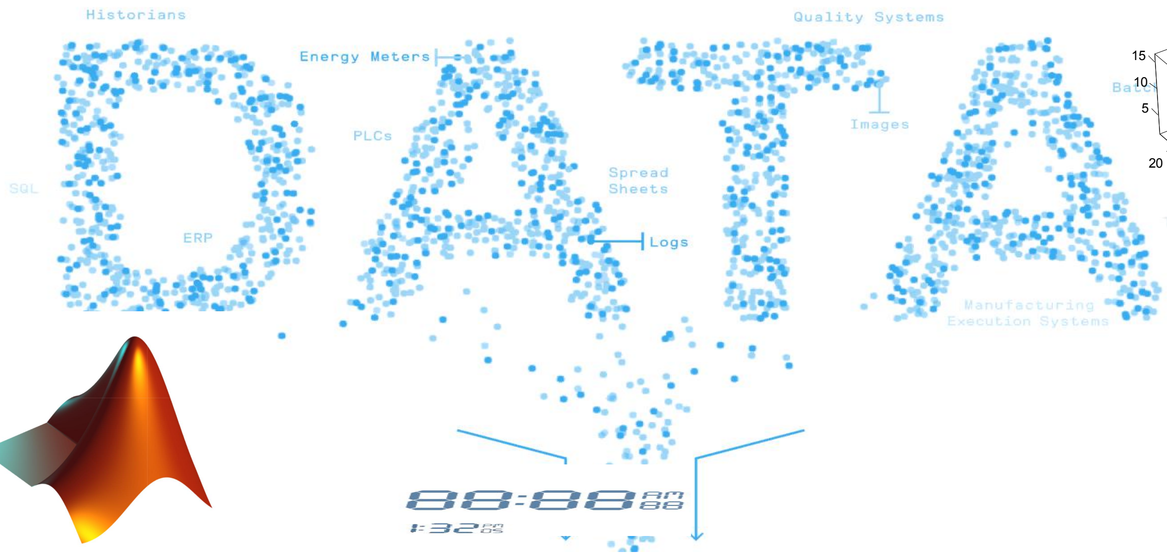
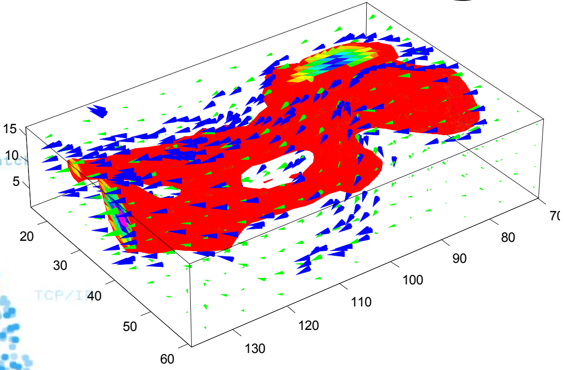
# Introduction to Artificial Intelligence
# - 05-01-03 Reinforcement Learning





**Dr Leo Chen**
leo.chen@ieee.org

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# Module Contents

1. Introduction
2. Evolutionary Computation
3. Artificial Neural Network
4. Fuzzy Logic and Fuzzy Systems
5. More AI Subsets
6. AI and Industry 4.0
7. AI Applications
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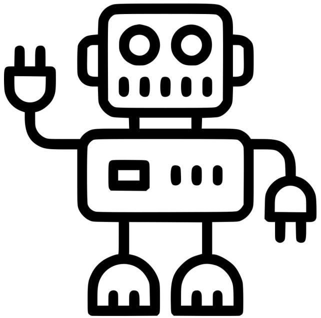
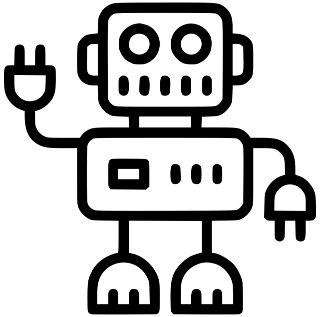
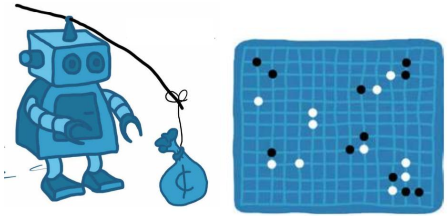
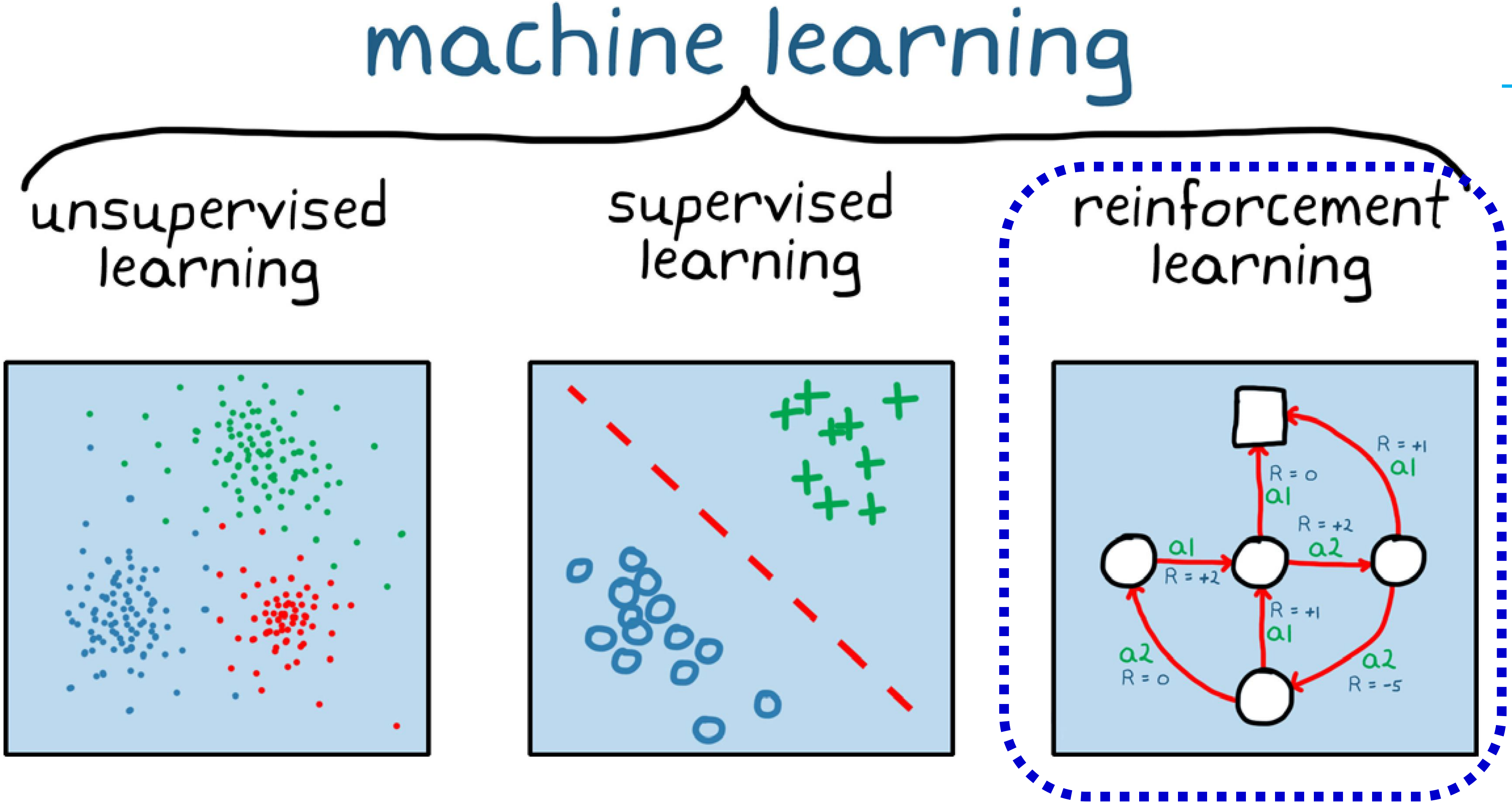


# Chapter Contents



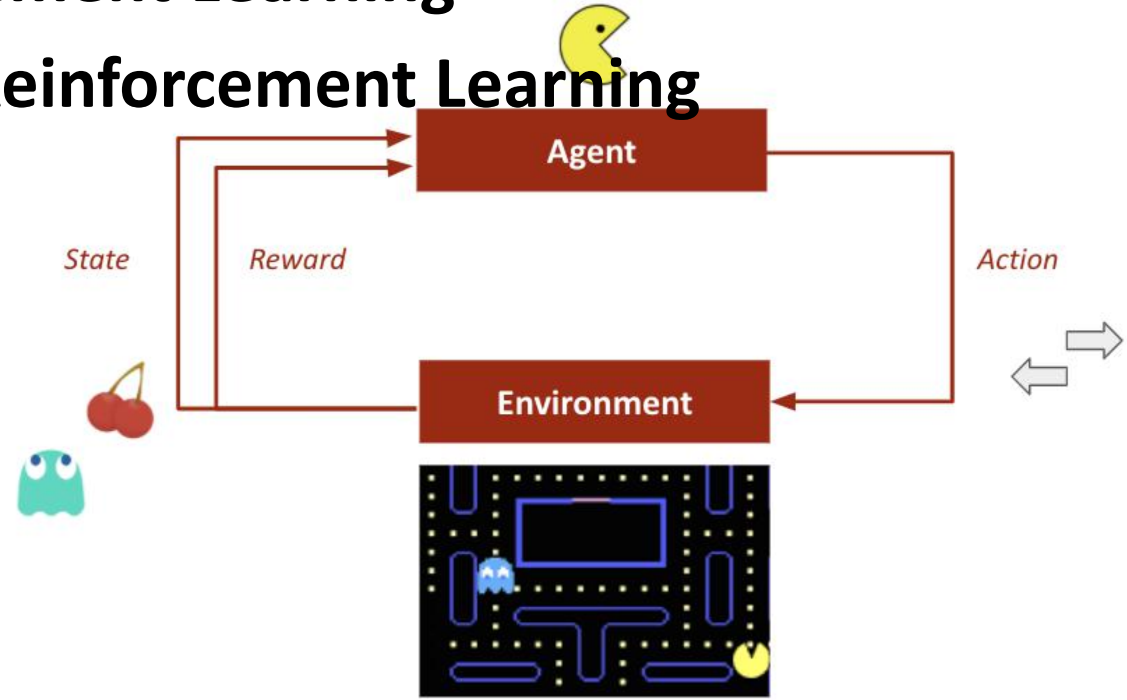




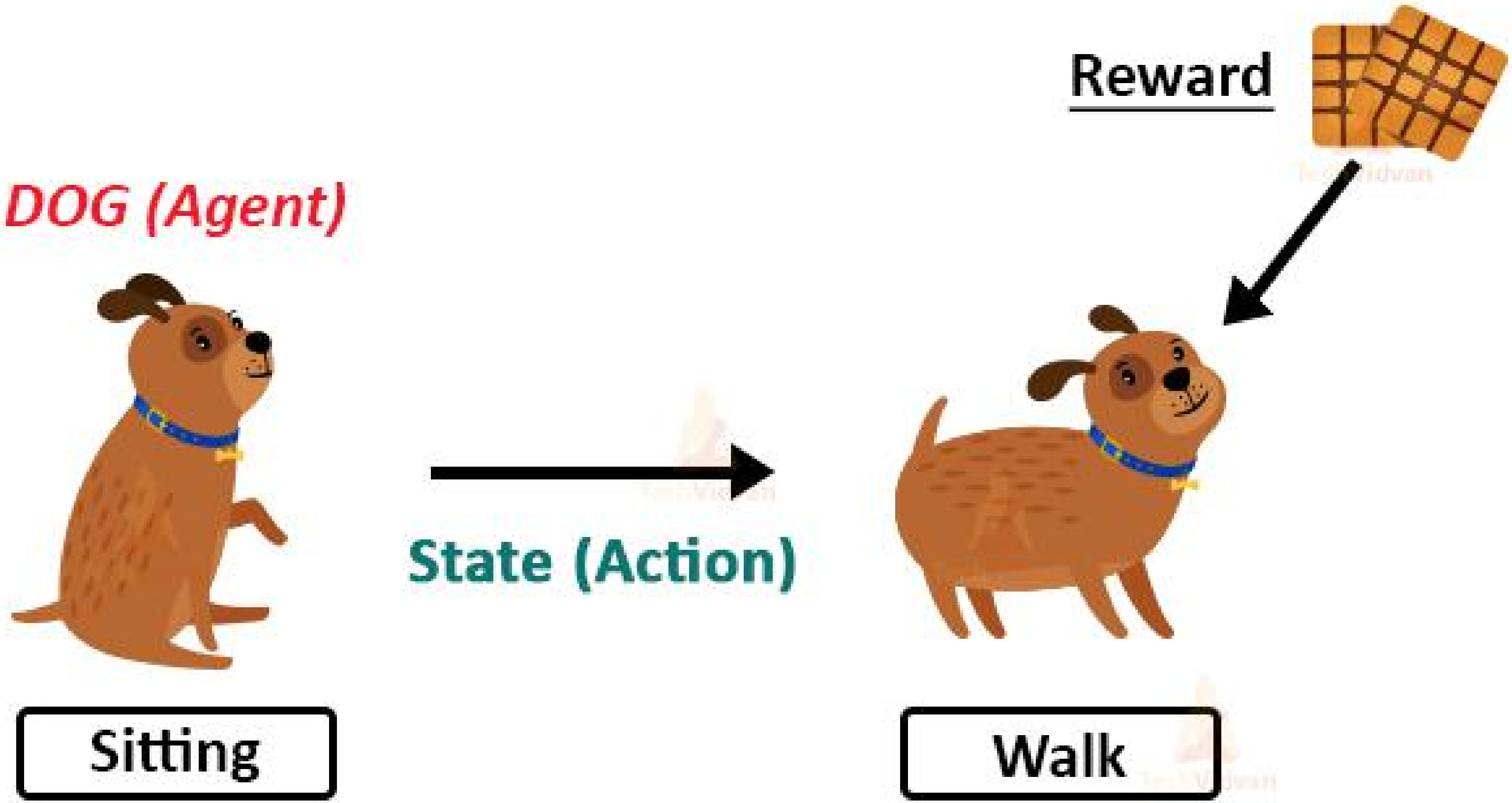

machine learning
unsupervised learning
supervised learning
reinforcement learning
R = +1
a1
R = 0
a1
R = +2
a2
a1
R = +2
R = +1
a1
a2
R = 0
a2
R = -5

# Section Contents

1. What Is Reinforcement Learning
2. Why Use Reinforcement Learning
3. Fundamentals of Reinforcement Learning
4. Applications



# Reinforcement Learning in ML

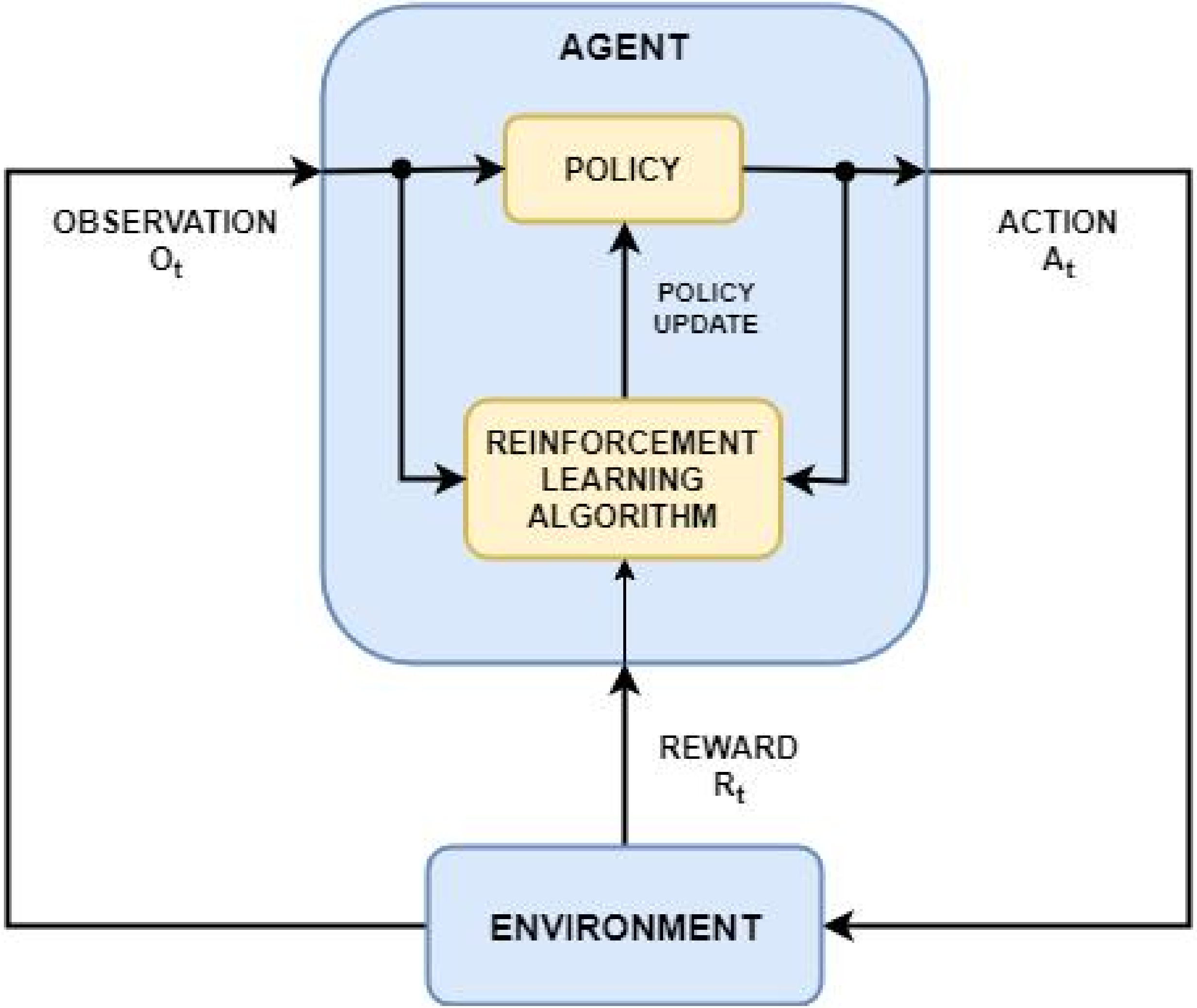


# 1 What Is Reinforcement Learning

- Reinforcement learning is a **goal-directed** computational approach where a computer learns to **perform** a task by **interacting** with **an unknown dynamic environment**.
- This learning approach **enables** a computer to **make a series of decisions** to maximize the cumulative reward for the task **without** human intervention and **without** being explicitly programmed to achieve the task.

# 1 What Is Reinforcement Learning

- The **goal** of reinforcement learning is to **train** an **agent** to complete a task within **an unknown environment**.
- The **agent** receives **observations** and a **reward** from the environment and sends actions to the environment.
- The **reward is a measure** of how successful an action is with respect to completing the task goal.


AGENT
POLICY
OBSERVATION
$O_t$
POLICY
UPDATE
ACTION
$A_t$
REINFORCEMENT
LEARNING
ALGORITHM
REWARD
$R_t$
ENVIRONMENT

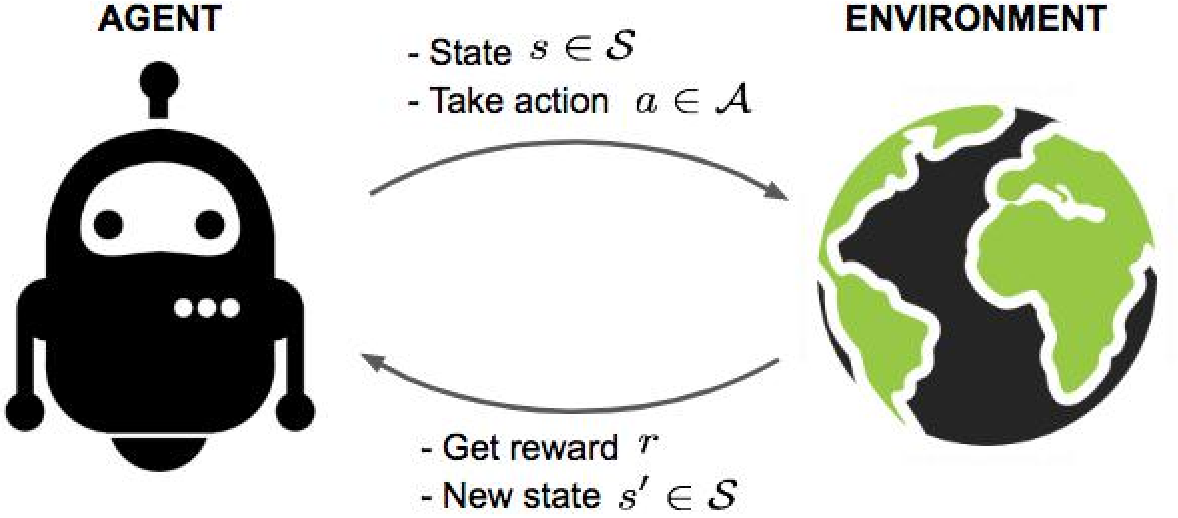
# The agent

## Two components:

- *a policy*
- *a learning algorithm*

# Policy

- The policy is a **mapping** that **selects actions** based on the **observations** from the **environment**.
- Typically, the policy is a **function approximator** with **tunable parameters**, such as a *deep neural network*.



# Learning algorithm

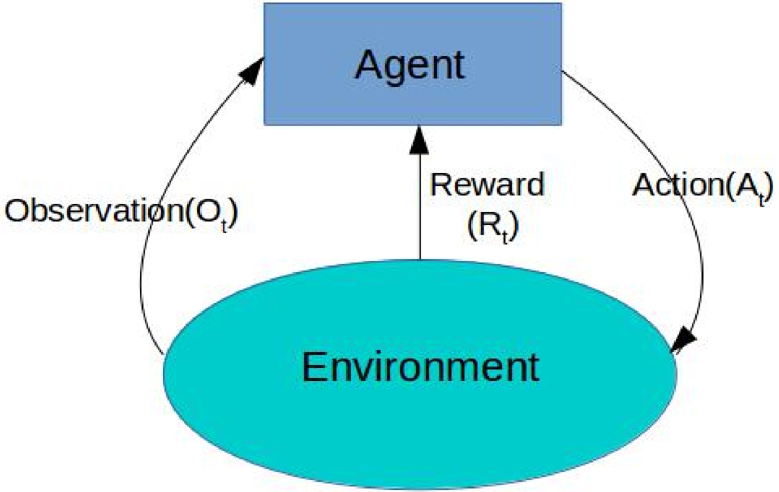
- The learning algorithm **continuously updates** the **policy parameters** based on the actions, observations, and reward.
- The goal of the learning algorithm is to **find an optimal policy** that **maximises** the cumulative **reward** received during the task.

# 2 Why Use Reinforcement Learning

- It helps you to find which **situation needs an action**
- Helps you to **discover** which **action** yields the **highest reward** over the **longer period**.
- Reinforcement Learning also provides the **learning** agent with a **reward** function.
- It also allows it to figure out the best method for **obtaining large rewards**.

# When Not to Use Reinforcement Learning?

- When you have **enough data** to solve the problem with a **supervised** learning method
- Reinforcement Learning is **computing-heavy** and **time-consuming**. in particular when the action space is **large**.



# 2 Why Use Reinforcement Learning

- Reinforcement learning involves an **agent** **learning** the **optimal *behavior*** through ***repeated*** **trial-and-error interactions** with the environment without human involvement.
- As an example, consider the task of parking a vehicle using an **automated driving** system.

# Automated driving system

The goal of this task is for the **vehicle computer (agent)** to park the vehicle in the **correct position and orientation**, to do so the **controller** uses:

- readings from cameras, accelerometers, gyroscopes, a GPS receiver, and lidar (**observations**)
- generating steering, braking, and acceleration commands (**actions**)

# Automated driving system

- The action commands are sent to the **actuators** that **control the vehicle**.
- The resulting **observations depend on** the actuators, sensors, vehicle dynamics, road surface, wind, and many other less-important factors.
- All these **factors**, that is, everything that is **not** the agent, make up the environment in reinforcement learning.

# Automated driving system

- To **learn** how to <u>generate the correct actions</u> from the observations, the computer repeatedly tries to park the vehicle using a **trial-and-error** process.
- To **guide** the learning process, you provide a **signal** that is one when the car **successfully** reaches the **desired** position and orientation and zero otherwise (**reward**).
- **During each trial**, the computer selects actions using a mapping (**policy**) initialised with some default values.

# Automated driving system

- After each trial, the computer updates the mapping to **maximise** the reward (**learning algorithm**).
- This process continues **until** the computer learns an optimal mapping that **successfully parks** the car.

# Reinforcement Learning Workflow

- Training an agent using reinforcement learning is an **iterative process**.
- Decisions and results in **later stages** can require you to return to an **earlier stage** in the learning workflow.

# For example

if the training process does **not** converge to an optimal policy within a **reasonable** amount of time, you

might have to **update** any of **the following** before retraining the agent:

- Training settings
- Learning algorithm configuration
- Policy representation
- Reward signal definition
- Action and observation signals
- Environment dynamics

# 3 Fundamentals of Reinforcement Learning

Three **methods** for reinforcement learning are

**A** Value-based

**B** Policy-based

**C** Model based learning

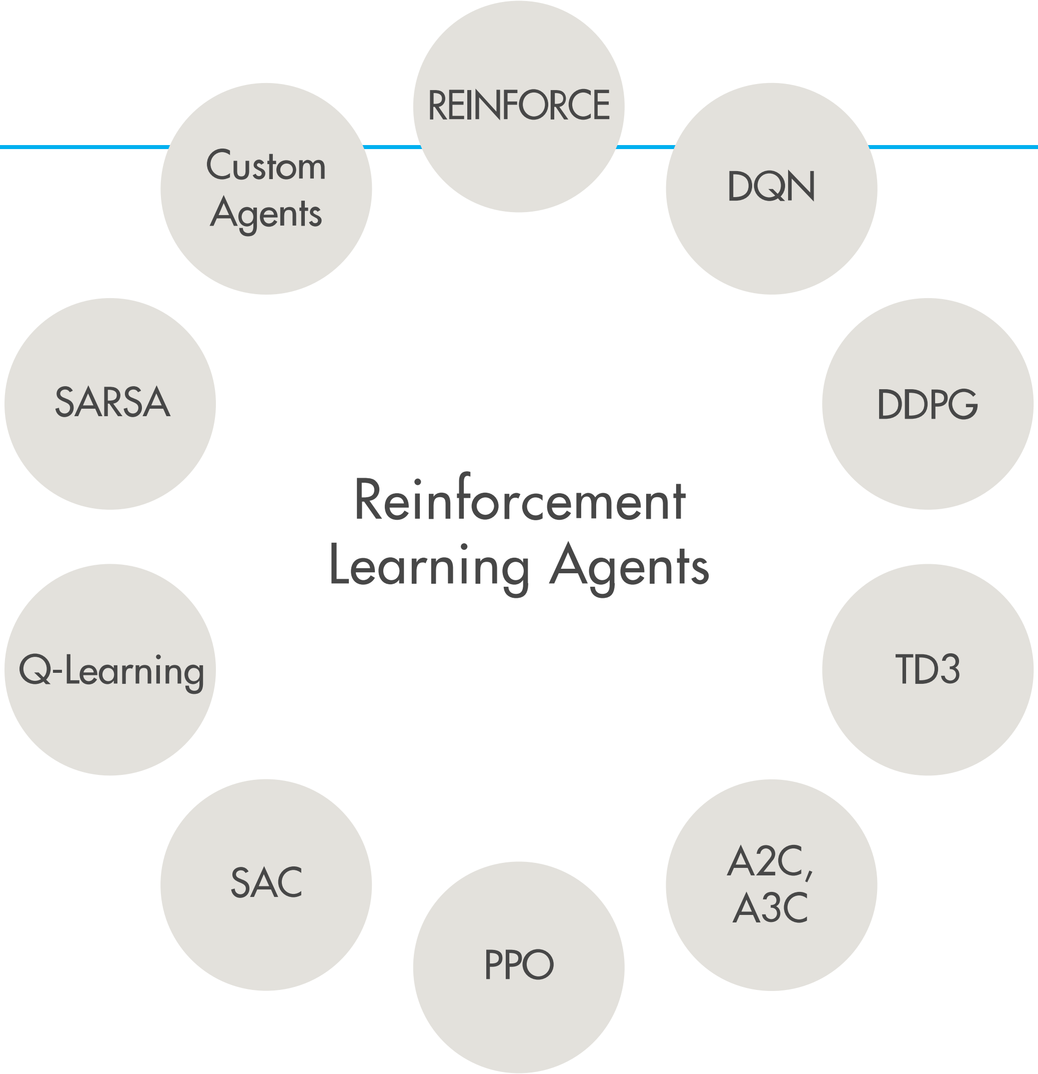
Two **types** of reinforcement learning are

**I** Positive

**II** Negative

# 3 Fundamentals of Reinforcement Learning

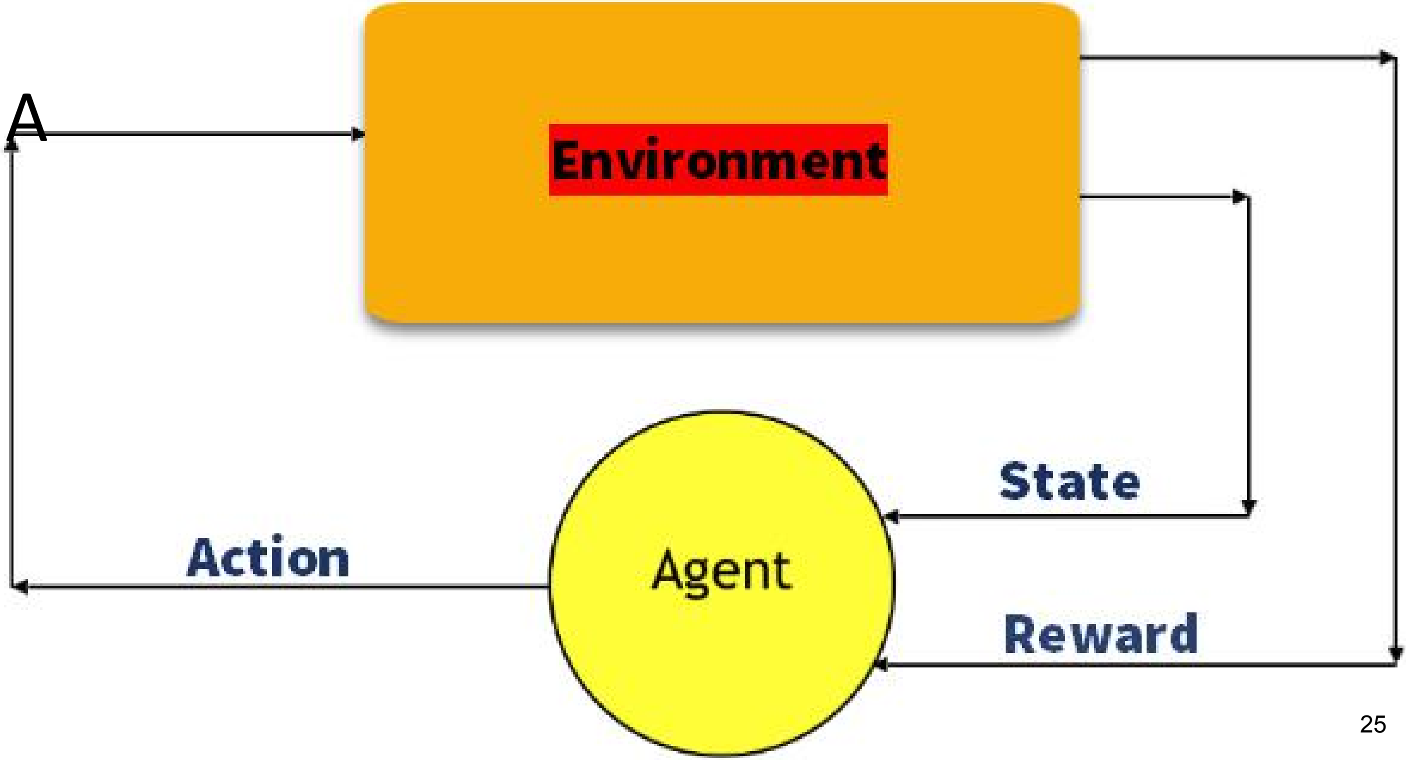
- Q-learning [A]
- Deep Q network [A + C]
- Markov Decision Process (MDP) = State-Action-Reward-State-Action (SARSA) [C]
- Deep Deterministic Policy Gradient (DDPG) [A+B]

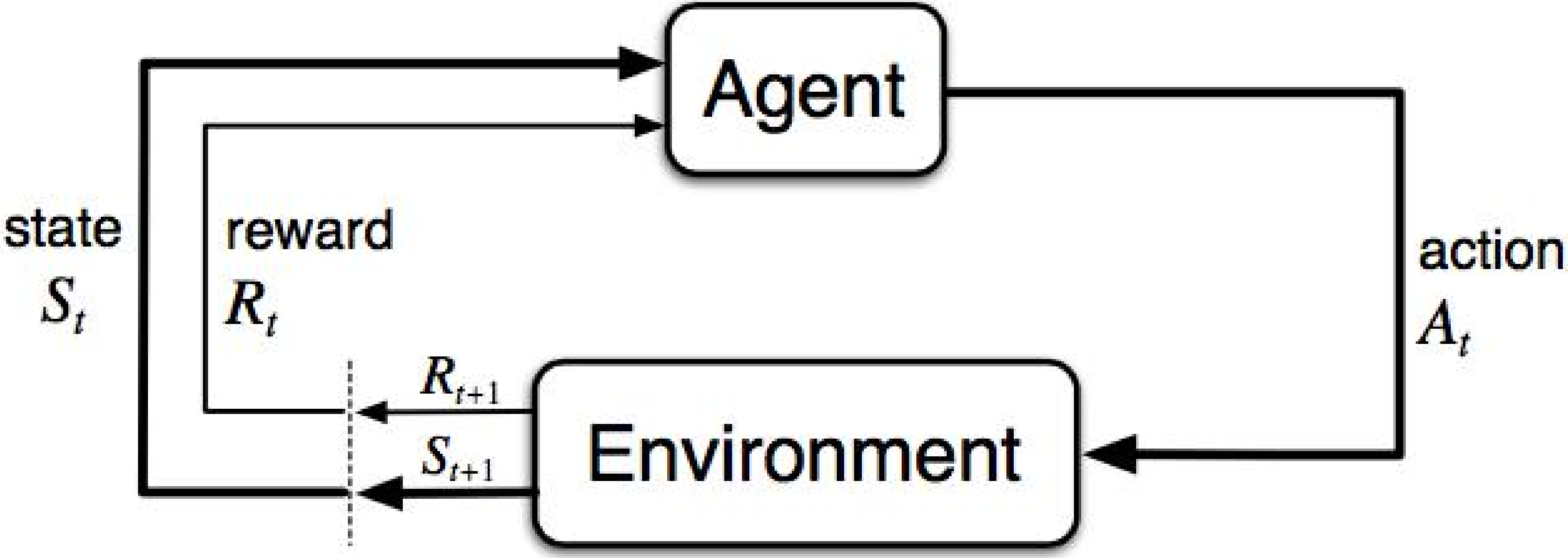

Reinforcement Learning Agents
REINFORCE
DQN
DDPG
TD3
A2C, A3C
PPO
SAC
Q-Learning
SARSA
Custom Agents

# Markov Decision Process

The following parameters are used to get a solution:

- Set of actions- A
- Set of states -S
- Reward- R
- Policy- n
- Value- V




Agent
state
$S_t$
reward
$R_t$
action
$A_t$
$R_{t+1}$
$S_{t+1}$
Environment

# Q-Learning

- Q learning is a **value-based** method of supplying information to inform which action an agent should take.
- Let’s understand this method by the following example:

There are five rooms in a building which are connected by doors.

Each room is numbered 0 to 4

The outside of the building can be one big outside area (5)

Doors number 1 and 4 lead into the building from room 5

# Q-Learning

Next, you need to **associate** a **reward** value to each door:

- Doors which lead **directly to the goal** have a reward of **100**
- Doors which is **not directly connected** to the target room gives **zero** reward
- As doors are two-way, and two arrows are assigned for each room
- Every arrow in the above image contains an instant reward value

# Q-Learning

an agent traverse from room number 2 to 5

Initial state = state 2

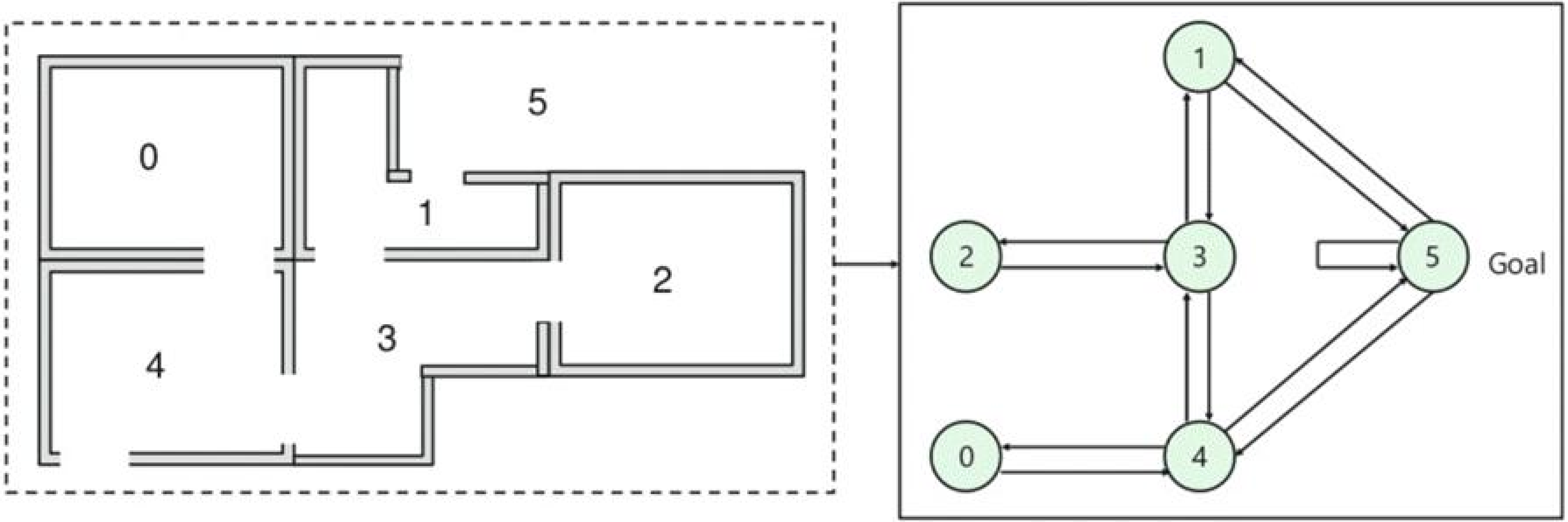
State 2-> state 3

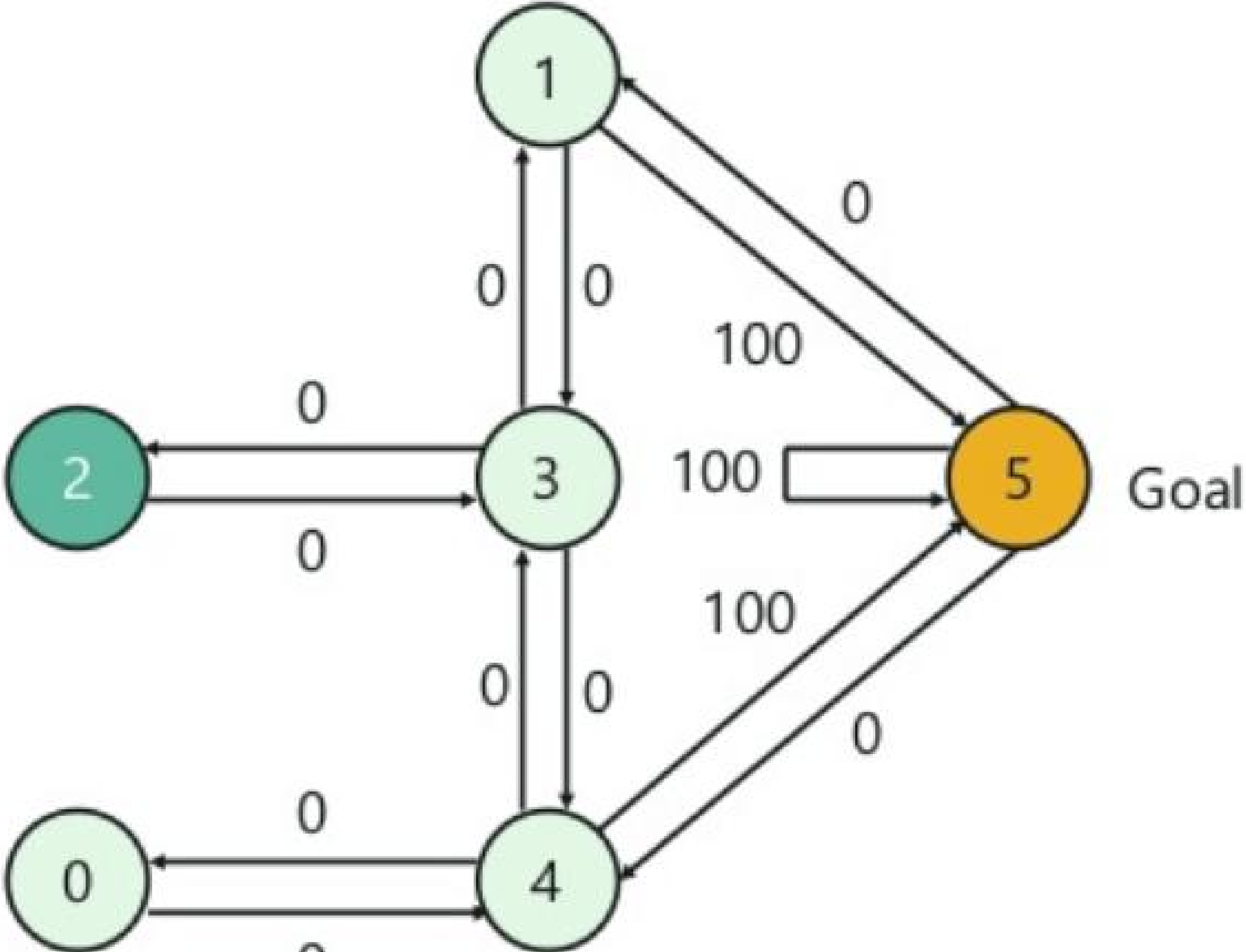
State 3 -> state (2,1,4)

State 4-> state (0,5,3)

State 1-> state (5,3)

State 0-> state 4


5
0
1
2
3
4
1
2
3
5
Goal
0
4


1
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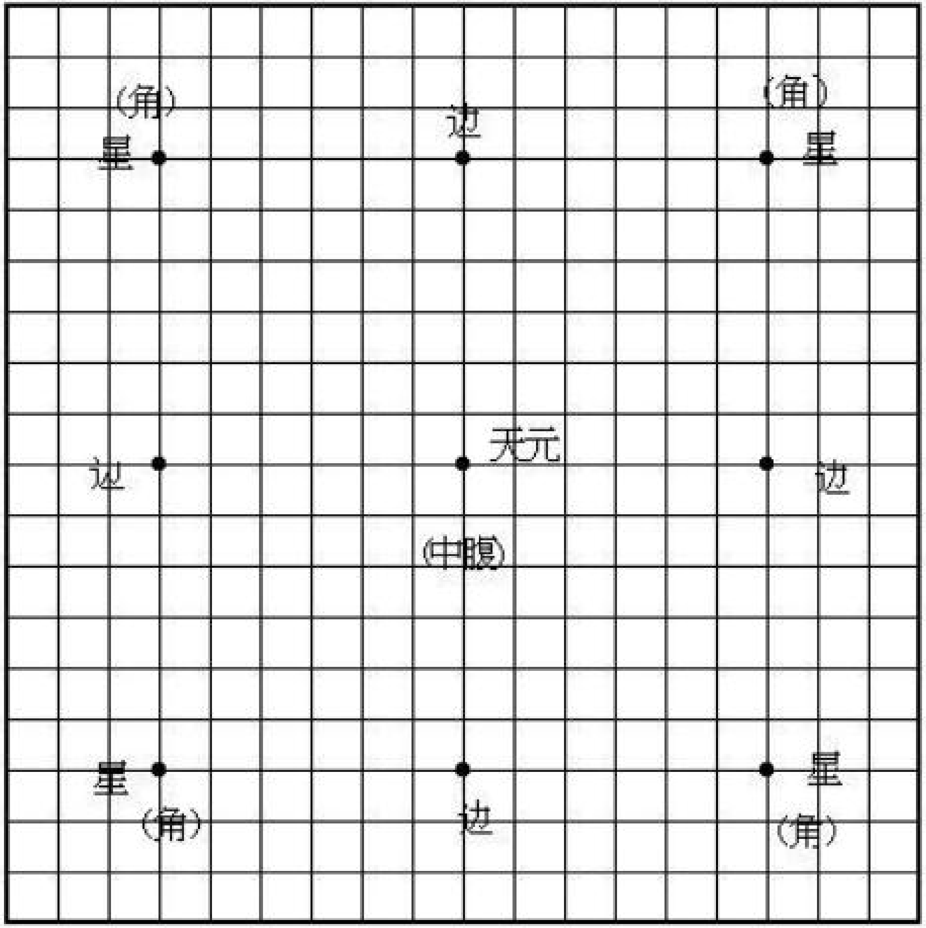
0
0
100
0
2
3
100
5
Goal
0
100
0
0
0
0
0
4

# 4 Applications

- Autonomous driving
- Robotics for industrial automation.
- Business strategy planning
- Personalized Recommendations
- Training systems
- Aircraft control and robot motion control
- Bidding and Advertising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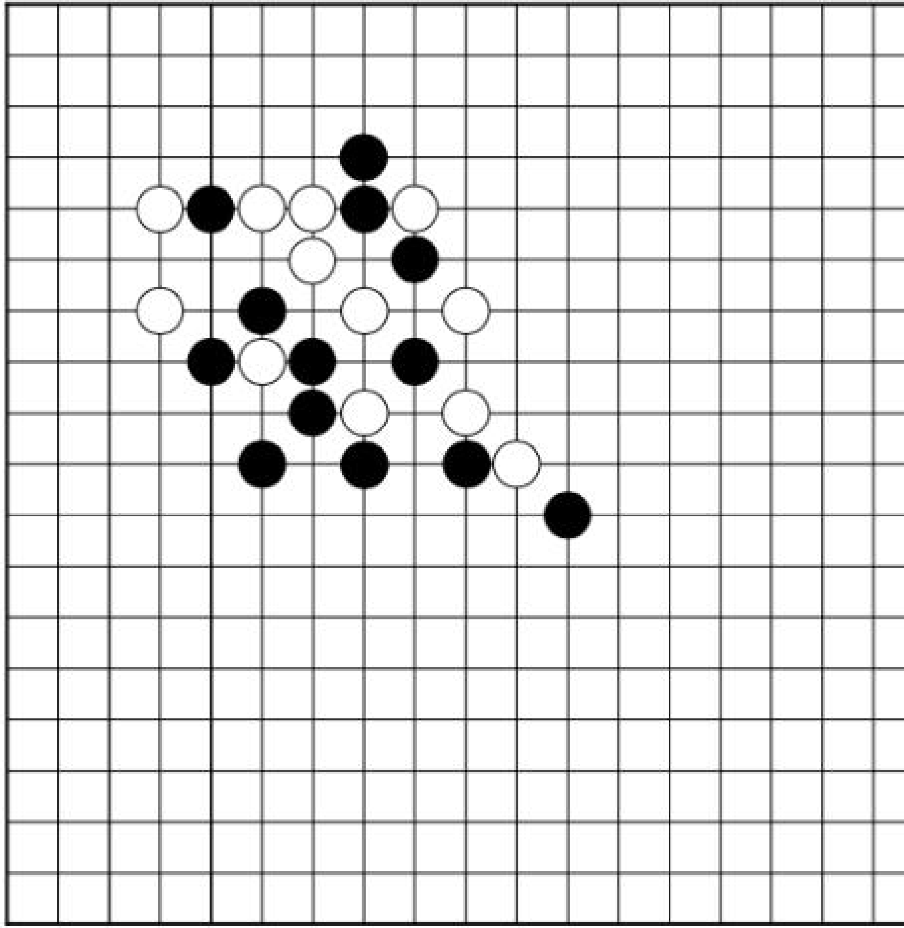


## Some important terms

- Agent: It is an assumed entity which performs actions in an environment to gain some reward.
- Environment (e): A scenario that an agent has to face.
- Reward (R): An immediate return given to an agent when he or she performs specific action or task.
- State (s): State refers to the current situation returned by the environment.
- Policy (π): It is a strategy which applies by the agent to decide the next action based on the current state.

## Some important terms

- Value (V): It is expected long-term return with discount, as compared to the short-term reward.
- Value Function: It specifies the value of a state that is the total amount of reward. It is an agent which should be expected beginning from that state.
- Model of the environment: This mimics the behavior of the environment. It helps you to make inferences to be made and also determine how the environment will behave.

# Some important terms

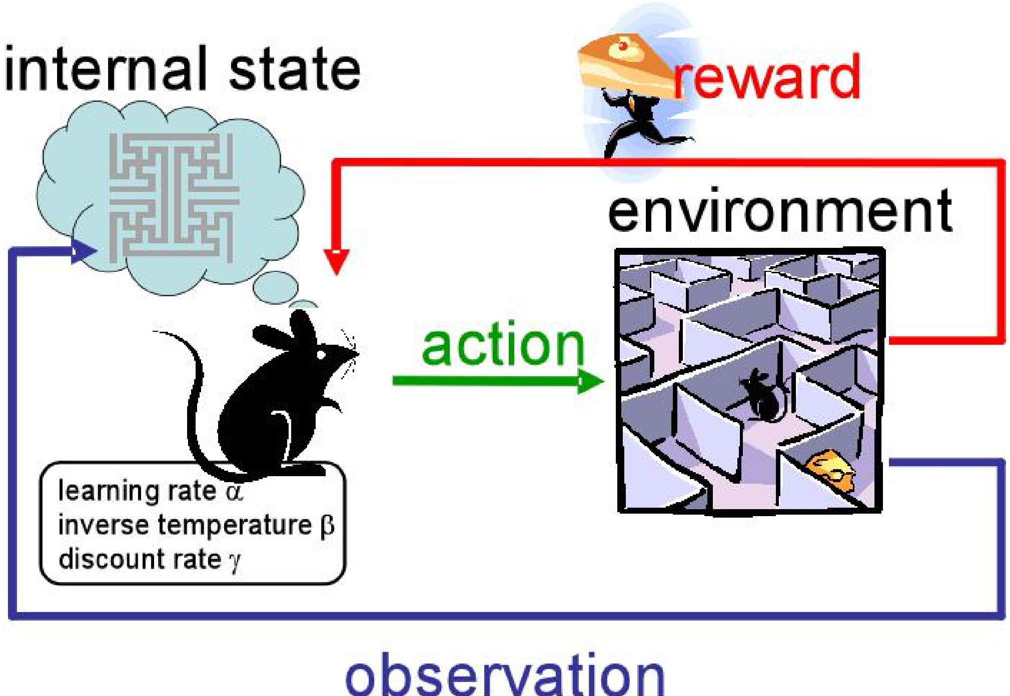
- Model based methods: It is a method for solving reinforcement learning problems which use model-based methods.
- Q value or action value (Q): Q value is quite similar to value. The only difference between the two is that it takes an additional parameter as a current action.

# Reinforcement Learning vs. Supervised Learning

| Parameters | Reinforcement Learning | Supervised Learning |
|---|---|---|
| Decision style | reinforcement learning helps you to take your decisions sequentially. | In this method, a decision is made on the input given at the beginning. |
| Works on | Works on interacting with the environment. | Works on examples or given sample data. |
| Dependency on decision | In RL method learning decision is dependent. Therefore, you should give labels to all the dependent decisions. | Supervised learning the decisions which are independent of each other, so labels are given for every decision. |
| Best suited | Supports and work better in AI, where human interaction is prevalent. | It is mostly operated with an interactive software system or applications. |
| Example | Chess game | Object recognition |

# Videos

- 01 Reinforcement Learning - Crash Course AI (11:27)
- 02 Reinforcement Learning for Engineers
  - ✓ Part 1 (14:10)
  - ✓ Part 2 (13:30)
  - ✓ Part 3 (17:50)
  - ✓ Part 4 (14:50)
  - ✓ Part 5 (16:07)



# Tutorial

## Reinforcement Learning Onramp

- https://matlabacademy.mathworks.com/details/reinforcement-learning-onramp/reinforcementlearning
- https://matlabacademy.mathworks.com/

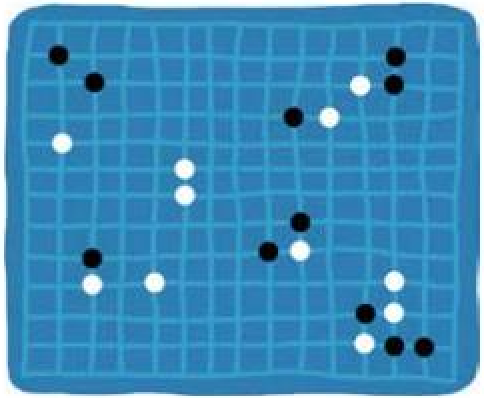
# Reference

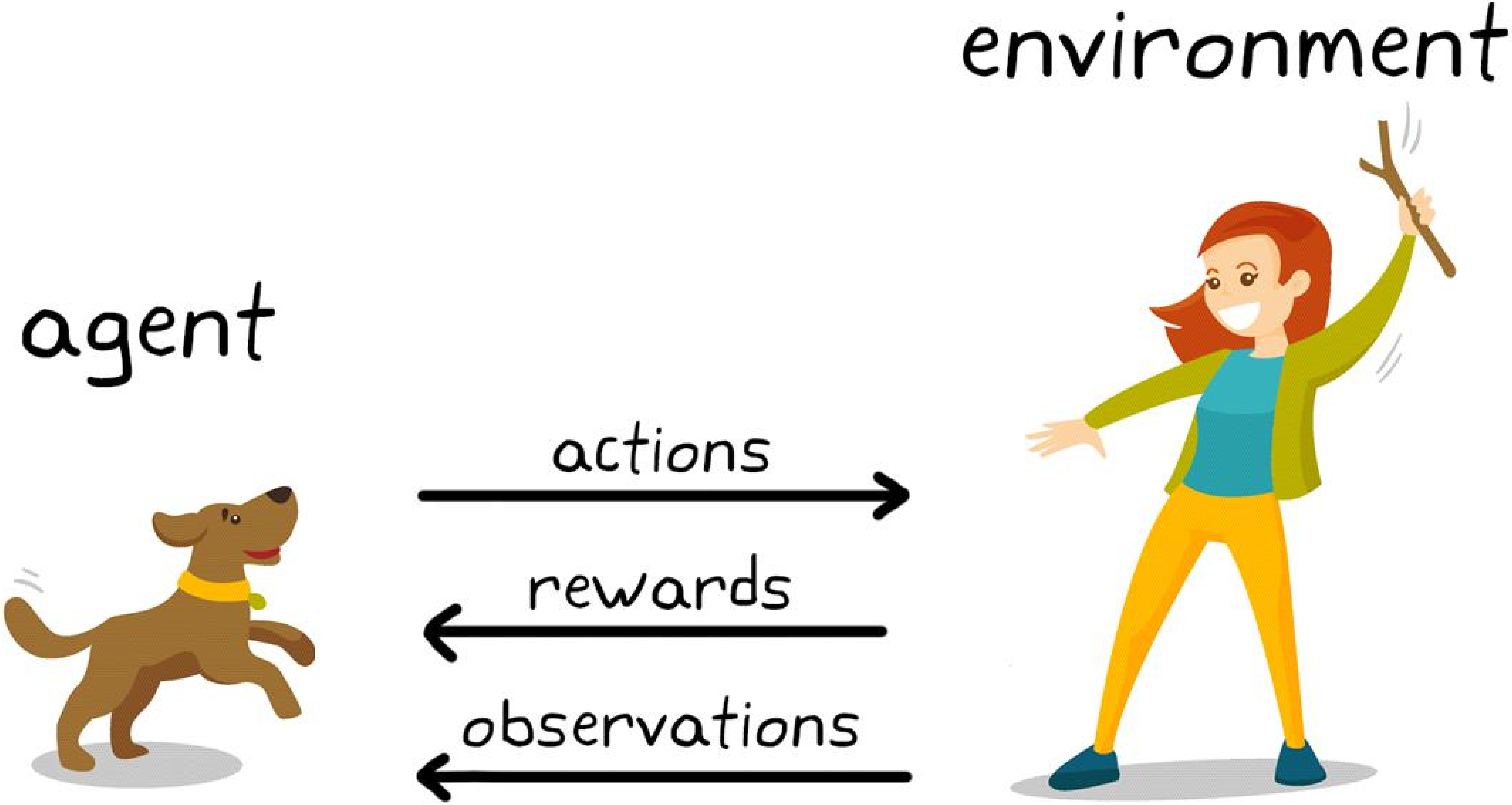
[1] Reinforcement Learning with MATLAB and Simulink

https://www.mathworks.com/campaigns/offers/reinforcement-learning-with-matlab-ebook.html

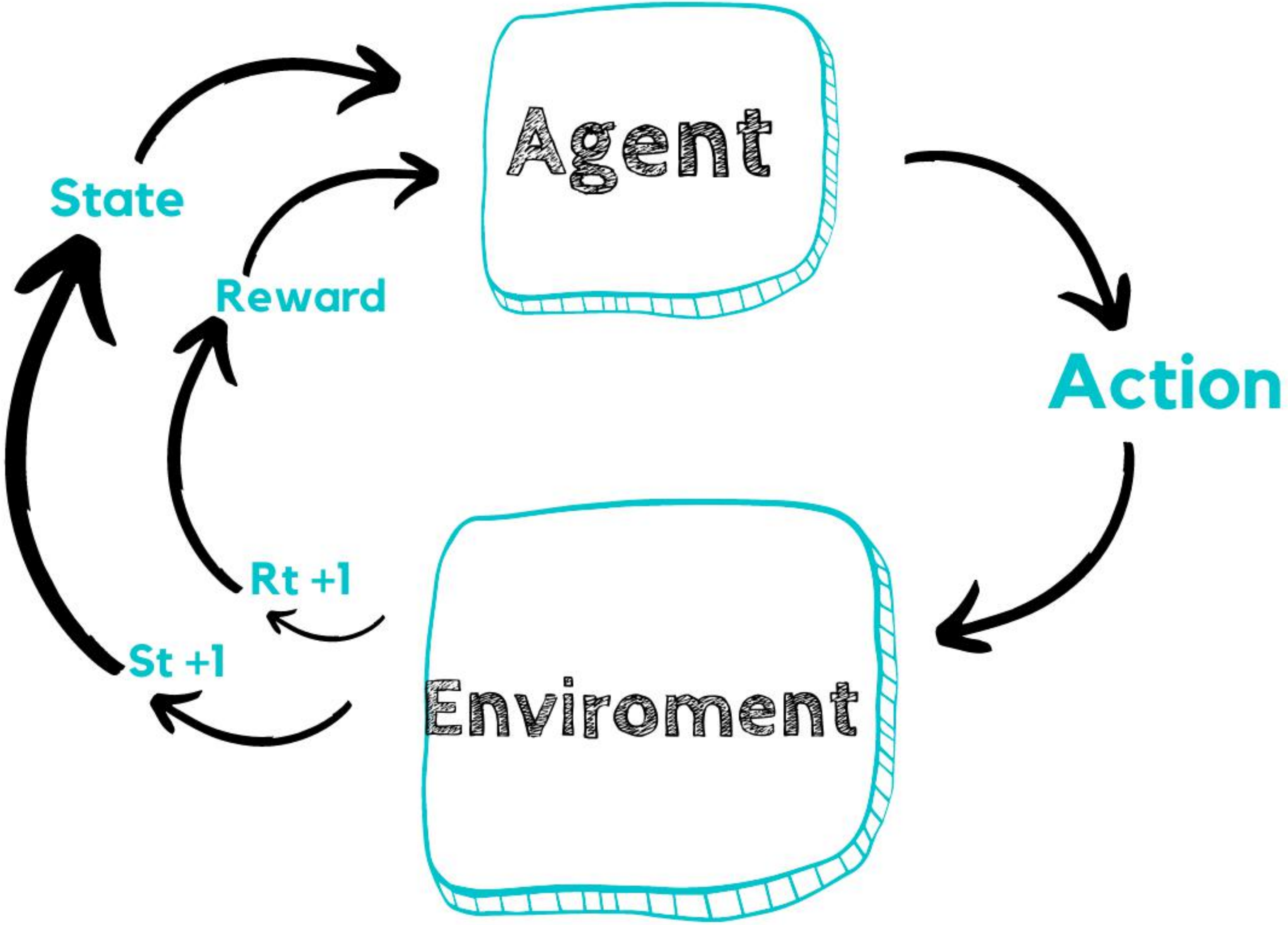
[2]What Is Reinforcement Learning?

https://www.mathworks.com/discovery/reinforceme





environment
agent
actions
rewards
observations



Agent
State
Reward
Action
Rt +1
St +1
Enviroment

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**Thanks and Questions**