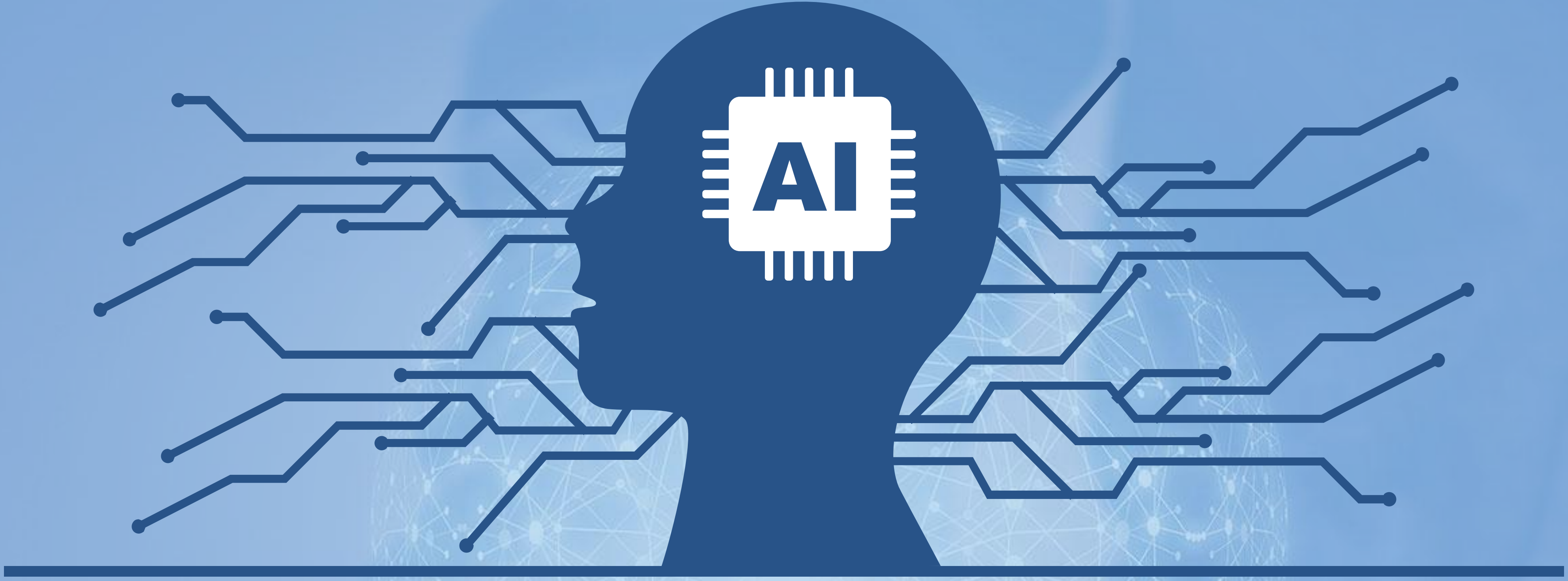


# Advanced Artificial Intelligence

## Introduction

**Dr. Qurat Ul Ain**
Assistant Professor
Dept. of AI & DS
FAST NUCES, Islamabad
Email: quratul.ain@isb.nu.edu.pk

# Google Classroom Code

**ayfrhbcg**

# What is Artificial Intelligence ?

| | | |
|---|---|---|
| THOUGHT | Systems that think like humans | Systems that think rationally |
| BEHAVIOUR | Systems that act like humans | Systems that act rationally |
| | HUMAN | RATIONAL |

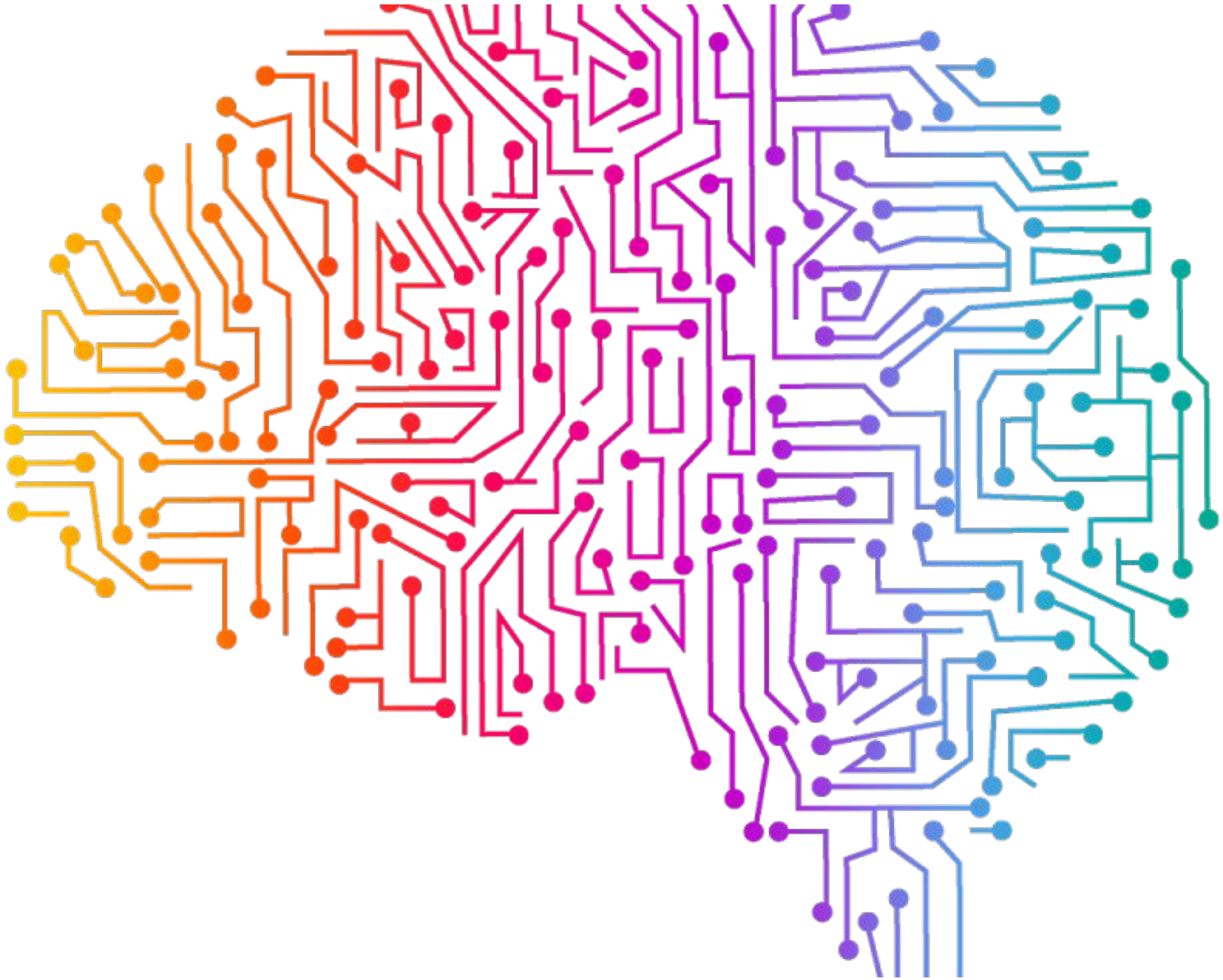
# Systems that act rationally: “Rational agent”

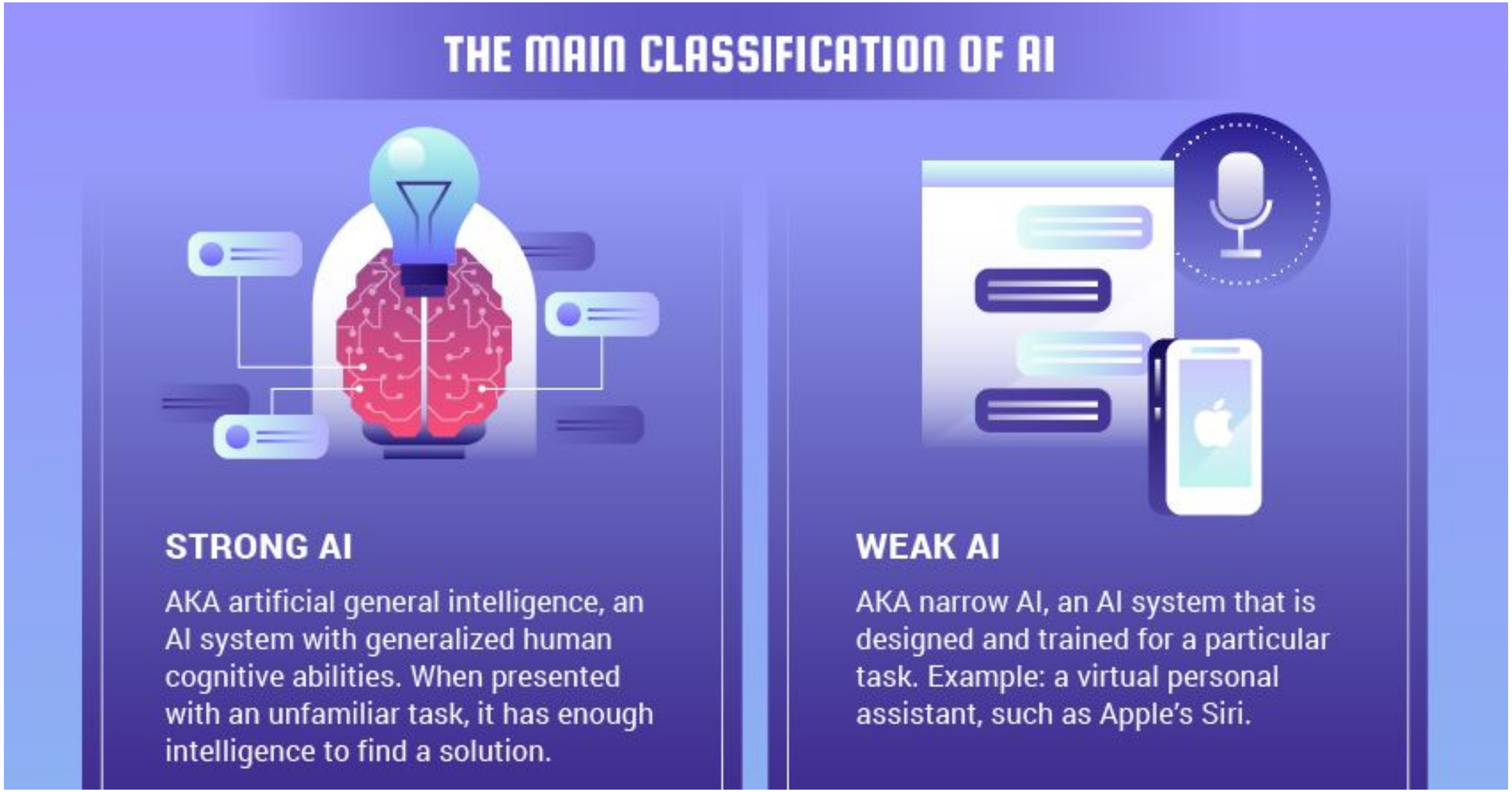
- Rational behavior: doing the right thing
- The right thing: that which is expected to maximize goal achievement, given the available information
- Giving answers to questions is ‘acting’.

# WEAK AI

# vs.

# STRONG AI





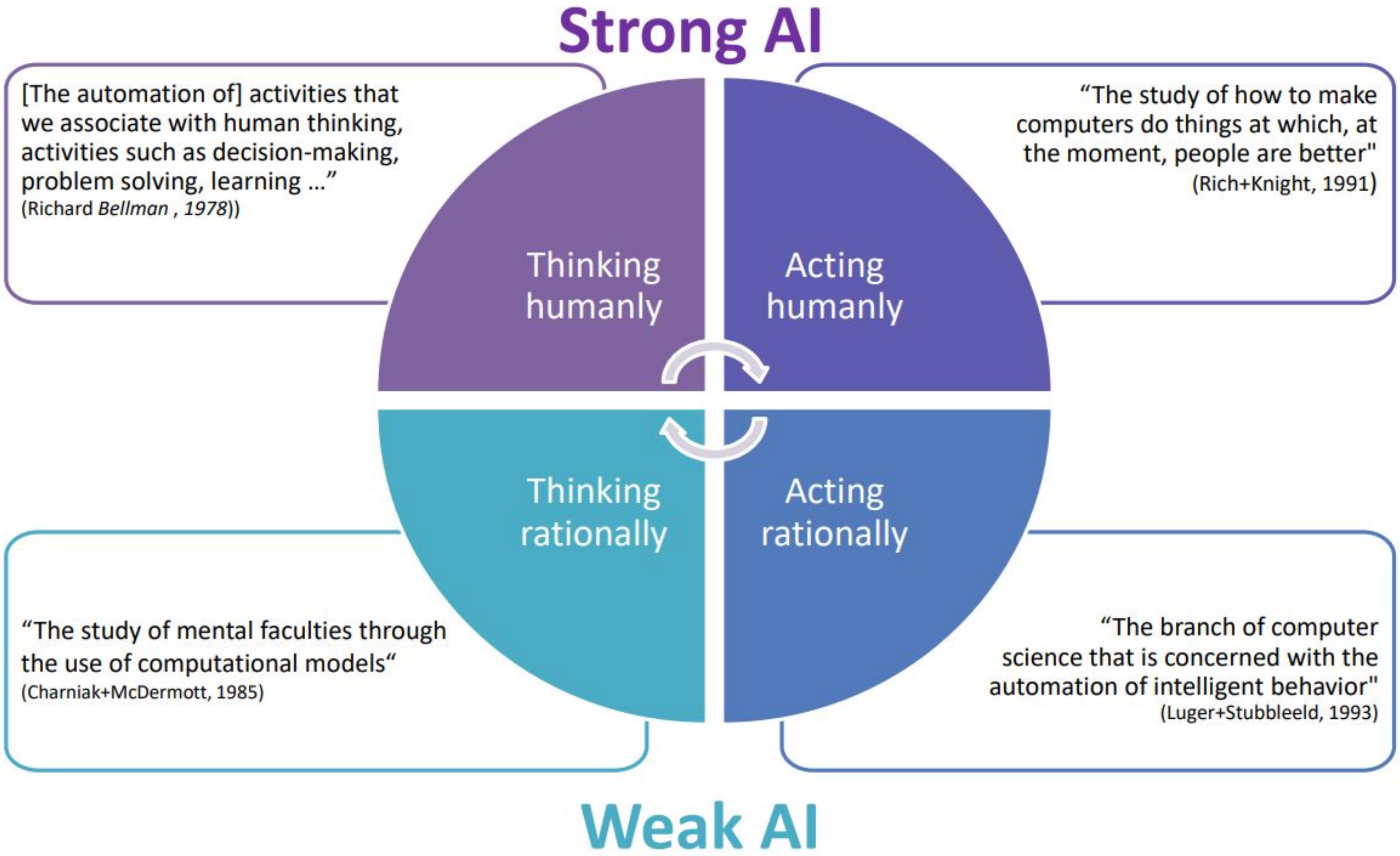
## THE MAIN CLASSIFICATION OF AI

### STRONG AI

AKA artificial general intelligence, an AI system with generalized human cognitive abilities. When presented with an unfamiliar task, it has enough intelligence to find a solution.

### WEAK AI

AKA narrow AI, an AI system that is designed and trained for a particular task. Example: a virtual personal assistant, such as Apple's Siri.



Strong AI

[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning …"
(Richard *Bellman , 1978*))

"The study of how to make computers do things at which, at the moment, people are better"
(Rich+Knight, 1991)

Thinking humanly

Acting humanly

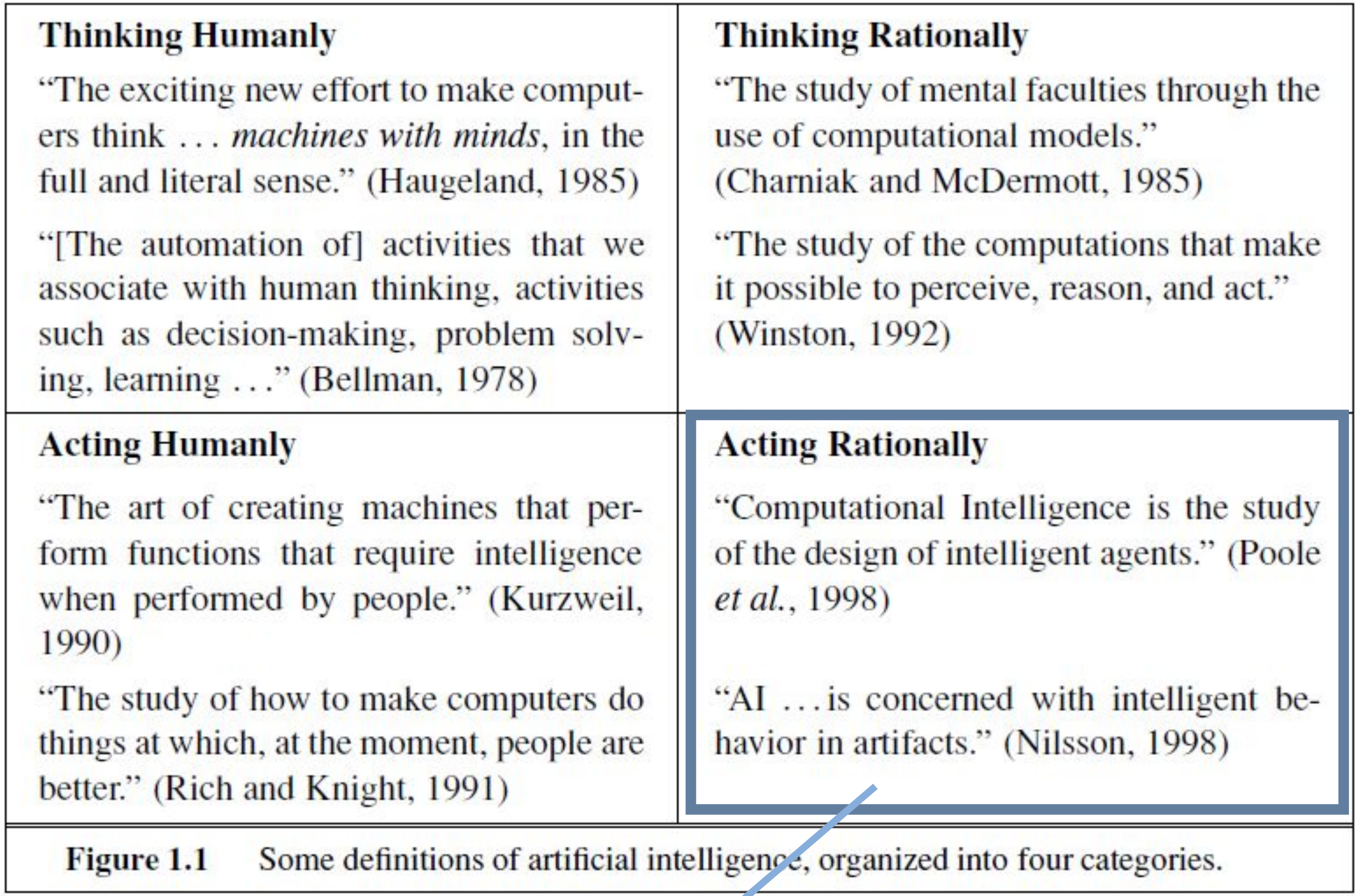
Thinking rationally

Acting rationally

"The study of mental faculties through the use of computational models"
(Charniak+McDermott, 1985)

"The branch of computer science that is concerned with the automation of intelligent behavior"
(Luger+Stubbleeld, 1993)

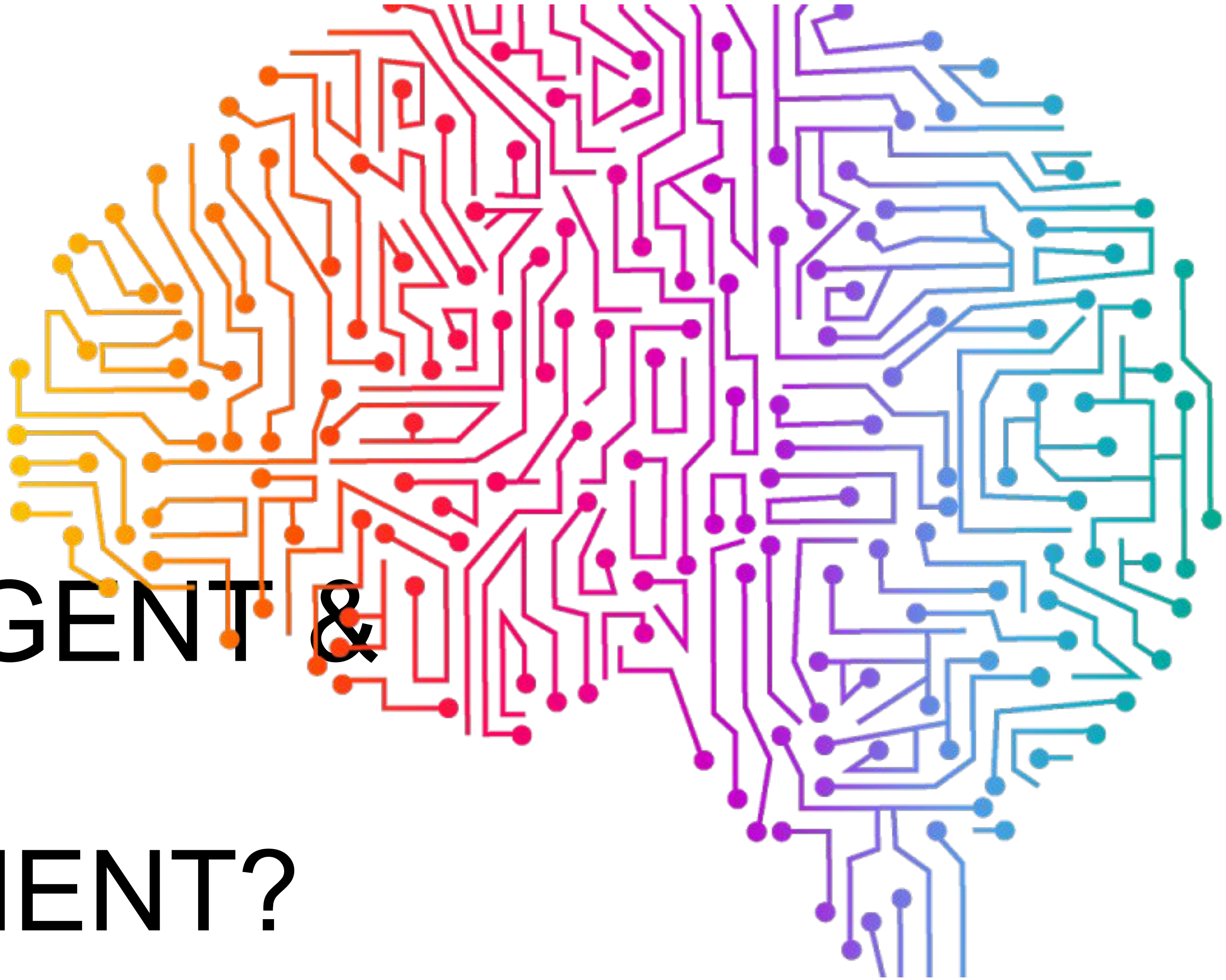
Weak AI



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

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

Focus of this course

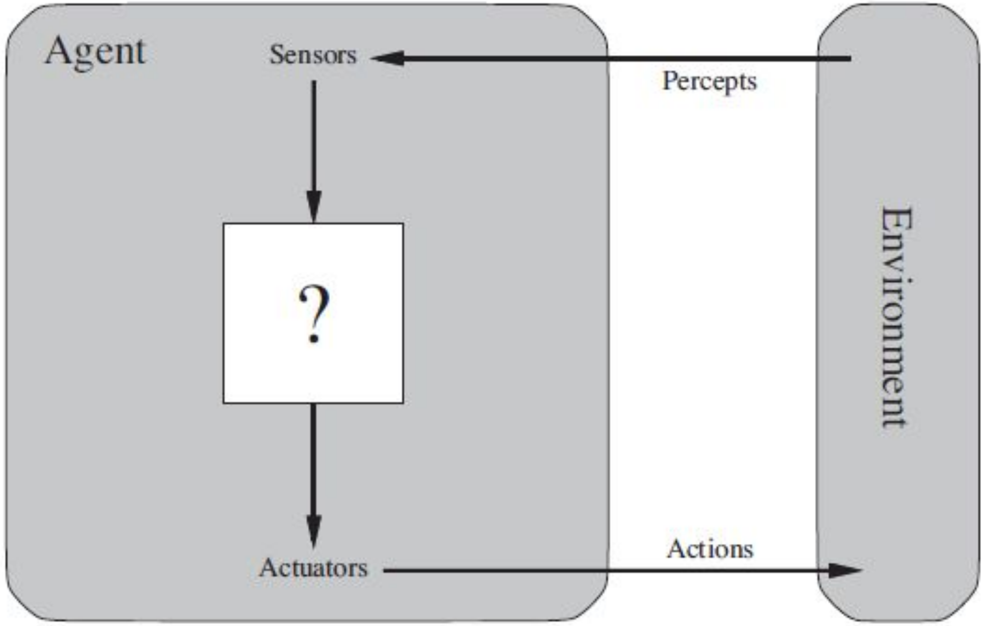


# WHAT IS AN AGENT &

# ITS ENVIRONMENT?

# Agents and Environment

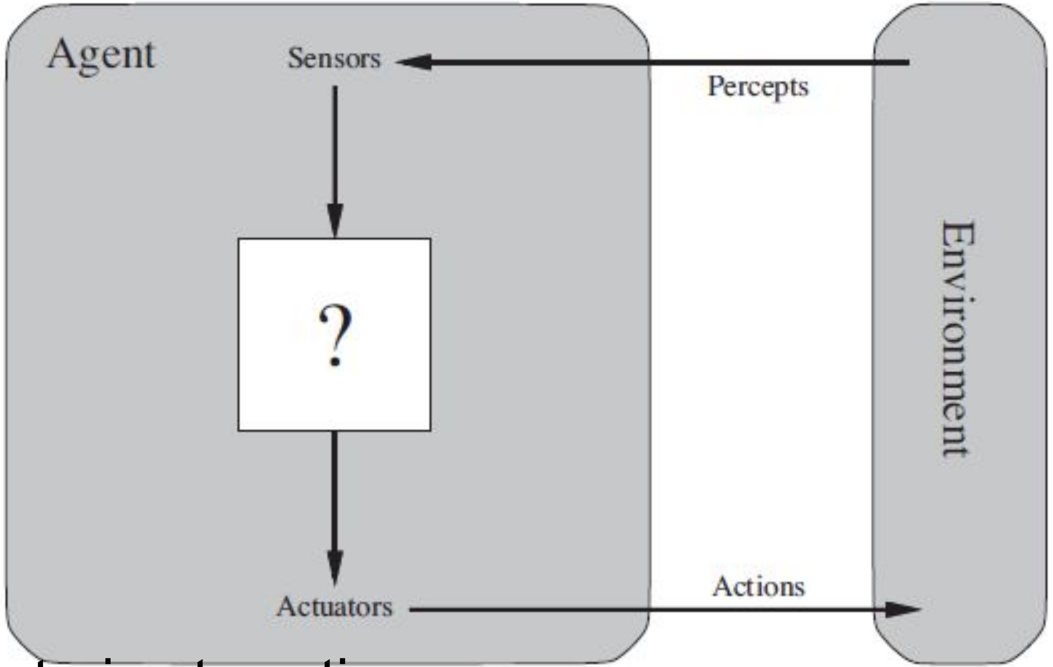
- An **agent** is anything that can be viewed as perceiving its **environment** through **sensors** and acting upon that environment through **actuators.**



| Agent | Sensor | Actuator |
|---|---|---|
| Human | Eyes, Nose, Ears, Touch | Arms/Legs |
| Robot | Camera, Infra Ranges | Motors |
| Software | Keystokes<br>File Receiving<br>Receive Packets | Screen Display<br>File Writing<br>Sending Packets |

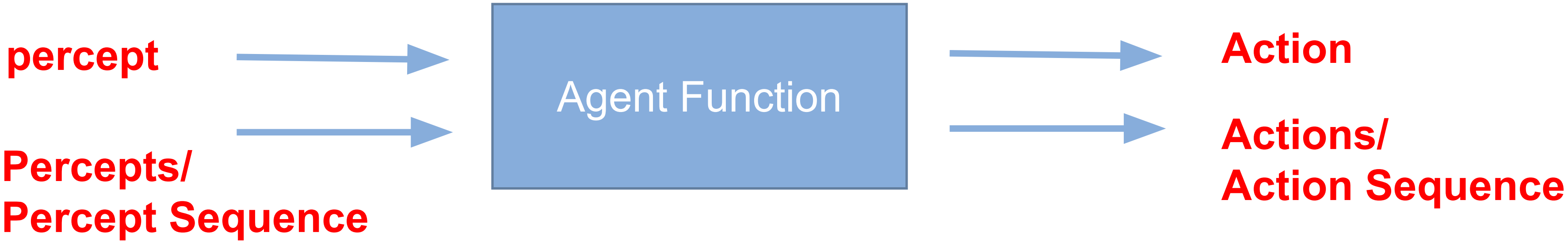
# Agents and Environment

- We use the term **percept** to refer to the agent's perceptual inputs at any given instant.
- Agent's **percept sequence** is the complete history of everything the agent has ever perceived.



The agent function maps from percept histories to actions:

$f : P^* \rightarrow A$



**percept**

**Percepts/ Percept Sequence**

Agent Function

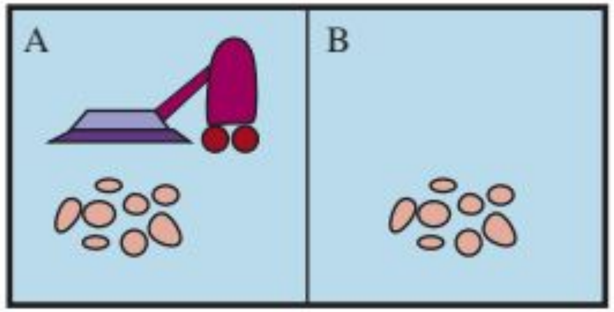
**Action**

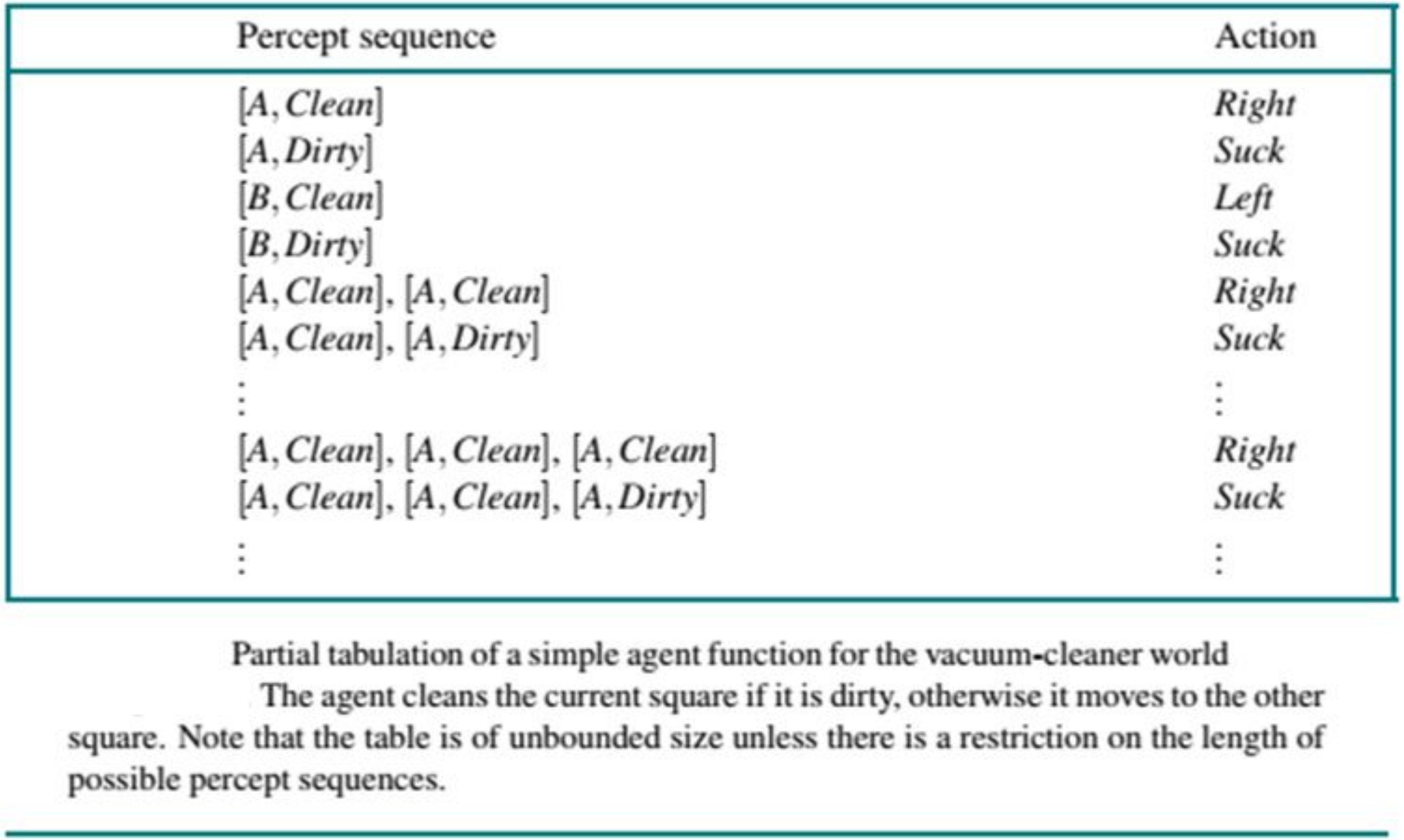
**Actions/ Action Sequence**

# Rational Agent

- A **rational agent** is one that does the right thing.
- When an agent is plunked down in an environment, it generates a sequence of actions according to the percepts it receives.
- This sequence of actions causes the environment to go through a sequence of states. If the sequence of states is desirable, then the agent has performed well.
- This notion of desirability is captured by a **performance measure** that evaluates any given sequence of environment states.

```
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
```



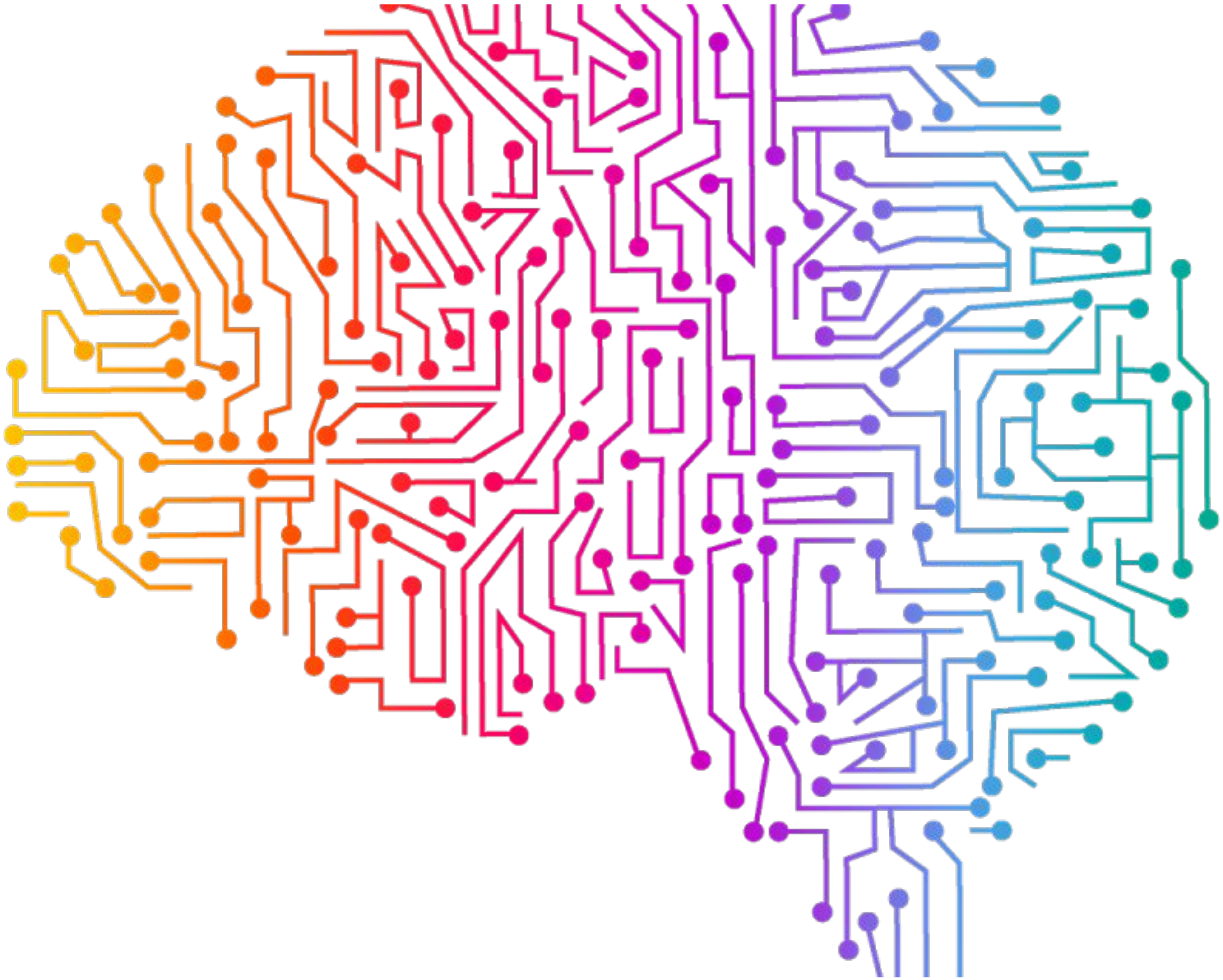


| Percept sequence | Action |
|---|---|
| $[A, Clean]$ | *Right* |
| $[A, Dirty]$ | *Suck* |
| $[B, Clean]$ | *Left* |
| $[B, Dirty]$ | *Suck* |
| $[A, Clean], [A, Clean]$ | *Right* |
| $[A, Clean], [A, Dirty]$ | *Suck* |
| ⋮ | ⋮ |
| $[A, Clean], [A, Clean], [A, Clean]$ | *Right* |
| $[A, Clean], [A,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

Partial tabulation of a simple agent function for the vacuum-cleaner world

The agent cleans the current square if it is dirty, otherwise it moves to the other square. Note that the table is of unbounded size unless there is a restriction on the length of possible percept sequences.

# RATIONALITY

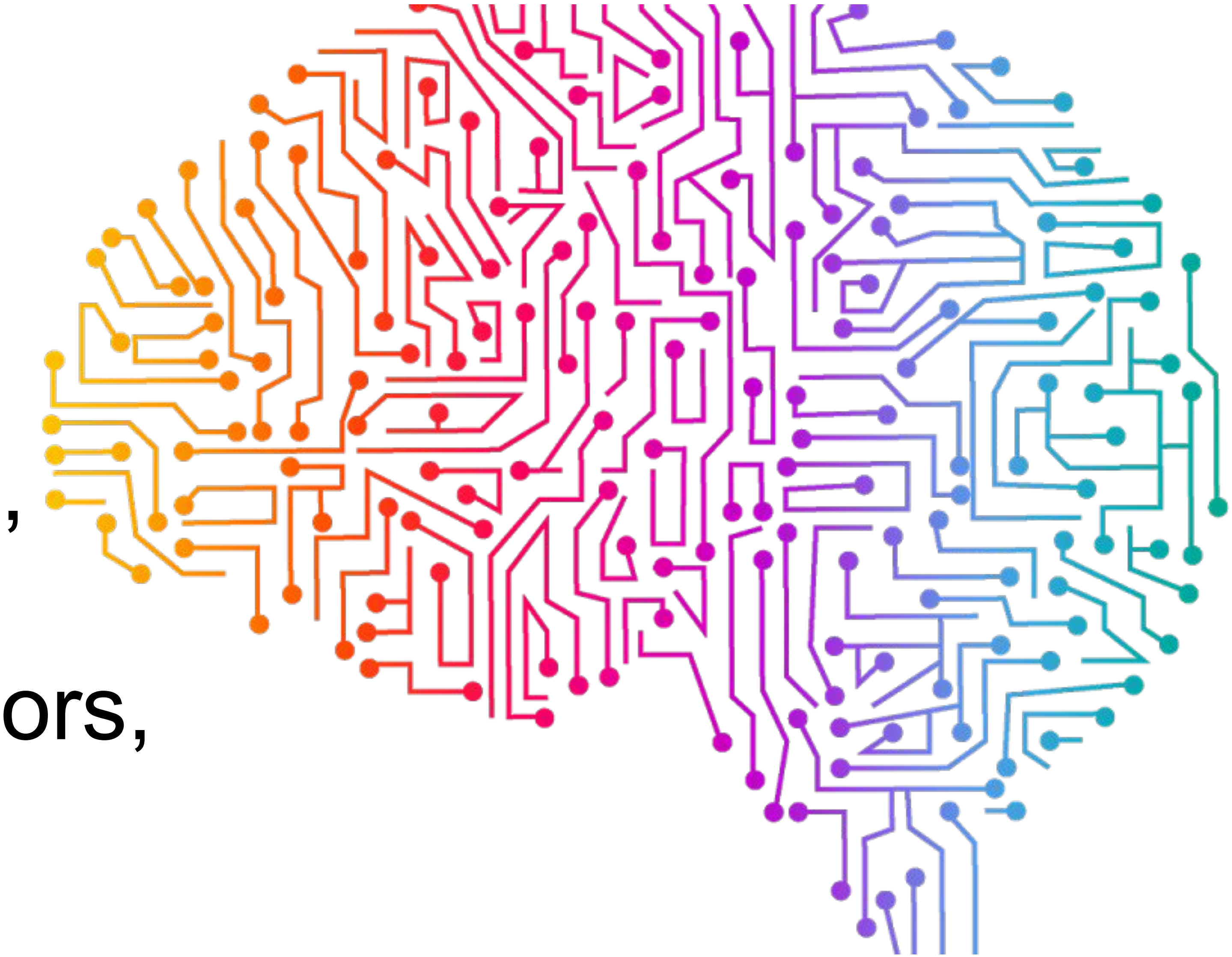


# Rationality

- What is rational at any given time depends on four things:
  - The performance measure that defines the criterion of success.
  - The agent’s prior knowledge of the environment.
  - The actions that the agent can perform.
  - The agent’s percept sequence to date

- This leads to a **definition of a rational agent:**
  - *For each possible percept sequence, a rational agent should select an action expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has.*

# PEAS (Performance, Environment, Actuators, Sensors)



# PEAS (Performance, Environment, Actuators, Sensors)

- To design a rational agent, we must specify the task environment
- Consider, e.g., the task of designing an automated taxi:
- Performance measure??
- Environment??
- Actuators??
- Sensors??

# PEAS

- To design a rational agent, we must specify the task environment
- Consider, e.g., the task of designing an **automated taxi**:
- Performance measure?? safety, destination, profits, comfort, optimum speed . . .
- Environment?? streets/freeways, traffic, pedestrians, weather, . . .
- Actuators?? steering, accelerator, brake, horn, speaker/display, . . .
- Sensors?? Video camera, gauges, engine sensors, keyboard, GPS, . . .

# Internet shopping agent

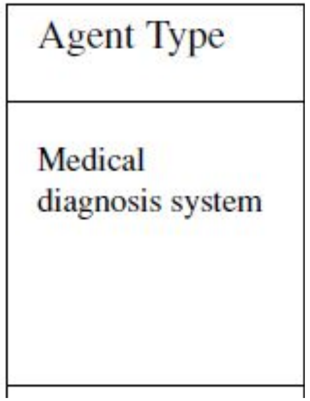
- Performance measure??
- Environment??
- Actuators??
- Sensors??

# 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 (text, graphics, scripts)

# PEAS (Performance, Environment, Actuators, Sensors)

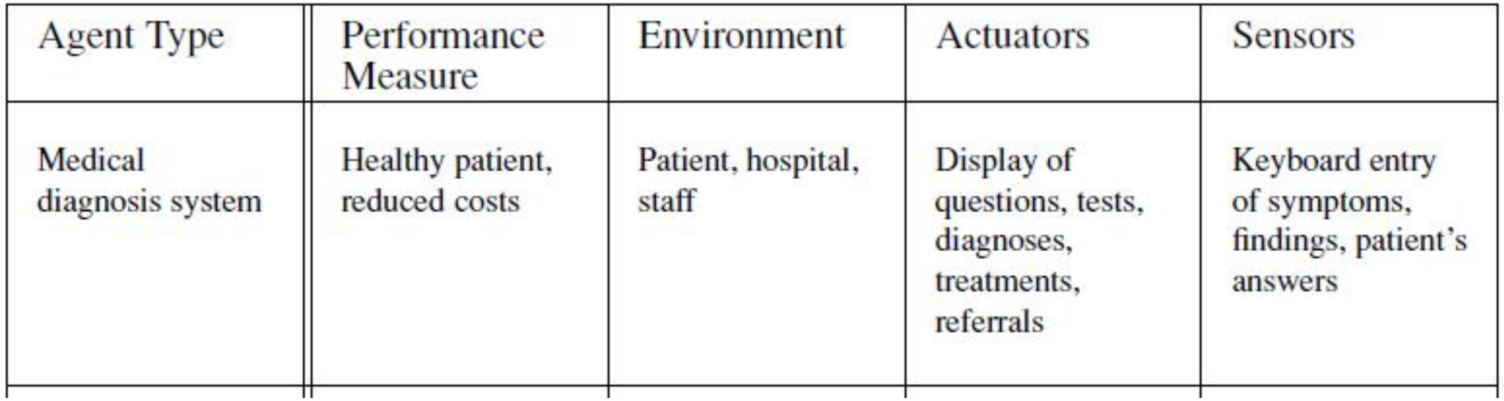
- Agent: Medical Diagnostic System



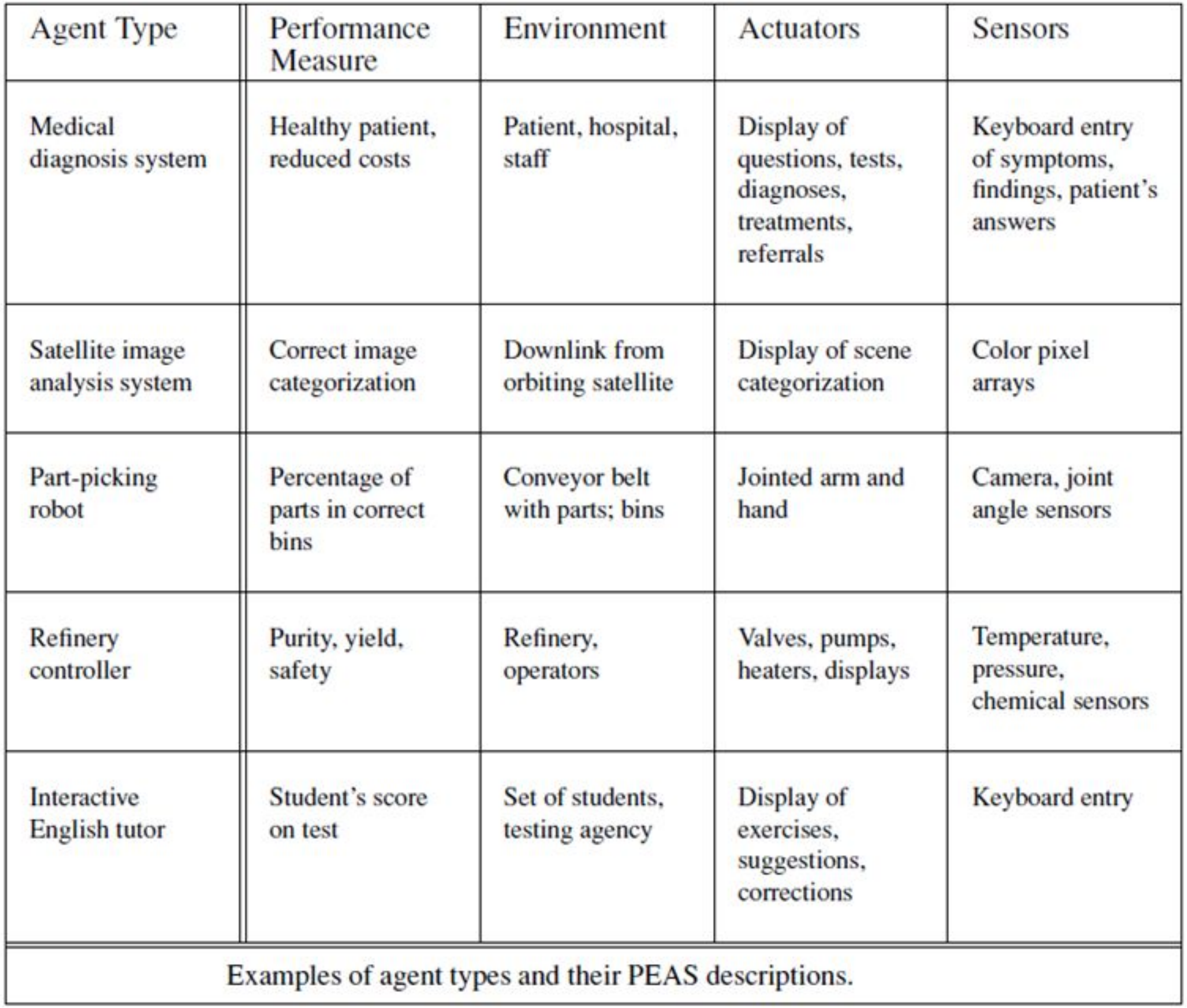
| Agent Type |
|---|
| Medical diagnosis system |

# PEAS (Performance, Environment, Actuators, Sensors)

- Agent: Medical Diagnostic System



| 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 |

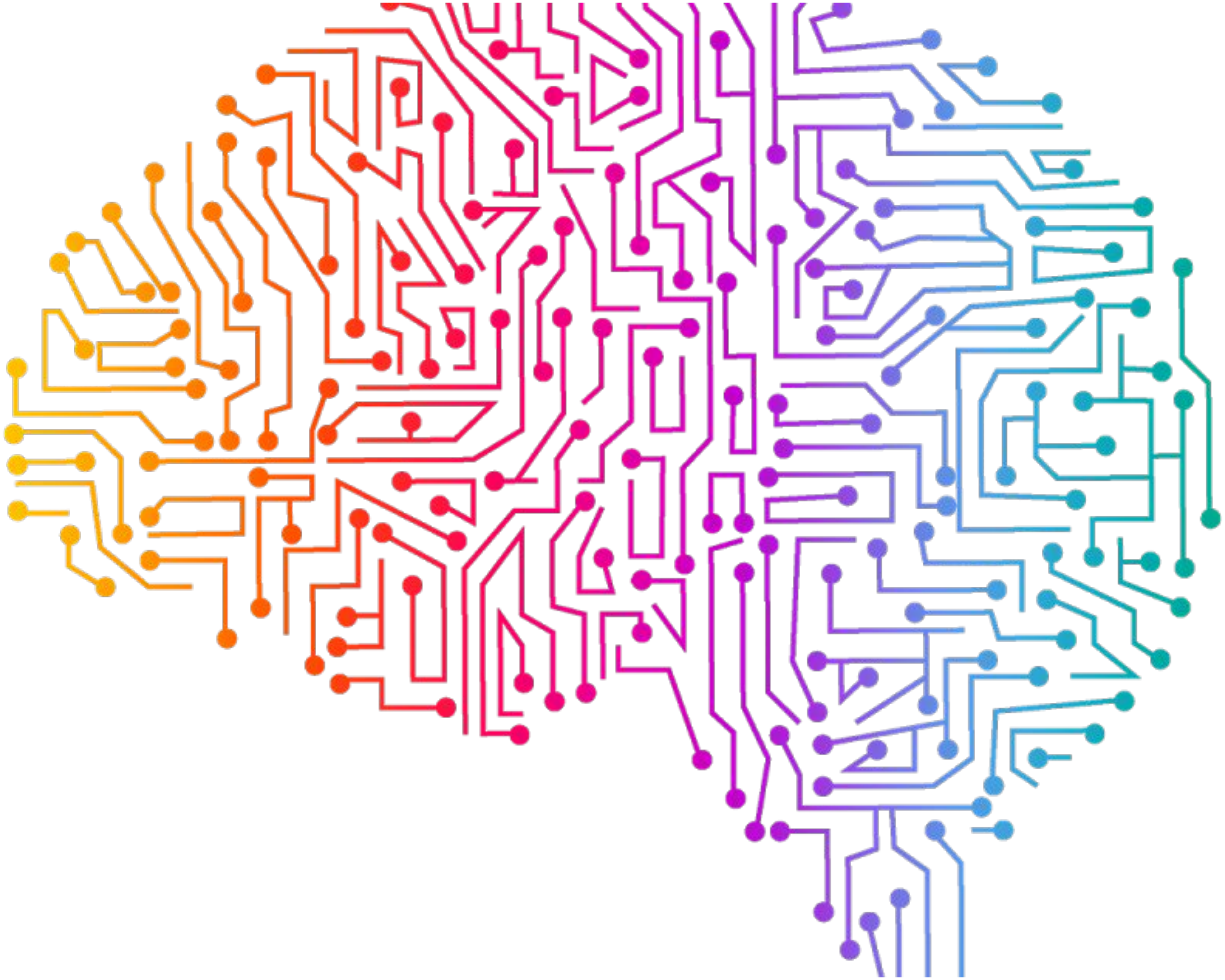


| Agent Type | Performance Measure | Environment | Actuators | Sensors |
|---|---|---|---|---|
| Medical diagnosis system | Healthy patient, reduced costs | Patient, hospital, staff | Display of questions, tests, diagnoses, treatments, referrals | Keyboard entry of symptoms, findings, patient's answers |
| 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 |

Examples of agent types and their PEAS descriptions.

# Types of Task

# Environment



# Types of Environment

- **Fully observable** vs. **partially observable**
- **Single agent** vs. **multi agent**
- **Deterministic** vs. **stochastic**
- **Episodic** vs. **sequential**
- **Static** vs. **dynamic**
- **Discrete** vs. **continuous**
- **Known** vs. **unknown**

# Fully observable vs. Partially observable

## Fully Observable

- If an agent's sensors give it access to the complete state of the environment at each point in time, then we say that the task environment is fully observable.
- Fully observable environments are convenient because the agent need not maintain any internal state to keep track of the world.

## Partially Observable

- An environment might be partially observable because of noisy and inaccurate sensors or because parts of the state are simply missing from the sensor data.
- For example, a vacuum agent with only a local dirt sensor cannot tell whether there is dirt in other squares, and an automated taxi cannot see what other drivers are thinking.

## Single

- An agent solving a crossword puzzle by itself is clearly in a single-agent environment.

## Multi-Agent

- whereas an agent playing chess is in a **two-agent environment.**
- For example, **in chess**, the opponent entity B is trying to maximize its performance measure, which, by the rules of chess, minimizes agent A's performance measure. Thus, chess is a **competitive** multiagent environment.
- In the **taxi-driving environment**, on the other hand, avoiding collisions maximizes the performance measure of all agents, so it is a partially **cooperative** multiagent environment.

## Deterministic

- If the next state of the environment is completely determined by the current state and the action executed by the agent, then we say the environment is deterministic

- The **vacuum world** is deterministic.

## Stochastic

- Otherwise, it is stochastic (or non-deterministic).

- In principle, an agent need not worry about uncertainty in a fully observable, deterministic environment. If the environment is partially observable, however, then it could *appear* to be stochastic.
- **Taxi driving** is clearly stochastic in this sense, because one can never predict the behavior of traffic exactly.

## Episodic

- In each episode the agent receives a percept and then performs a single action. Crucially, the next episode does not depend on the actions taken in previous episodes. E.g. spotting faults in an assembly line.
- Episodic environments are much simpler than sequential environments because the agent does not need to think ahead

## Sequential

- In sequential environments, on the other hand, the current decision could affect all future decisions.
- **Chess and taxi driving** are sequential: in both cases, short-term actions can have long-term consequences.

## Static

- Static environments are easy to deal with because the agent need not keep looking at the world while it is deciding on an action, nor need it worry about the passage of time.
- Crossword puzzles are static.

## Dynamic

- **If the environment can change while an agent is deliberating**, then we say the environment is dynamic for that agent
- If the environment itself does not change with the passage of time but the agent’s performance score does, then we say the environment is **semidynamic**.
- **Taxi driving** is clearly **dynamic**: the other cars and the taxi itself keep moving while the driving algorithm dicides what to do next.
- **Chess,** when played with a clock, is **semidynamic.**

**Discrete**

- The environment in which a finite set of possibilities can drive the outcome of the task.
- **Chess** -> Discrete states, percepts and actions

**Continuous**

- Rely on unknown and rapidly changings data sources
- **Taxi Driving -> Continuous** state-time problem including actions like steering angles, although location, speed of taxi and camera input can be “discretized”.

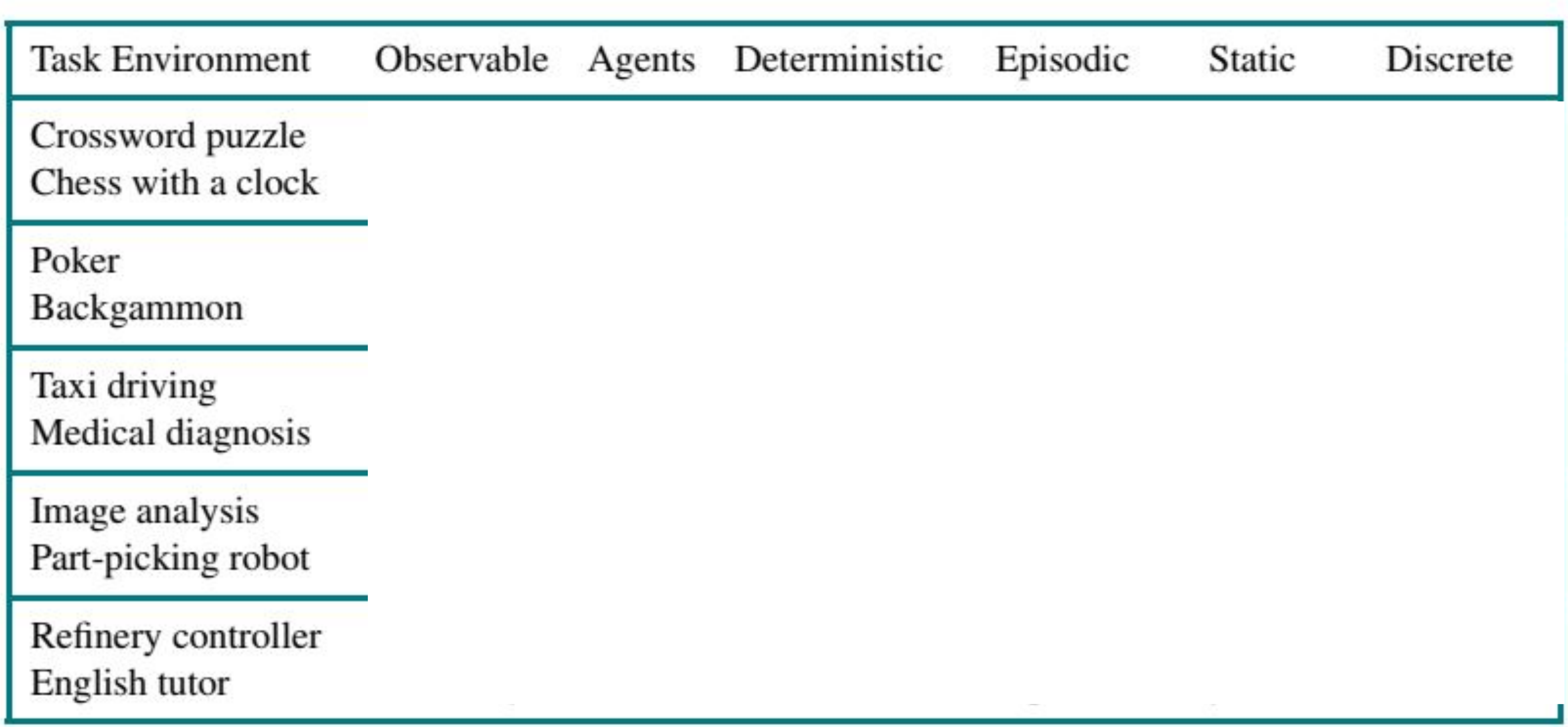
## Known

- Strictly speaking, this distinction refers not to the environment itself but to the agent's (or designer's) state of knowledge.
- In a known environment, the outcomes (or outcome probabilities if the environment is stochastic) for all actions are given.
- It is quite possible for a *known* environment to be *partially* observable—for example, in solitaire card games, I know the rules but am still unable to see the cards that have not yet been turned over.

## Unknown

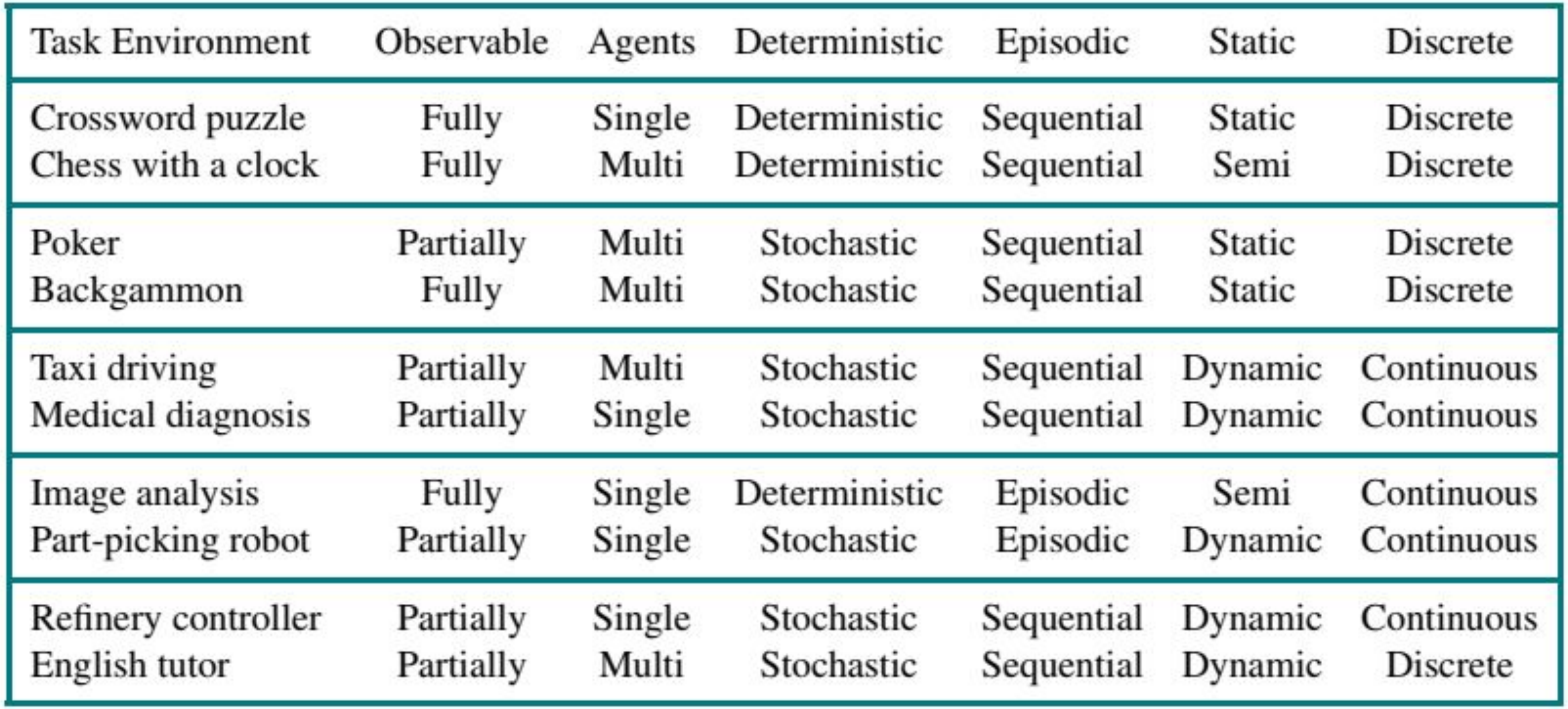
- The distinction between known and unknown environments is not the same as the one between fully and partially observable environments.
- Conversely, an *unknown* environment can be *fully* observable—in a new video game, the screen may show the entire game state but I still don't know what the buttons do until I try them.

# Environment types



| Task Environment | Observable | Agents | Deterministic | Episodic | Static | Discrete |
|---|---|---|---|---|---|---|
| Crossword puzzle | | | | | | |
| Chess with a clock | | | | | | |
| Poker | | | | | | |
| Backgammon | | | | | | |
| Taxi driving | | | | | | |
| Medical diagnosis | | | | | | |
| Image analysis | | | | | | |
| Part-picking robot | | | | | | |
| Refinery controller | | | | | | |
| English tutor | | | | | | |

# Environment types



| 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 |

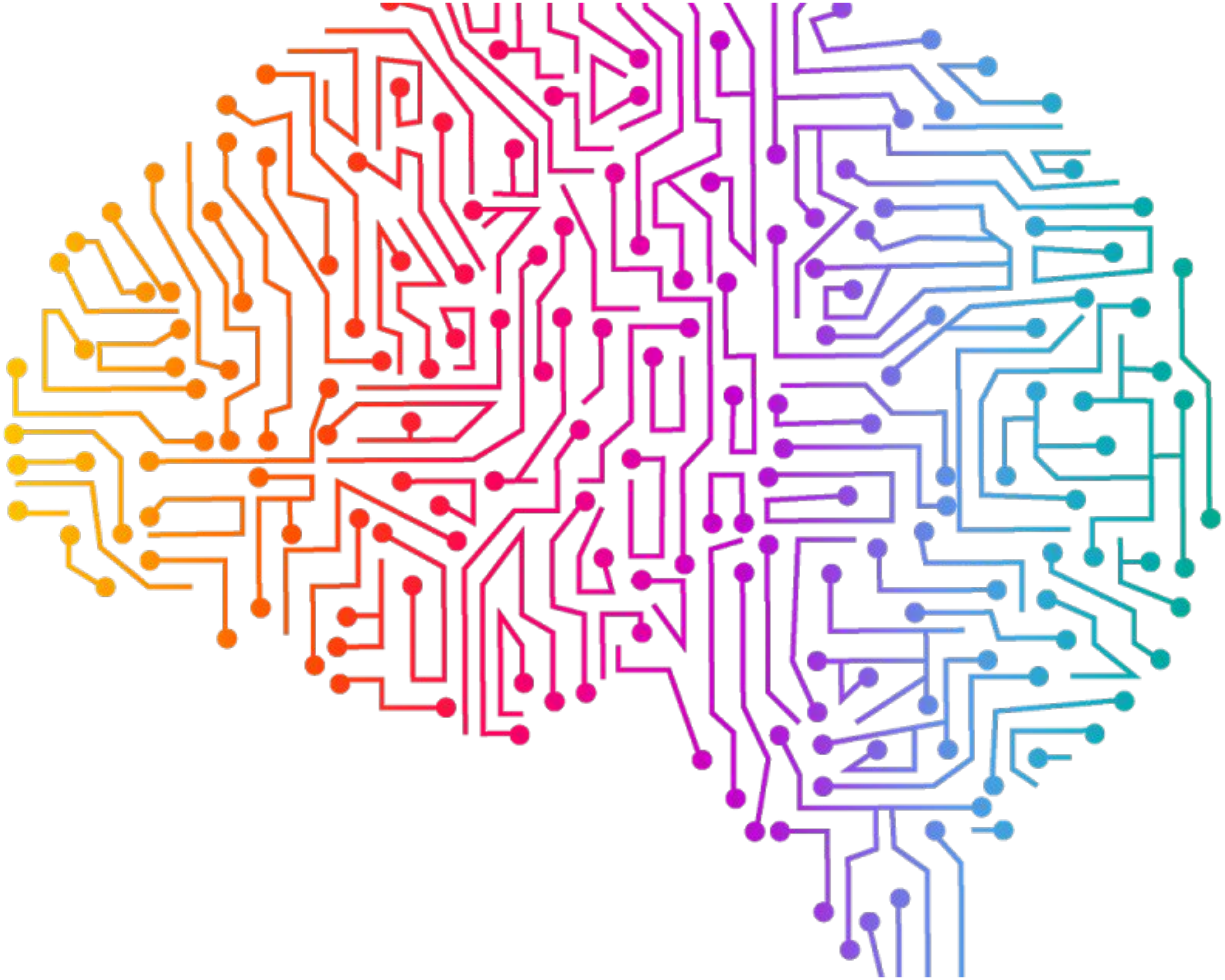
# Environment types

| | Medical Diagnostic sys | Internet Shopping | Automated Taxi | Chess |
|---|---|---|---|---|
| Observable?? | | | | |
| Deterministic?? | | | | |
| Episodic?? | | | | |
| Static?? | | | | |
| Discrete?? | | | | |
| Single-agent?? | | | | |

# Environment types

| | Medical Diagnostic sys | Internet Shopping | Automated Taxi | Chess |
|---|---|---|---|---|
| Observable?? | Partially | No | Partially | Yes |
| Deterministic?? | No | Partly | No | Yes |
| Episodic?? | No | No | No | No |
| Static?? | No | Semi | No | Yes |
| Discrete?? | No | Yes | No | Yes |
| Single-agent?? | No | Yes | No | No |

# Agent Types



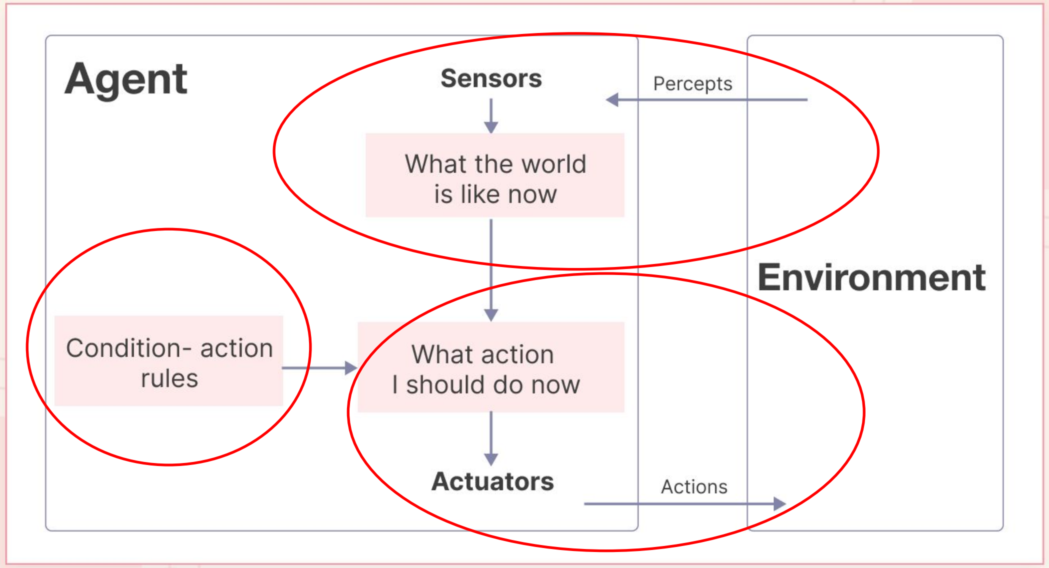
# Agent Types

- simple reflex agents
- reflex agents with state
- goal-based agents
- utility-based agents

- All of these 4 types can be turned into **learning agents**

# Simple Reflex Agent

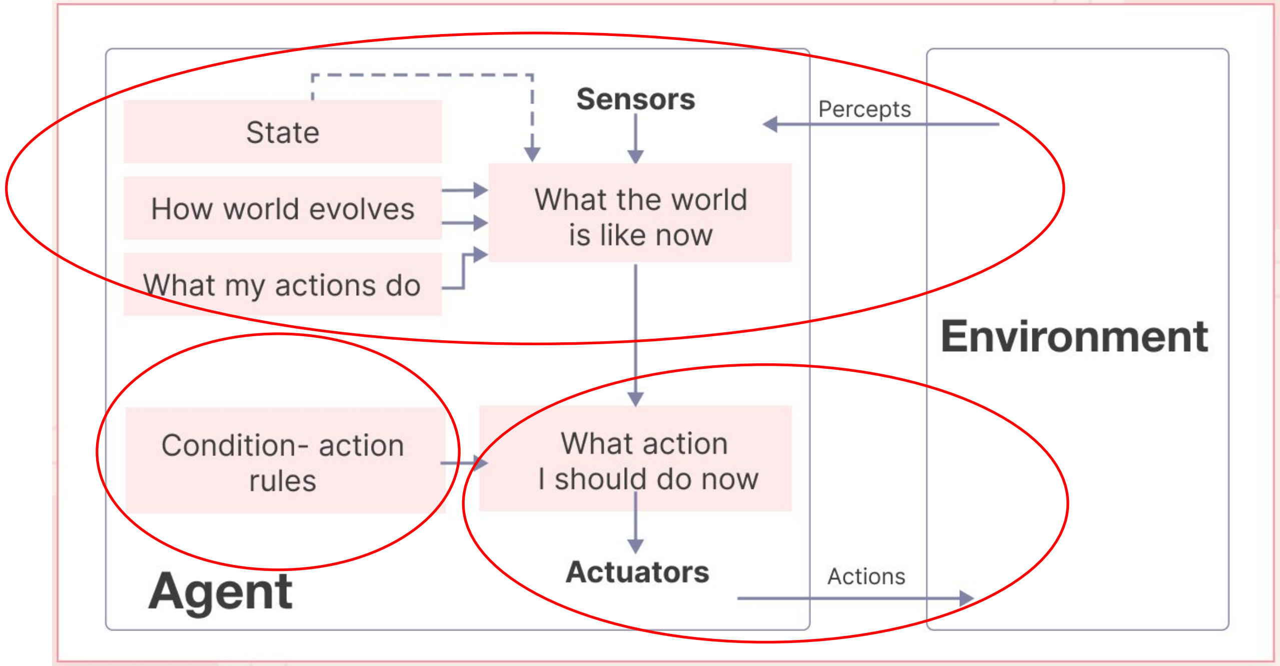
- A simple reflex agent is an AI system that follows pre-defined rules to make decisions. It only responds to the current situation without considering the past or future ramifications.
- A simple reflex agent is suitable for environments with **stable rules and straightforward actions,** as its behavior is purely reactive and responsive to immediate environmental changes.
- **if** *car-in-front-is-braking* **then** *initiate-braking*
- **Example:** A rule-based system developed to support automated customer query. The system can automatically generate a predefined response containing instructions on resetting the password etc.



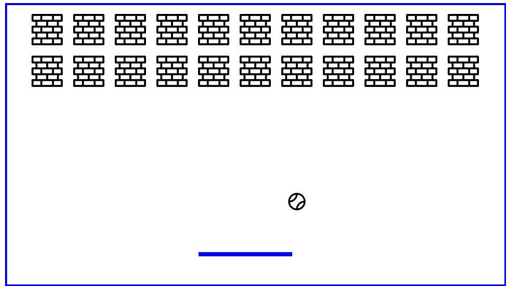
# Model-based reflex agents

- A model-based reflex performs actions based on a current percept and an internal state representing the unobservable word. It updates its internal state based on two factors:
  - How the world evolves independently of the agent
  - How does the agent's action affect the world

- **Example:** Amazon Services that uses foundational models to simulate operations, gain insights, and make informed decisions for effective planning and optimization.



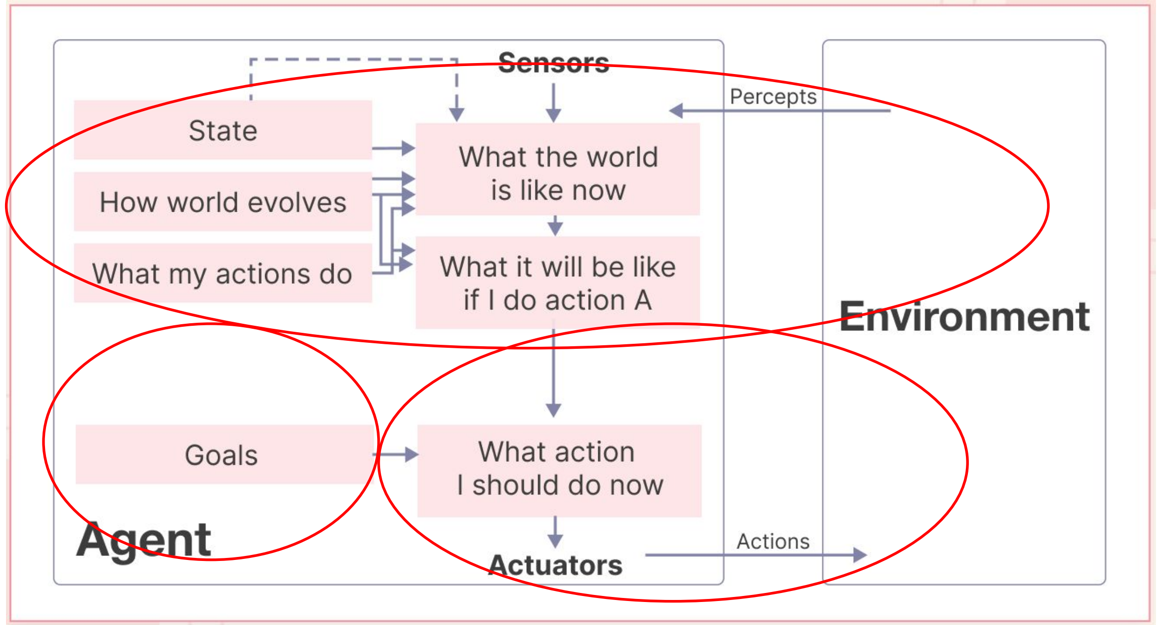
# Goal-based Agents



- Goal-based agents are AI agents that use information from their environment to achieve specific goals. They employ search algorithms to find the most efficient path towards their objectives within a given environment.

- These agents are also known as rule-based agents, as they follow predefined rules to accomplish their goals and take specific actions based on certain conditions.

▯ **Example:** Google Bard, it has a goal or objective to provide high-quality responses to user queries. It chooses its actions that are likely to assist users in finding the information they seek and achieving their desired goal of obtaining accurate and helpful responses.

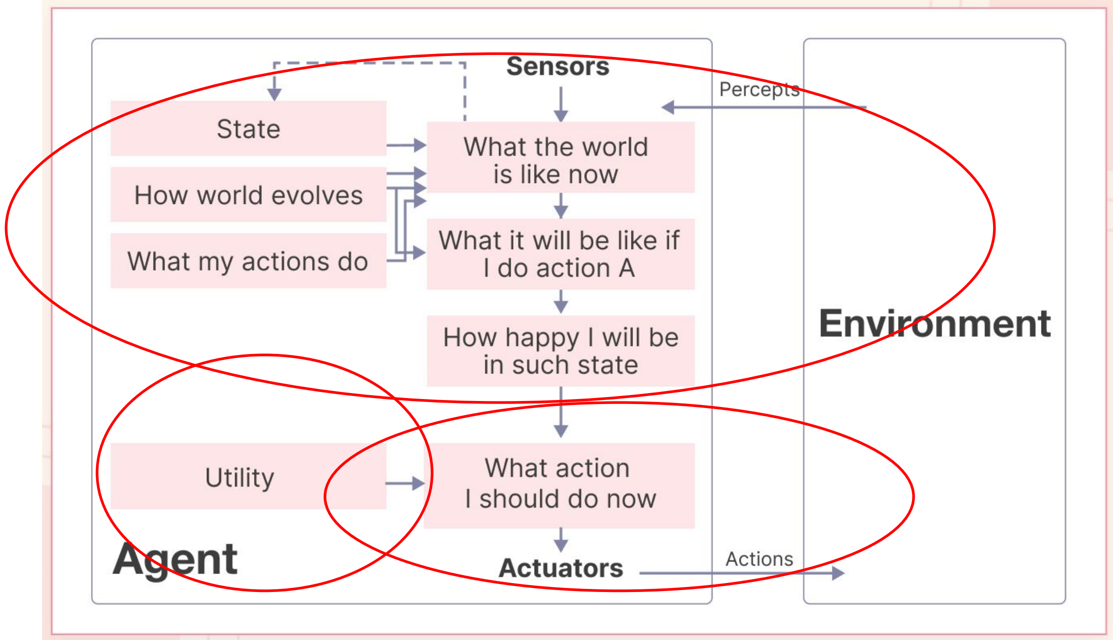


# Utility-based Agents

- Many ways to achieve a “goal” e.g. to reach a particular destination but which one is quicker, cheaper and more reliable? (Performance Measures)
- Utility-based agents are AI agents that make decisions based on maximizing a utility function or value. They choose the action with the highest expected utility, which measures how good the outcome is.

- **Example:** An AI-based banking card service, whose goal is to help cardmembers maximize their rewards and benefits from using cards, is a utility-based agent.

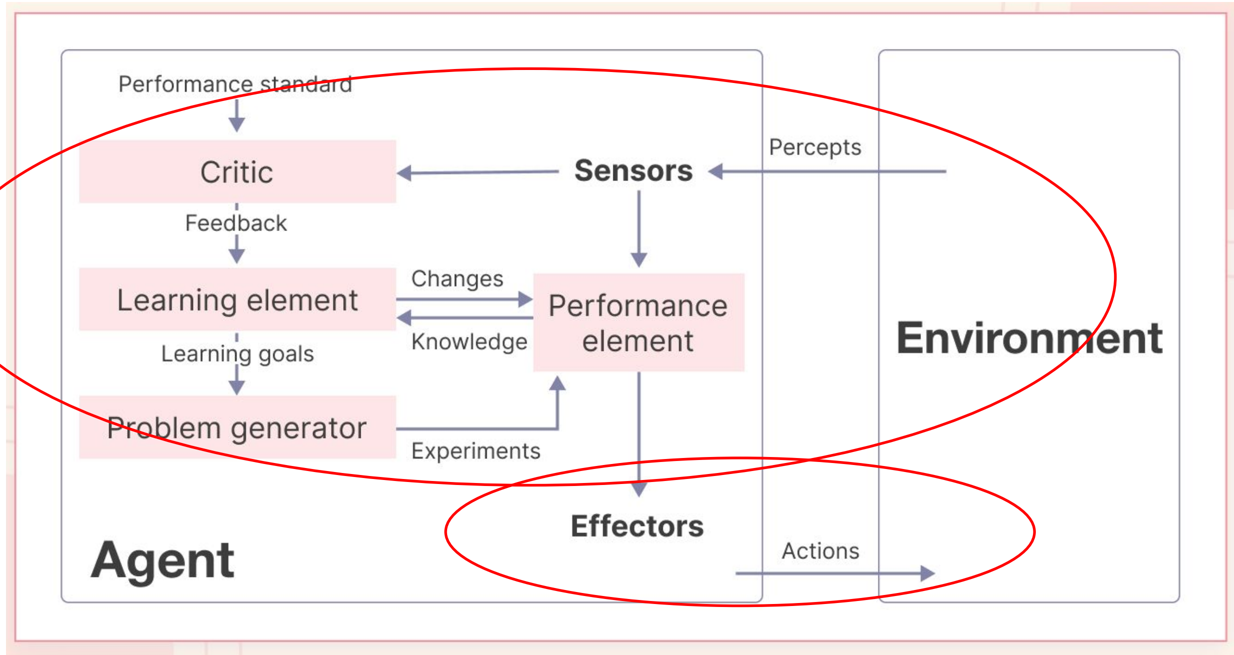
- Because to achieve its goal, it employs a utility function to assign numerical values representing success or happiness to different states.


Sensors
Percepts
State
What the world is like now
How world evolves
What it will be like if I do action A
What my actions do
How happy I will be in such state
Environment
Utility
What action I should do now
Agent
Actuators
Actions

# Learning Agents

- An AI learning agent is a software agent that can learn from past experiences and improve its performance. It initially acts with basic knowledge and adapts automatically through machine learning.

  - **Example:** Human
  - AI-Robot that learns from past experiences and data.
  - A spam filtration system that learns from user feedback.
  - Any agent type can be converted into an Leraning agent.



Questions
?
Answers
?
?