Lecture 4 - Artificial Intelligence Agent & Introduction to Reinforcement Learning

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Basic Concepts

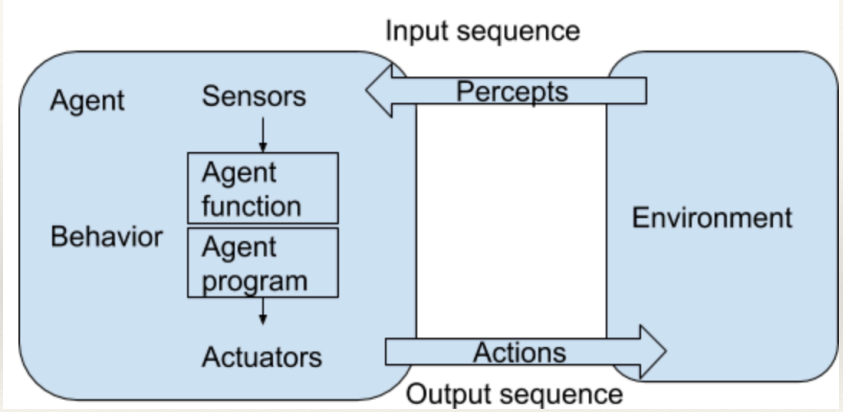
- **Rational agents** is the central to artificial intelligence.
- Tow questions to answer in this lecture: What is the rational agent and How to build such an agent successfully?
- Rational means doing right thing. So, a rational agent is the artificial intelligent agent who does right things.
- Again, what does that mean doing the right things?
- Before answering it, let's consider the agents and environments.

Agents & Environments

- An **agent** is defined as *anything* that can be viewed as *perceiving* its *environment* through **sensors** and *acting* upon that *environment* through **actuators.**.
- Important concepts: environment, action, sensors and actuators.
  - **Actuator -** is defined as a device that causes a machine or other device to operate, such as mechanical arms, rolling belts of robots, etc.
  - **Sensor -** is defined as a device which detects or measures a physical property and records, indicates, otherwise responds to it. For example, camera, radar, infrared ray sensor, sound sensor, like microphone.
- Many types of sensors:

Sensor Type	Samples/images
Light sensor — a transducer used for detecting light and creates a voltage difference equivalent to the light intensity fall on a light sensor	
Proximity sensor: Infrared transceivers; Ultrasound sensor — detect the presence of nearby objects without any physical contact	
Sound sensors—a microphone used to detect sound and return a voltage equivalent to the sound level	
Temperature sensors—used for sensing the change in temperature of the surrounding	
Acceleration sensor—used for measuring acceleration and tilt.	

- Agent's behaviour is described by the **agent function** that maps any given percept sequence (input sequence to agent) to an action. It is an abstract mathematical description.
- The implementations of agent functions are called **agent programs.** It is the concrete implementation, running on the agent architecture.



Agent Architecture

Concept of Rationality

- What is the agent behaviour?
  - the action that is performed after any given sequence of percepts.
- Rationality means the agent does right things—has good behaviour.
- If making agents most successful means doing the good thing,
- Thus, measure success can indicate how good the agent behaves, in turn determine the rationality of the agent.
- By measure the agent performance, one can know the success of the agent.
- Rationality <— behaviour <— success <— performance.

Performance Measure

- The idea behind the performance measurement is:
  - Performance measures embody the criterion for success of an agent's behaviour.
  - When an agent is running 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 is desirable, then the agent has performed well.

Performance Measure

- Two types of performance measurement:
  - Subjective — determined by the agent itself.
  - Objective — built-in by the designer.
  - More suitable approach — reward an agent for doing right, on the contrast, penalty the agent for doing the wrong things. — this is the core mechanism and is the overall basic principle studied widely in reinforcement learning.
  - Balancing the exploration and exploitation. (achieve both short-term and long-term goals).

Rationality

- Therefore, the rationality for an artificial intelligent agent is about the **initial knowledge of the environment** plus the **capability to learn from experience**.
- This is the concepts of ***exploitation*** and ***exploration*** in reinforcement learning.

The Nature of Environment

- The **task environments** are essentially the "problems" to which rational agents are the "solutions."
- The task environments define the problems for rational agents.
- Specifying the task environment is the first step to design an agent.
- Use **PEAS** (**P**erformance, **E**nvironment, **A**ctuators, **S**ensors) approach to describe the task environments.

A Sample PEAS Table

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

Categories of Task Environments

Task Environment	Description	Difficulty
Observable vs. partially observable	Environment is completely or partially observable - agent knows all states in the environment and no need to keep track of states.	No uncertainty vs. uncertainty Observable < partially
Deterministic vs. Stochastic	Environment is completely determined by the current state; otherwise it is stochastic -- in other words the environment is randomly determined by the current state.	No uncertainty vs. uncertainty Deterministic < stochastic
Episodic vs. sequential	Each episode is independent and consists of the agent perceiving and then single action; short-term actions can have long-term consequences and actions are dependent on each other	Classification tasks vs. time-scaling tasks Episodic < sequential

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Categories of Task Environments

Task Environment	Description	Difficulty
Static vs. dynamic	Environment can change while an agent is deliberating; otherwise it is static.	Static < dynamic
Discrete vs. continuous	The state of the environment is time relevant - continus; otherwise it is discrete.	Discrete < continuous
Single agent vs. multi-agent	Each agent is independent and agent corporate with each other.	Single < multi-agent

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Categories of Task Environments

The hardest case is *partially observable, stochastic, sequential, dynamic, continuous, and multi-agent.*

Example of Task Environment

Task Environment	Observable	Deterministic	Episodic	Static	Discrete	No. Agents
Taxi driving	Partially	Stochastic	Sequential	Dynamic	Continuous	Multiple

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Structure of Agent

Agent Type	Description
Simple reflex agent	Select actions from current percepts.
Model-based reflex agent	Not only current states, also history states
Goal-based agent	Goals and planning
Learning agent	Adopt environment, learning from experience, (reward)
Utility agent	Not only goals, consider the policy to explore the states to reach the maximum long-term goals -- policy, reward, and penalty.

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- Questions to ask when designing an agent:
  1. What is the performance measure
  2. What is the environment where the agent operates
  3. What are actuators for actions
  4. What are sensors for inputs

Introduction to Reinforcement Learning

What is about Reinforcement Learning (RL)

- RL is a problem that involves learning what to do—how to map situations to actions—so as to maximize a numerical reward signal. [1]:
  - being closed-loop in an essential way,
  - not having direct instructions as to what actions to take,
  - where the consequences of actions, including reward signals, play out over extended time periods.

Reference:

[1]. Sutton and Barto, 1998; 2017;*Introduction to Reinforcement Learning*.

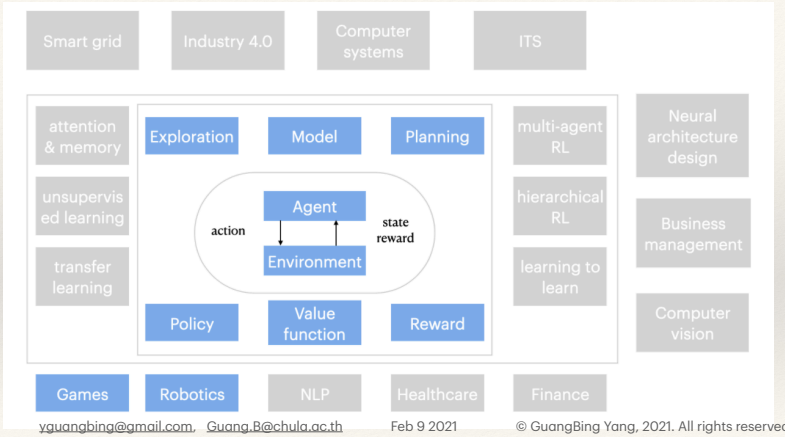
What is about Reinforcement Learning (RL)

- In other words, RL is about an **agent** [1]:
  - **interacting** with the **environment**,
  - **learning** an **optimal policy**, by **trial** and **error**,
  - **making decisions** for sequential **problems** in a variety of research fields and domains

Reference:

[1]. Sutton and Barto, 1998; 2017;*Introduction to Reinforcement Learning*.

- David Silver, the major contributor of AlphaGo (Silver et al., 2016a), even made a formula: artificial intelligence = reinforcement learning + deep learning (Silver, 2016).
- Here we might say Artificial intelligence is the combination of reinforcement and deep learning.
- This course will cover the core of RL.



The conceptual organization of the overview

Background

- Reinforcement learning is a kind of machine learning.
- Other three categories of the machine learning are:
  - Supervised learning
  - Unsupervised learning
- Reinforcement learning is a computational approach to learn from interaction.
- It focuses on goal-directed learning from interaction and learning to do—how to map situations to actions—so as to maximize a numerical reward signal.

ML Category	Basic Concepts	Background Theorems	Date sets & Procedures	Performance Evaluation	Examples
Supervised Learning	Labelled/target data; Regress and classify new data; One-shot, instant reward	Probability theory, statistics, linear algebra and calculus, information theory and optimization.	{X, y} pairs; Training, validation, and testing datasets.	Training/testing errors, regularization and overfitting/ under-fitting	Linear regression/ logistic regression (regression/ classification), neural network, SVM, etc
Unsupervised Learning	No labelled data; Pattern discovery and clustering; One-shot, instant reward	Same as the above	{X} only, no y	Same as the above	K-means, mixture Gaussian, etc

ML Category	Basic Concepts	Background Theorems	Date sets & Procedures	Performance Evaluation	Examples
Deep Learning	Deep neural network; non-linear regression and classification, both for supervised and unsupervised	Same as the above	{X, y} pairs or {X} only, e.g., Auto-encoder	Same as the above	CNN, RNN, LSTM, etc
Reinforcement Learning	Environment feedback; Multiple rewards, long-term goals	Same as the above, plus, optimal control, game theory, psychology, neuroscience.	Environment definitions, policy data maps, rewards, trial-and-error, exploration & exploitation	efficiency of automated	Q-learning, TD learning, SARSA, MDP, etc.

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Background

- A learning agent interacts with its environment to achieve a goal.
- Such agent must be able to:
  - sense the state of the environment,
  - take actions that affect the state,
  - have a goal or goals,
  - learn from its experience, also from interactions, so not like supervised learning,
  - maximize rewards rather than find hidden structure, not like the unsupervised learning.
- One of the challenges that arise in reinforcement learning, and not in other kinds of learning, is the trade-off between exploration and exploitation — the exploration-exploitation dilemma.

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Elements of Reinforcement Learning

- Environment
- Agent
- Policy - which can:
  - define learning behaviours,
  - map state to actions—a set of stimulus-response rules or associations, a lookup table or search, it can be stochastic
- Reward signal - define the goal in a reinforcement learning problem
- Value function - what is good for a long-run, it acts as the prediction of the rewards. Actions choice is based on the value judgements that seek actions that bring about states highest value, not highest reward because these actions bring us the greatest amount of rewards over long run.
- Model of the environment—it mimics the behaviour of the environment. It is for inferencing the environment. It is used for planning—which means any way of deciding on a course of action by considering possible future situations before they are actually experienced.

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Recap

- An agent is a software system that perceives and acts in an environment.
- A rational agent does the right things.
- The behaviour of an agent is that actions are performed according to the precepts of the agent.
- The performance measure evaluates the behaviour of the agent in an environment that determines the rationality.
- A rational agent acts so as to maximize the expected value of the performance measure, given the percept sequence it has seen so far.
- A task environment specification includes the performance measure, the external environment, the actuators. and the sensors.
- In designing an agent, the first step must always be to specify the task environment as fully as possible.

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Recap

- A task environments vary along several significant dimensions.
- They can be fully or partially observable, single-agent or multi-agent, deterministic or stochastic, episodic or sequential, static or dynamic, discrete or continuous, and known or unknown.
- Simple reflex agents respond directly to percepts.
- Model-based reflex agents maintain internal state to track aspects of the world that are not evident in the current percept.
- Goal-based agents act to achieve their goals, and
- Utility-based agents try to maximize their own expectation.
- All agents can improve their performance through learning.

Recap

- Reinforcement learning is a computational approach to understanding and automating goal-directed learning and decision making.
- It is different from other kinds of machine learning approaches.
- It focuses on learning by an agent from direct interaction with its environment, without requiring exemplary supervision or complete models of the environment.
- Agent, policy, reward, value functions, and model are components of RL.
- The concepts of value and value function are key to most of the reinforcement learning methods.
- The value functions are important for efficient search in the space of policies.

Questions?