Behavior (1957, B. F. Skinner) :
  - Behaviorist approach to language learning
  - Reviewed by Noam Chomsky
    - criticised lack of notion of creativity in language
- Syntactic Structures (1957, Noam Chomsky)
  - Computational linguistics / natural language processing as a part of AI
    - Understanding a language is realized as more complex than ever
    - Context, subject matter knowledge
      - complicated it further
    - Representing language consumed volume of work done in NLP, in early times

Deep Learning Breakthroughs (2012 – Present)

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- In 2012, deep learning beat previous benchmark in the ImageNet competition.
- In 2013, deep learning is used to understand "conceptual meaning" of words.
- In 2014, similar breakthroughs appeared in language translation.

Google Translate

- These have led to advancements in Web Search, Document Search, Document Summarization, and Machine Translation.

Modern AI (2012 – Present): Deep Learning Impact

Computer vision

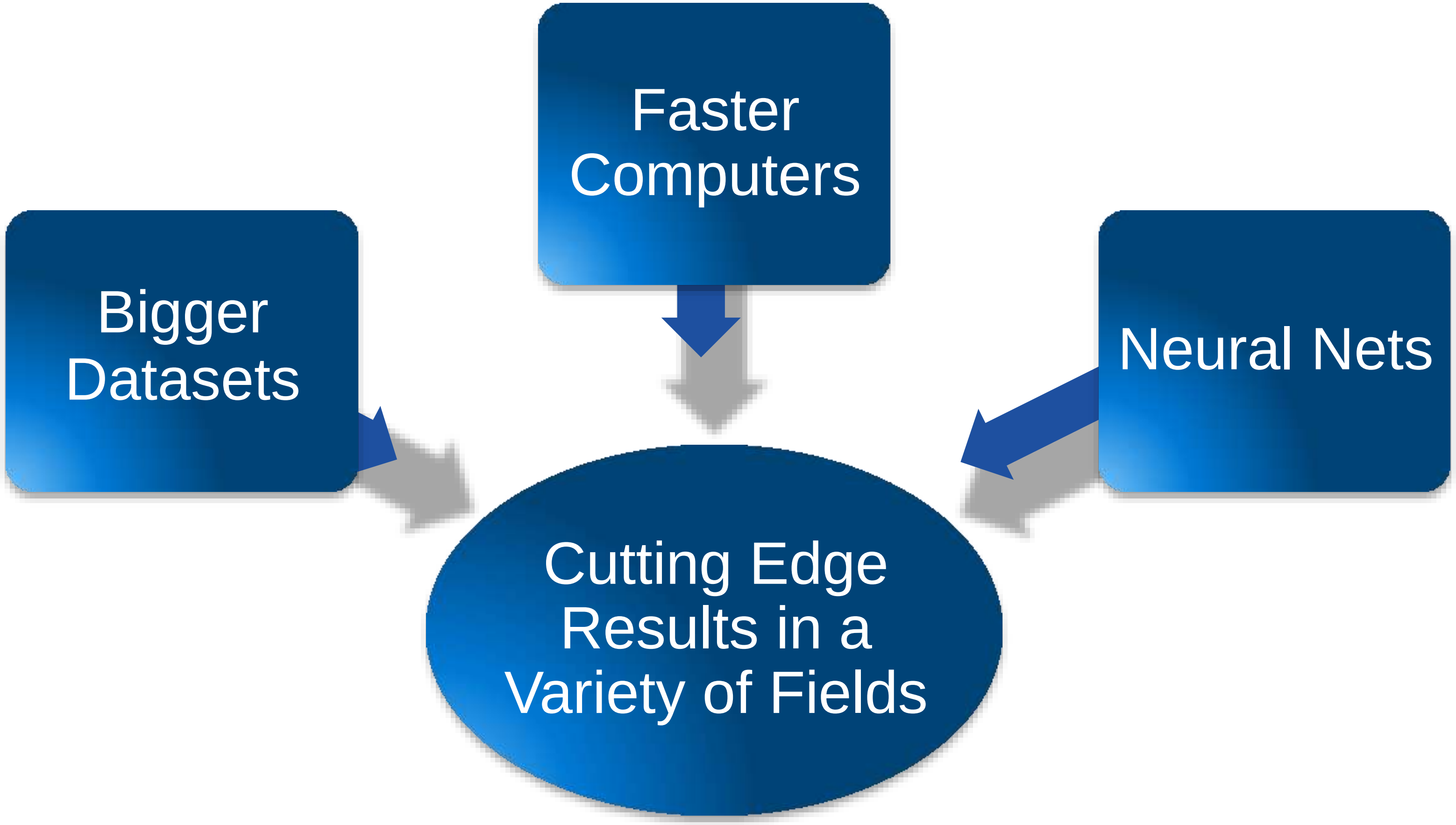
Self-driving cars: object detection

Healthcare: improved diagnosis

Natural language

Communication: language translation

How is the AI of this Era is Different?



Other Modern AI Factors

- Continued expansion of open source AI, especially in Python*, aiding machine learning and big data ecosystems.
- Leading deep learning libraries *open-sourced*, allowing further adoption by industry.
- Open sourcing of large datasets of millions of labeled images, text datasets such as Wikipedia has also driven breakthroughs.

AI in Transportation

Navigation

Google & Waze find the fastest route, by processing traffic data.

Ride sharing

Uber & Lyft predict real-time demand using AI techniques, machine learning, deep learning.

AI in Social Media

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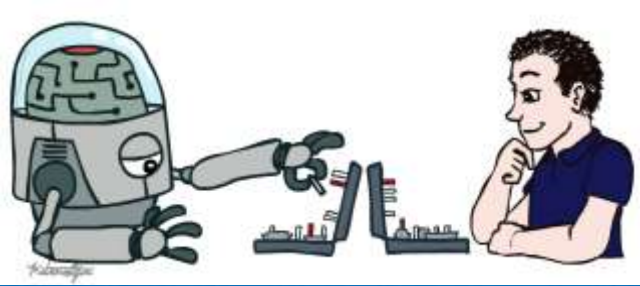
Audience

Facebook & Twitter use AI to decide what content to present in their feeds to different audiences.

Content

Image recognition and sentiment analysis to ensure that content of the appropriate “mood” is being served.



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#2. Intelligent Agents

Sunday, September 6, 2020

Dr. Saikishor Jangiti

Outline

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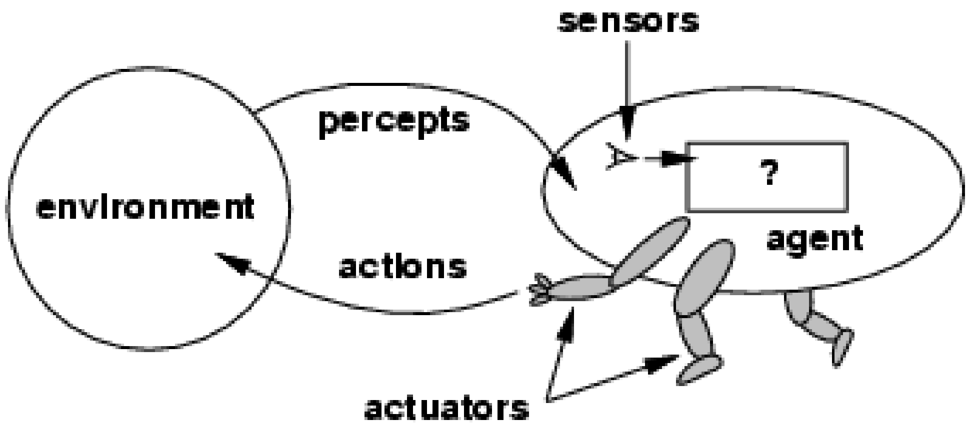
- Agents and environments
- Rationality
- PEAS
  - Performance measure
  - Environment
  - Actuators
  - Sensors
- Environment types
- Agent types

Agents

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators
- Human agent:
  - eyes, ears, and other organs for sensors;
  - hands, legs, mouth, and other body parts for actuators
- Robotic agent:
  - cameras and infrared range finders for sensors;
  - various motors for actuators

Agents and environments



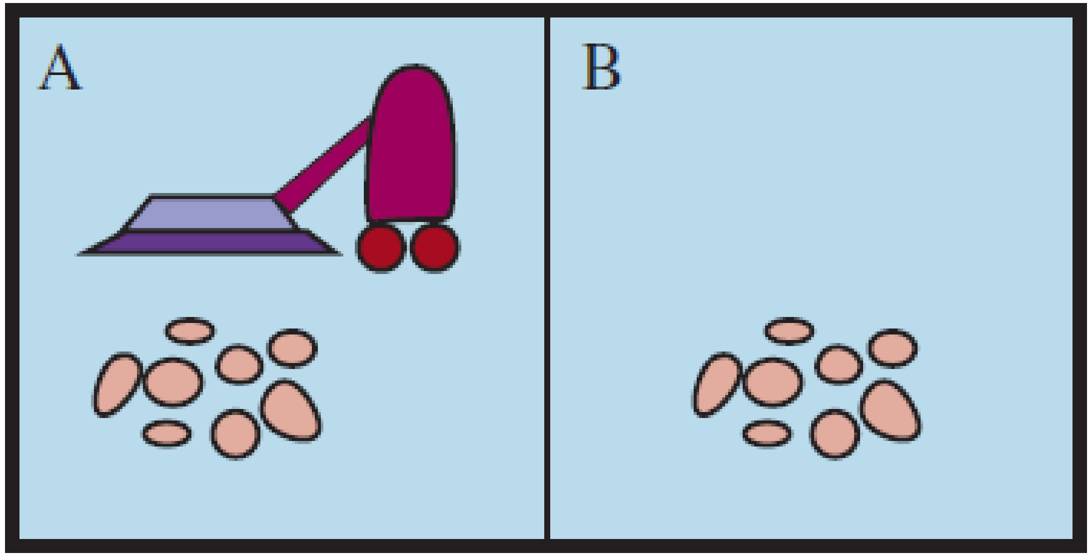
- The agent function maps from percept histories to actions:

$$[f: \mathcal{P}^* \rightarrow \mathcal{A}]$$

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

agent = architecture + program

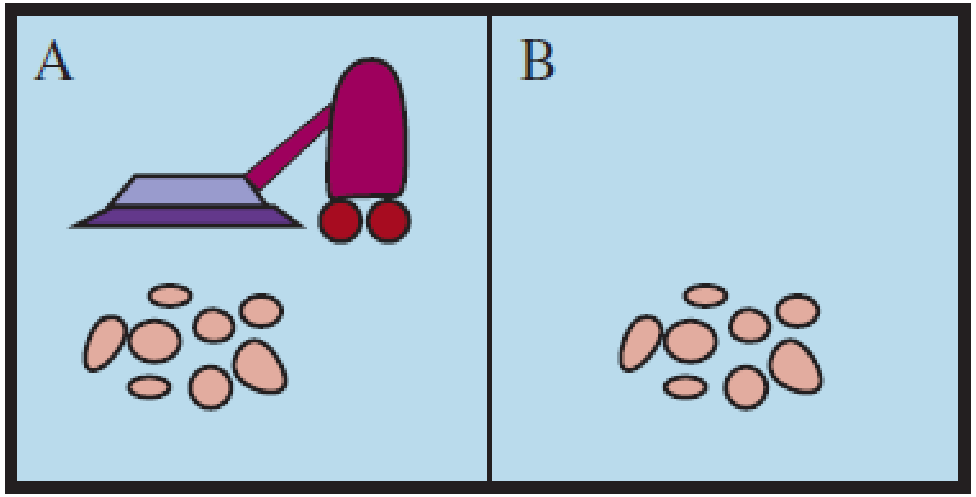
Vacuum-cleaner world



- Percepts: location and contents, e.g., [A , Dirty]
- Actions: *Left*, *Right*, *Suck*, *NoOp*

A vacuum-cleaner agent

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



Rational agents

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- An agent should strive to "do the right thing",
  - based on what it can perceive and the actions it can perform.
  - The right action is the one that will cause the agent to be most successful
- Performance measure: An objective criterion for success of an agent's behavior
  - E.g., performance measure of a vacuum-cleaner agent
    - » amount of dirt cleaned up
    - » amount of time taken
    - » amount of electricity consumed
    - » amount of noise generated, etc.

Rational agents

- Rational Agent: For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has.

Rational agents

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- Rationality is distinct from omniscience
  - Omniscience (all-knowing with infinite knowledge)
- Agents can perform actions in order to modify future percepts so as to obtain useful information (information gathering, exploration)
- An agent is autonomous if its behavior is determined by its own experience (with ability to learn and adapt)

PEAS

- PEAS:
  - Performance measure
  - Environment
  - Actuators
  - Sensors

PEAS - Automated taxi driver

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– Performance measure: Safe, fast, legal, comfortable trip, maximize profits
– Environment: Roads, other traffic, pedestrians, customers
– Actuators: Steering wheel, accelerator, brake, signal, horn
– Sensors: Cameras, sonar, speedometer, GPS, odometer, engine sensors, keyboard

PEAS - Medical diagnosis system

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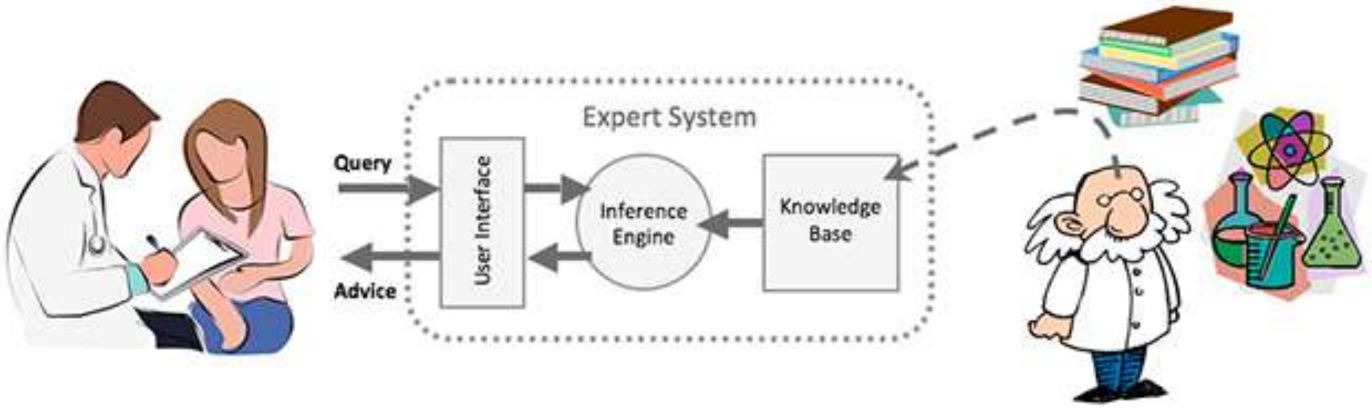
- Performance measure: Healthy patient, minimize costs, lawsuits
- Environment: Patient, hospital, staff
- Actuators: Screen display (questions, tests, diagnoses, treatments, referrals)
- Sensors: Keyboard (entry of symptoms, findings, patient's answers)



PEAS - Part-picking robot

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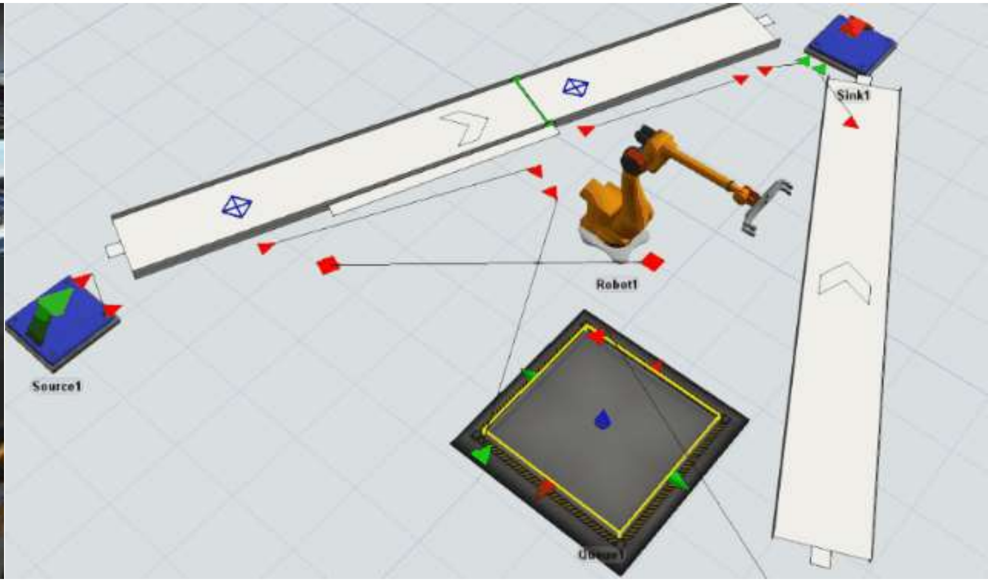
- Performance measure: Percentage of parts in correct bins
- Environment: Conveyor belt with parts, bins
- Actuators: Jointed arm and hand
- Sensors: Camera, joint angle sensors

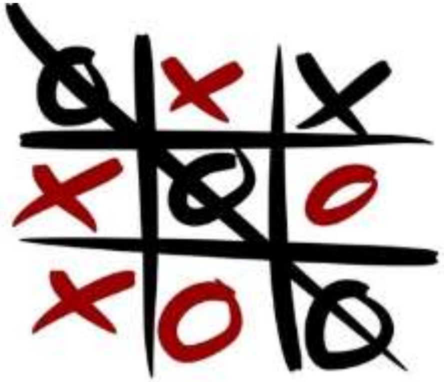


PEAS - Interactive English tutor

- Performance measure: Maximize student's score on test
- Environment: Set of students
- Actuators: Screen display (exercises, suggestions, corrections)
- Sensors: Keyboard

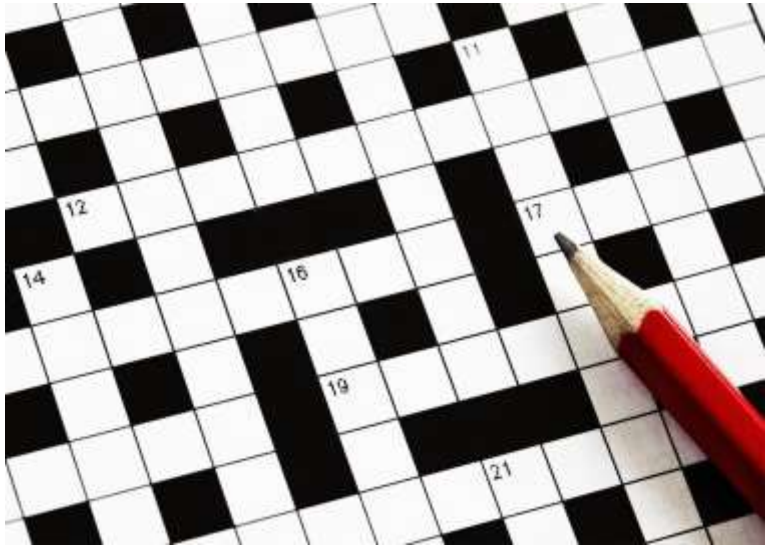
Environment types

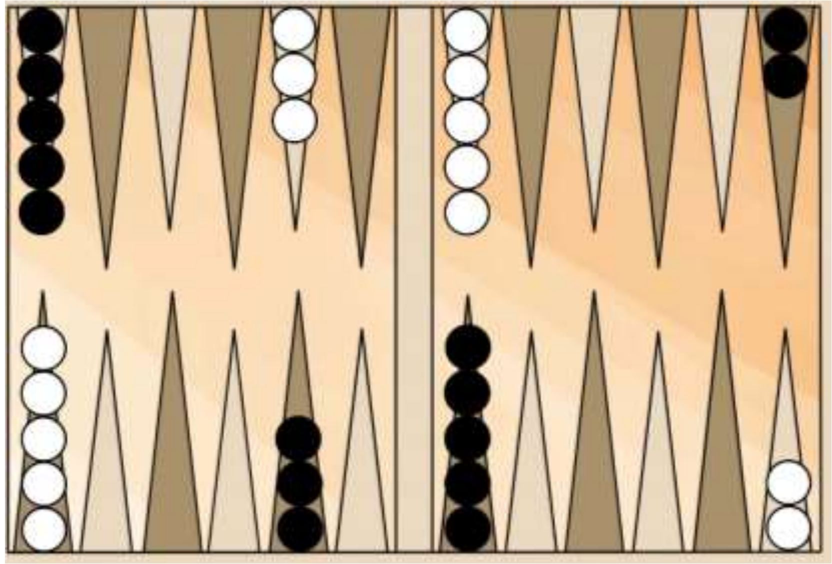
- Fully observable (vs. partially observable): An agent's sensors give it access to the complete state of the environment at each point in time.



Environment types

- Deterministic (vs. stochastic): The next state of the environment is completely determined by the current state and the action executed by the agent. (If the environment is deterministic except for the actions of other agents, then the environment is strategic)





Environment types

- Episodic (vs. sequential): The agent's experience is divided into atomic "episodes" (each episode consists of the agent perceiving and then performing a single action), and the choice of action in each episode depends only on the episode itself.

Environment types

- Static (vs. dynamic): The environment is unchanged while an agent is deliberating. (The environment is semidynamic if the environment itself does not change with the passage of time but the agent's performance score does)

Rubik's Cube

vs.

Football playing robots

Environment types

- Discrete (vs. continuous): A limited number of distinct, clearly defined percepts and actions.

VS.

Environment types

- Single agent (vs. multiagent): An agent operating by itself in an environment.

Robot helping an old patient to walk

VS.

Car-manufacturing robots

Environment types

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- The environment type largely determines the agent design
- The real world is (of course) partially observable, stochastic, sequential, dynamic, continuous, multi-agent

Task Environment	Observable	Agents	Deterministic	Episodic	Static	Discrete
Crossword puzzle	Fully	Single	Deterministic	Sequential	Static	Discrete
Chess with a 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	Semi	Continuous
Part-picking robot	Partially	Single	Stochastic	Episodic	Dynamic	Continuous
Refinery controller	Partially	Single	Stochastic	Sequential	Dynamic	Continuous
English tutor	Partially	Multi	Stochastic	Sequential	Dynamic	Discrete

Agent functions and programs

- An agent is completely specified by the agent function mapping percept sequences to actions

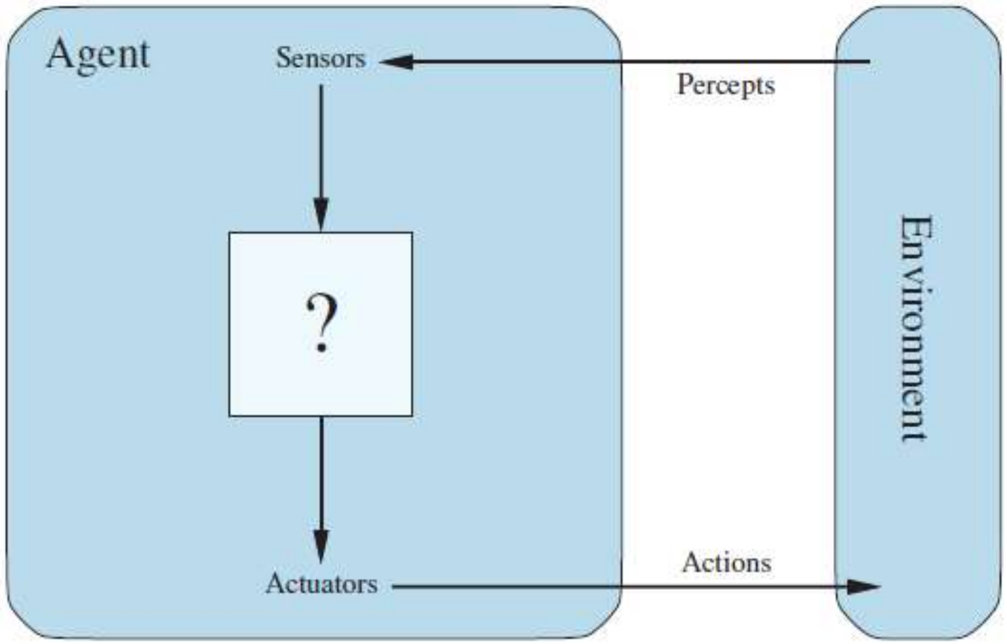

Table-lookup agent

function TABLE-DRIVEN-AGENT(*percept*) **returns** an action
  persistent: *percepts*, a sequence, initially empty
    table, a table of actions, indexed by percept sequences, initially fully specified
  append *percept* to the end of *percepts*
  action ←LOOKUP(*percepts*, *table*)
return *action*

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*
⋮	⋮
[*A*, *Clean*], [*A*, *Clean*], [*A*, *Clean*]	*Right*
[*A*, *Clean*], [*A*, *Clean*], [*A*, *Dirty*]	*Suck*
⋮	⋮

- Drawbacks:
  - Huge table
  - Take a long time to build the table
  - No autonomy
  - Even with learning, need a long time to learn the table entries

Agent types

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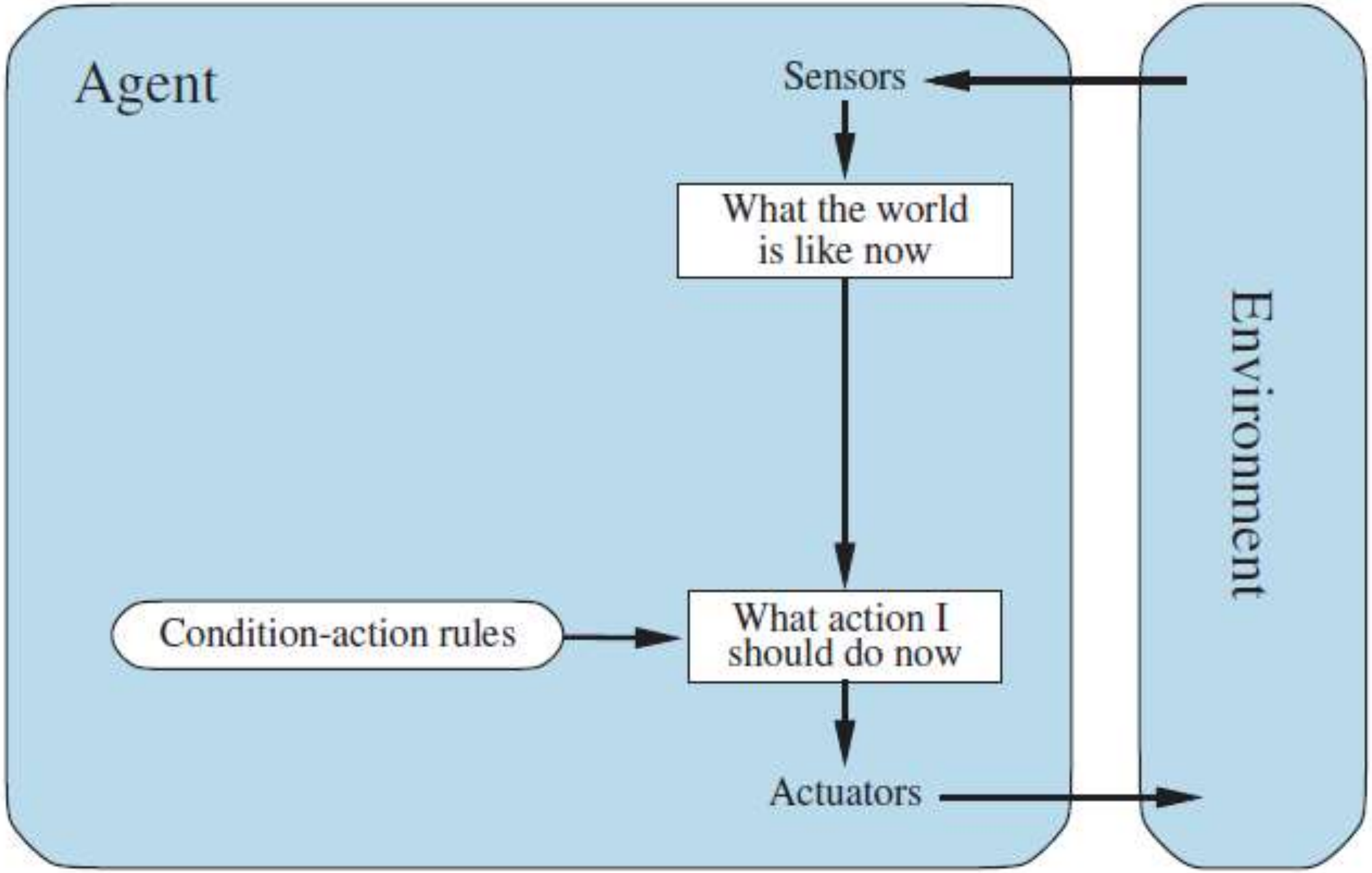
- Four basic types in order of increasing generality:
  - Simple reflex agents
  - Model-based reflex agents
  - Goal-based agents
  - Utility-based agents

Simple reflex agents



Simple reflex agents

function SIMPLE-REFLEX-AGENT(*percept*) returns an action

persistent: *rules*, a set of condition–action rules

state←INTERPRET-INPUT(*percept*)

rule←RULE-MATCH(*state*, *rules*)

action ←*rule*.ACTION

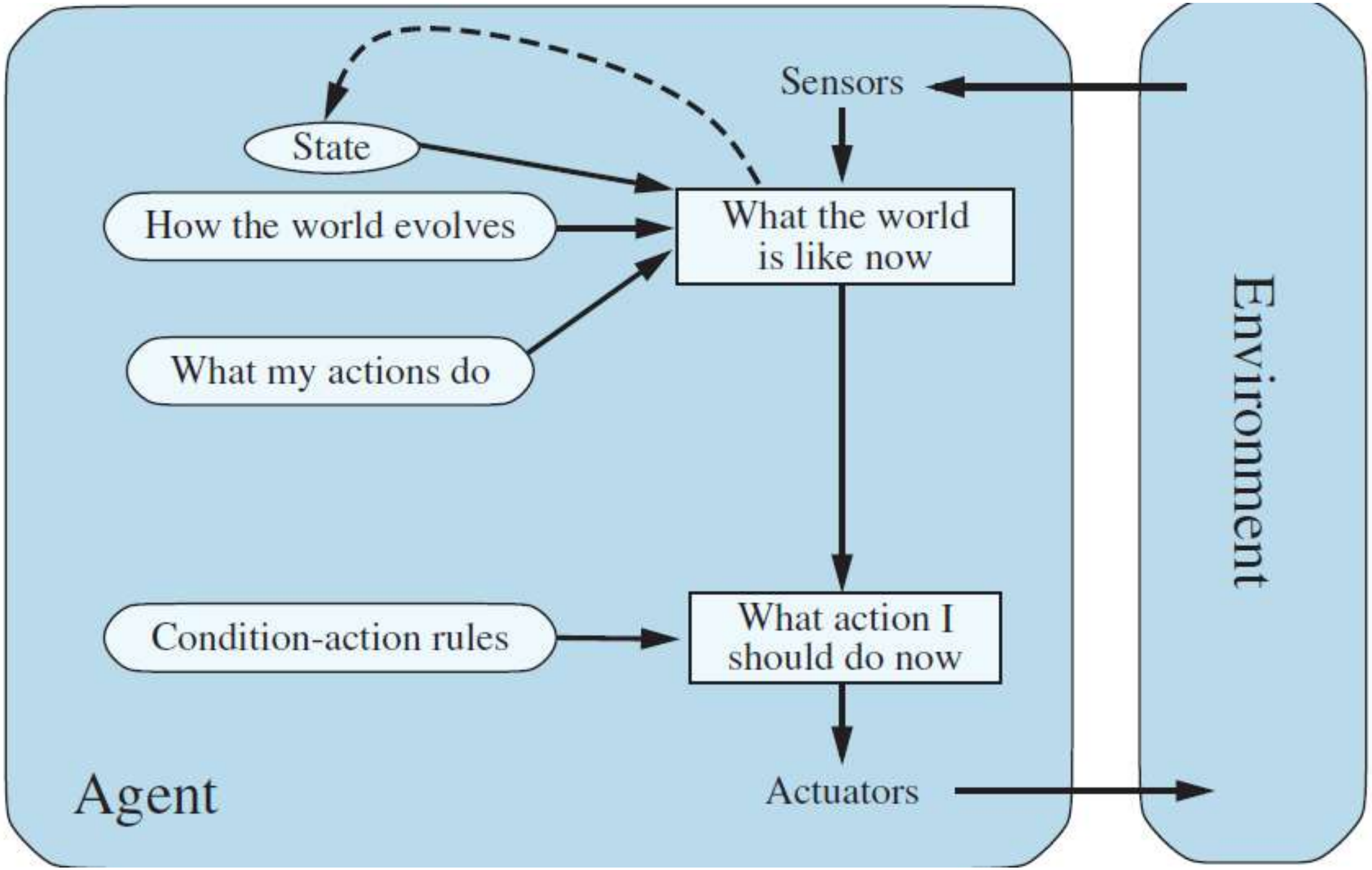
return *action*

Agent program for a vacuum-cleaner agent

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

Model-based reflex agents



Model-based reflex agents

function MODEL-BASED-REFLEX-AGENT(*percept*) **returns** an action

persistent: *state*, the agent's current conception of the world state
transition model, a description of how the next state depends on the current state and action
sensor model , a description of how the current world state is reflected in the agent's percepts
rules, a set of condition–action rules
action, the most recent action, initially none

state←UPDATE-STATE(*state*, *action*, *percept*, *transition model*, *sensor model*)

rule←RULE-MATCH(*state*, *rules*)

action ←*rule*.ACTION

return *action*

Goal-based agents

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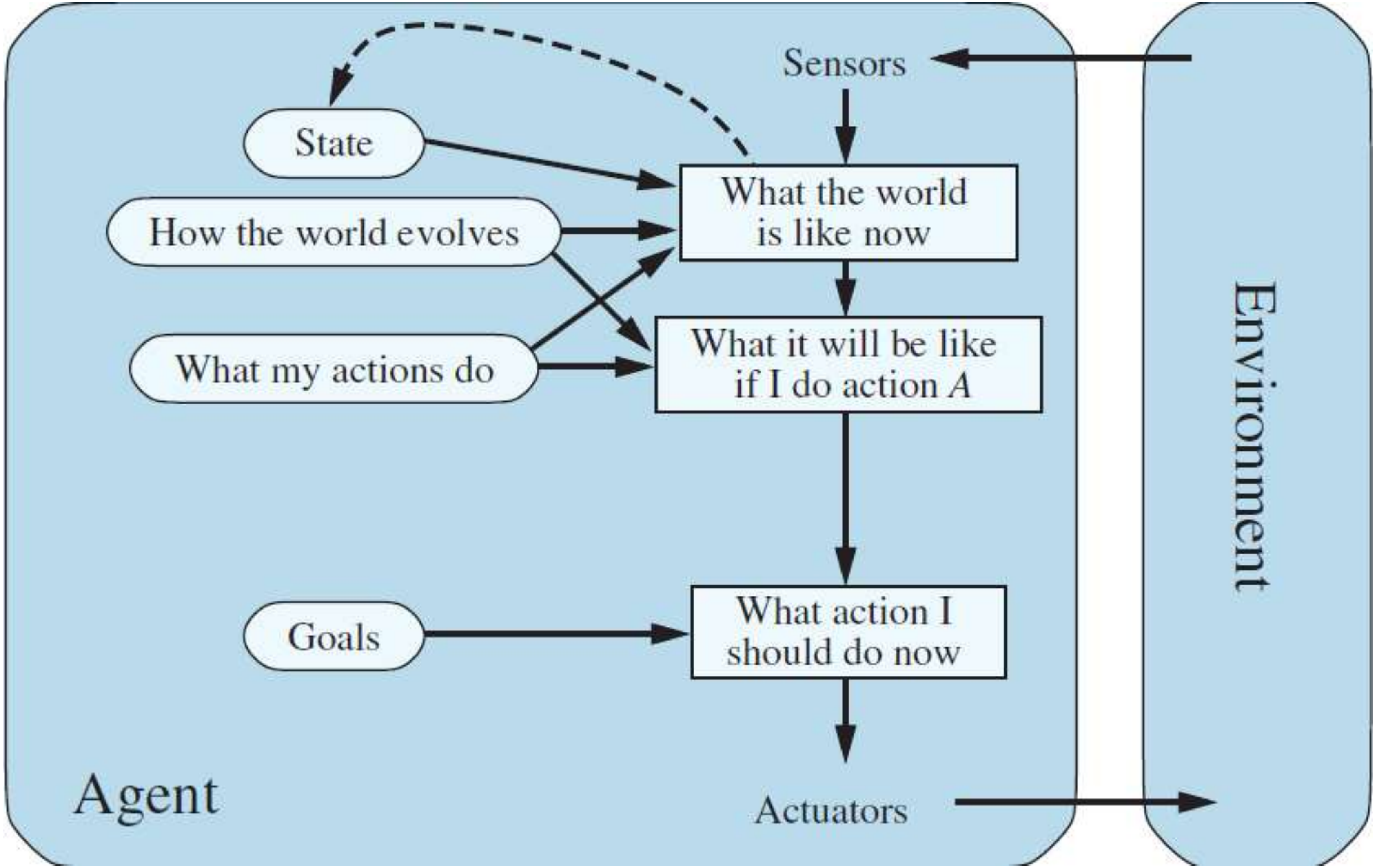
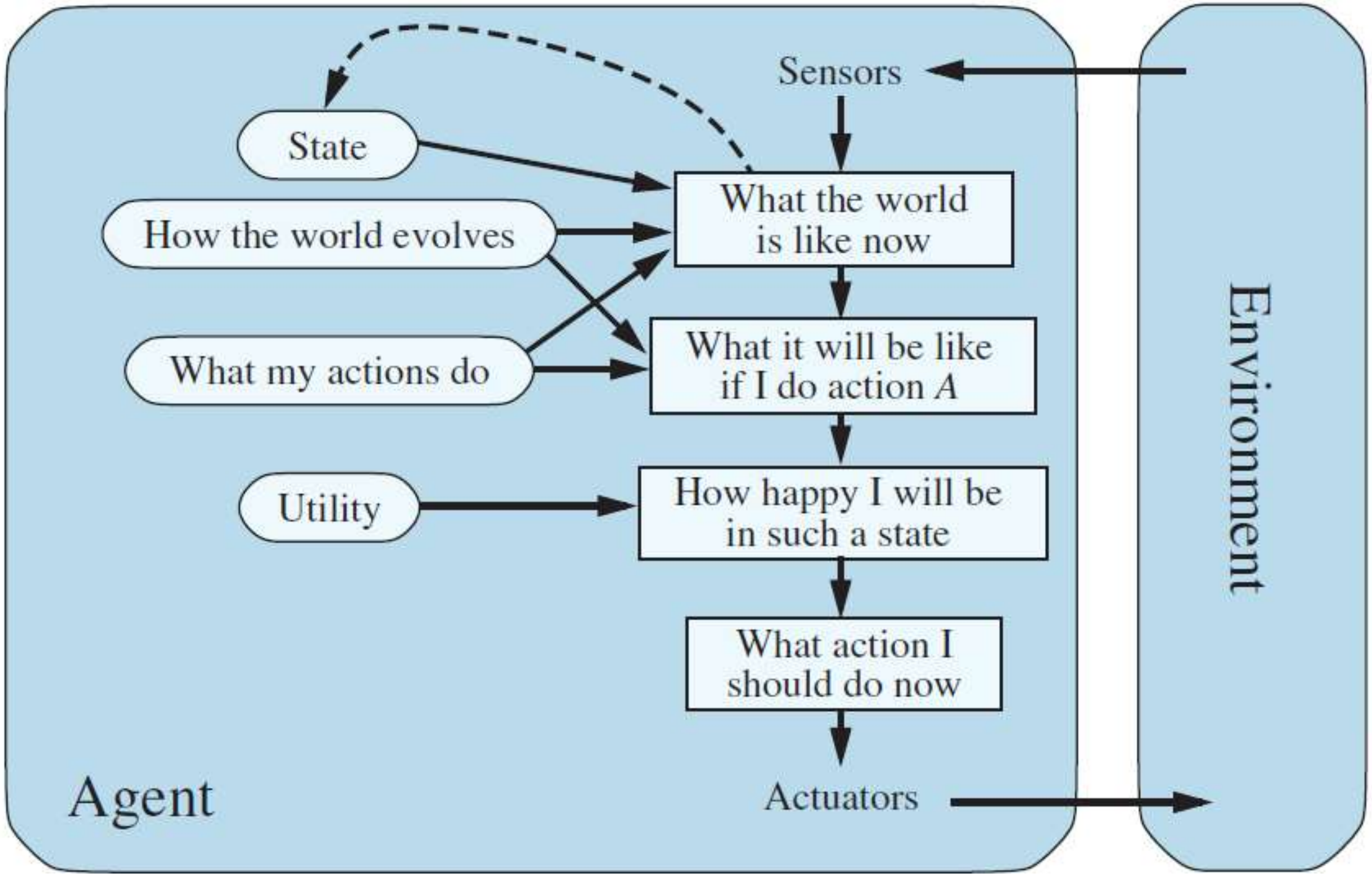
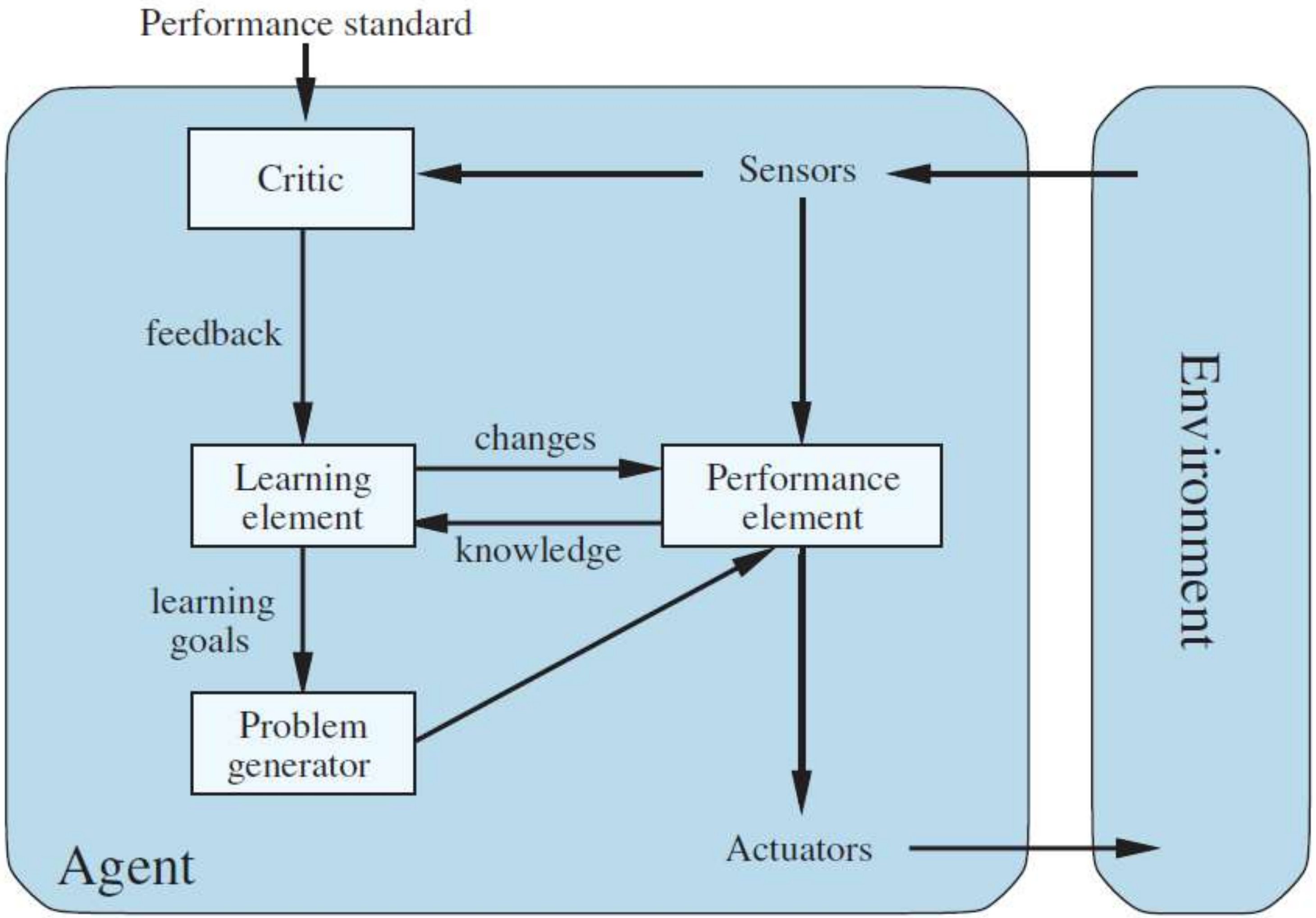


Utility-based agents



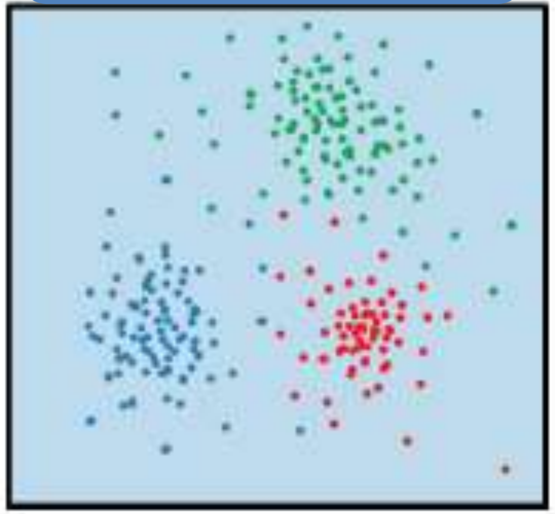
Learning agents



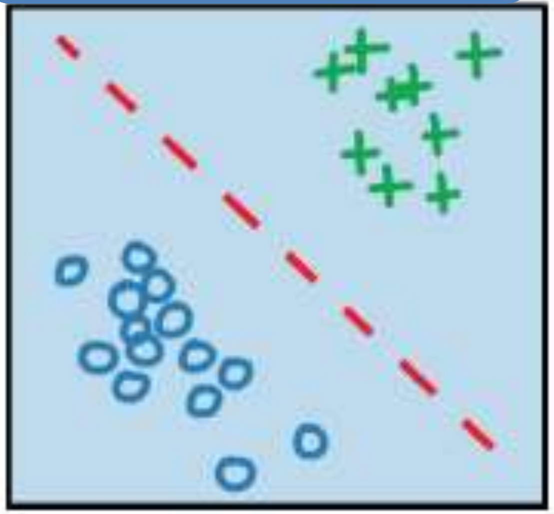
Three broad categories of ML

Machine Learning

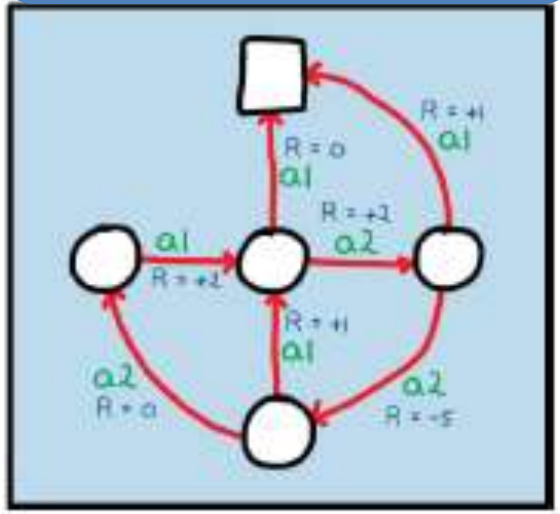
Unsupervised Learning



Supervised Learning



Reinforcement Learning



Google Data Centre Cooling

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- DeepMind AI Reduces Google Data Centre Cooling Bill by 40%

Google Data Centre Cooling

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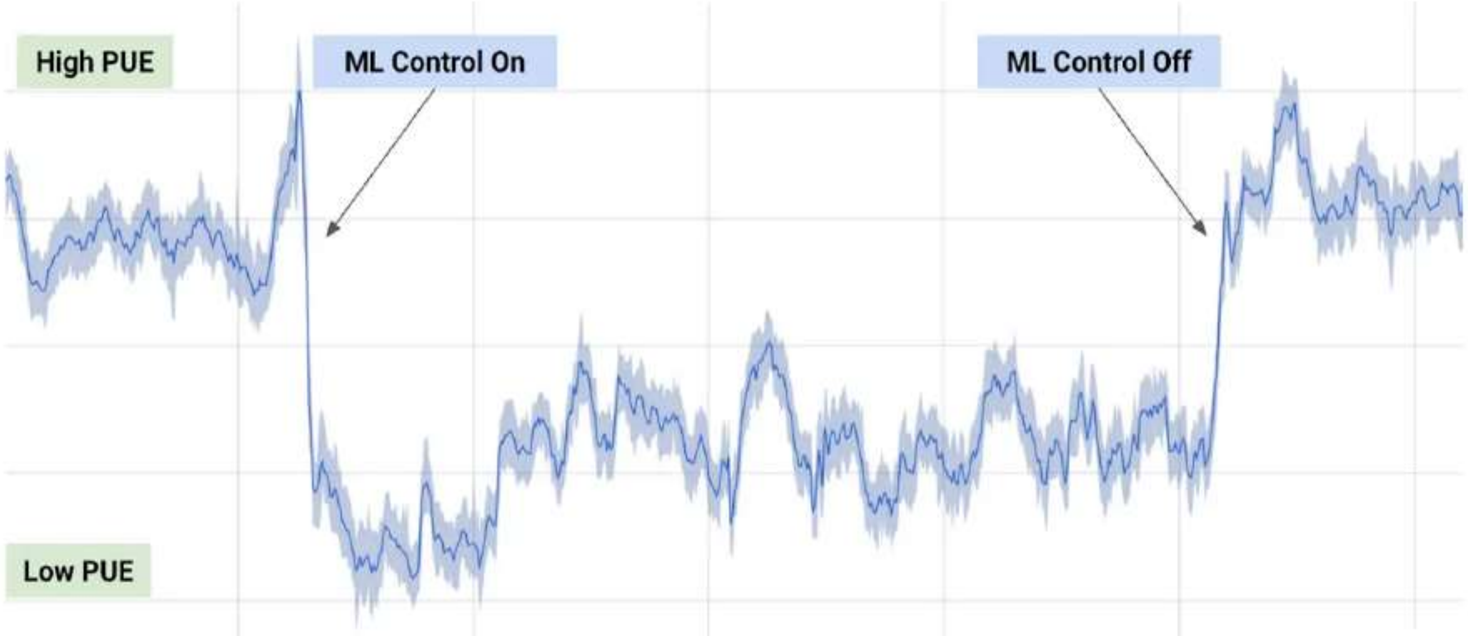
- DeepMind AI Reduces Google Data Centre Cooling Bill by 40%



Google Data Centre Cooling

- DeepMind AI Reduces Google Data Centre Cooling Bill by 40%
- Optimal operation of pumps, chillers and cooling towers
- Compared to five years ago, Google get around 3.5 times the computing power out of the same amount of energy

The sequence episode of actions from the start to the terminal state is an episode, or a trial

Reward-free exploration An algorithm for Reward-Free Exploration (RFE) sequentially collects a database of trajectories in the following way. In each time step t, a policy $\pi^t = (\pi_h^t)_{h=1}^H$ is computed based on data from the $t-1$ previous episodes, a *reward-free episode* $z_t = (s_1^t, a_1^t, s_2^t, a_2^t, \dots, s_H^t, a_H^t)$ is generated under the policy π^t in the MDP starting from a first state $s_1^t \sim P_0$: for all $h \in [H]$, $s_h^t \sim p_h(s_{h-1}^t, \pi^t(s_{h-1}^t))$ and the new trajectory is added to the database: $\mathcal{D}_t = \mathcal{D}_{t-1} \bigcup \{z_t\}$. At the end of each episode, the algorithm can decide to stop collecting data (we denote by τ its random stopping time) and outputs the dataset $\mathcal{D}_\tau$.

- Reference: Emilie Kaufmann et al. Adaptive Reward-Free Exploration https://arxiv.org/pdf/2006.06294.pdf

Thank You

?

Any more Queries

Note : Some of the slides are adopted from Prof. Vimal archives