Review and Team Projects

COMP 741/841 Week 9

Spring 2024

Agenda

- Reinforcement learning (RL)
- Team projects

Reinforcement Learning

- Agent, states, start/goal states, actions per state, rewards
- Agent performs action **a_t** in state **s_t**
    - To transition in the next state **s_(t+1)**
    - For which it gets a reward (numerical score)
- Agent purpose: maximize the reward

RL: Q Function and Q Table

- Learns the value of an action in a given state
- Uses Q-function (quality of state & action combination):
- Calculates the Q values of the *maximum expected future rewards* in each state, for each action
- Records and iteratively updates the values in a **Q table**
  - Columns are the actions
  - Rows are the possible states

RL: Q-Learning Algorithm

- Initially, Q values in the Q tables are set to an arbitrary fixed value
- At each time **t**, the agent
  - Agent selects action **a_t**
  - Agent observes the reward **R_(t+1)**
  - Agent transitions to state **S_(t+1)** (based on state **s_t**)
  - New **Q(s_t, a_t)** value updates current Q value
- Introduced by Chris Watkins in 1989

New Q Value Calculation

New Q value uses Bellman equation, which depends on:

- Learning rate α
- Discount factor γ
- Maximum expected future reward given the new state and ALL possible actions in the new state

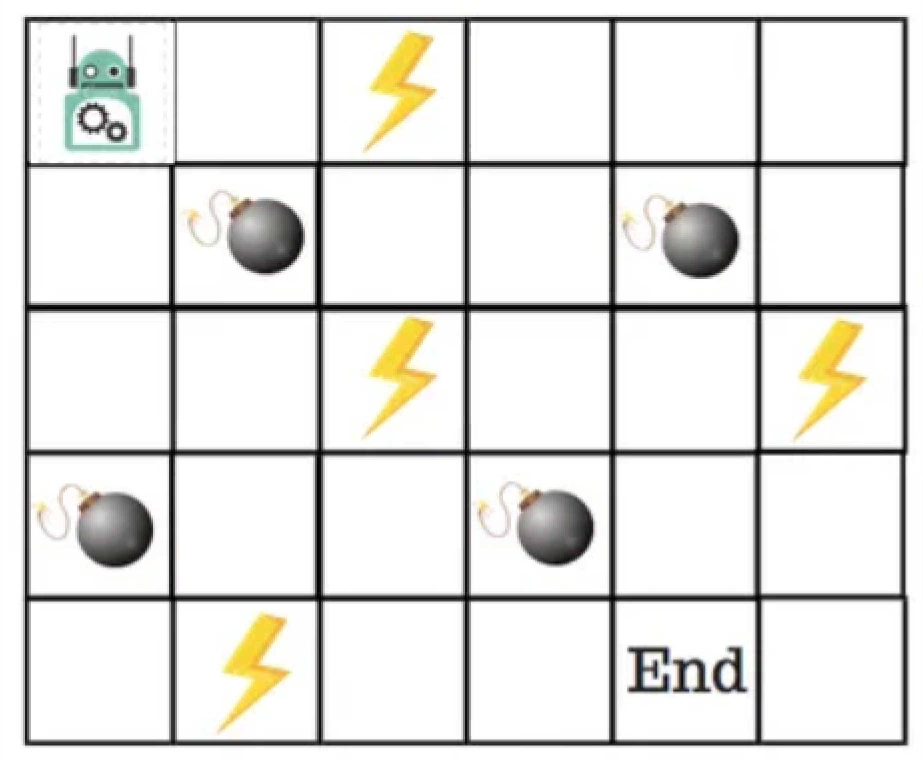
Deep Q-Learning and More

- Deep Q-Learning (DQN)
    - Google DeepMind patents Q-learning applied to deep learning (DQN) in 2014
    - Can play Atari games at expert human levels
    - Uses a deep convolutional neural network
- Other types of Q-learning
    - Double DQN, Delayed Q-learning, multi-agent (mini-max) Qlearning

Classic Q-Learning Algorithm Example

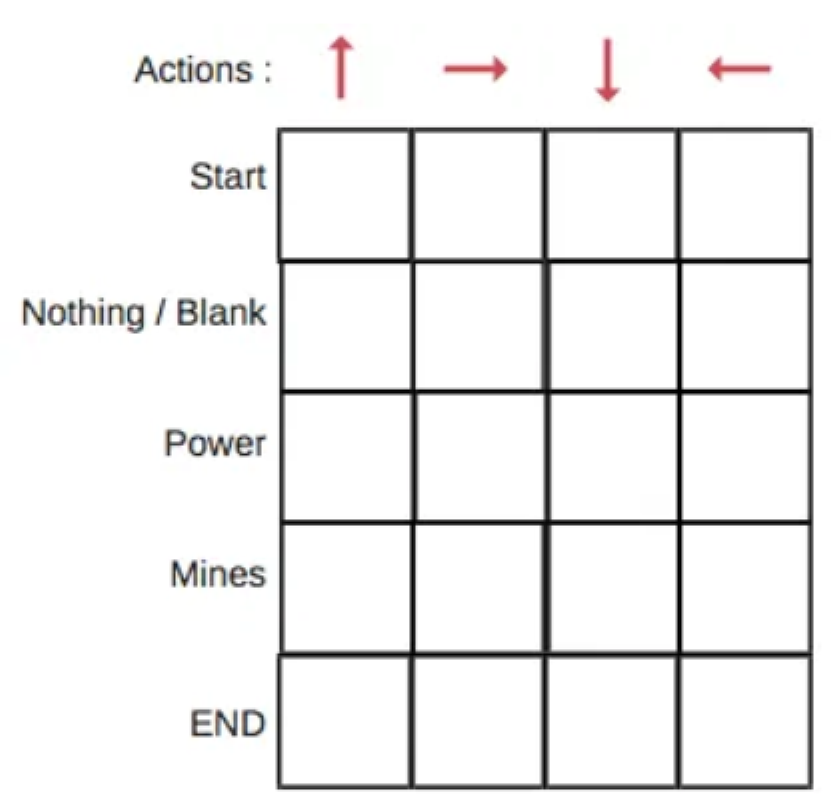
Source: ADL. 2018. An Introduction to Q-Learning: Reinforcement Learning. freeCodeCamp.Org. September 3, 2018. https://www.freecodecamp.org/news/an-introduction-to-q-learning-reinforcement-learning-14ac0b4493cc/

Problem: Train the robot to reach the end goal with the shortest path without stepping on a mine



Q-Table Example

- 4 actions: up, right, down, left
- 5 possible states: start, end, power, mine, nothing/blank
- Q-table score: maximum expected future reward the robot gets IF it takes the action at the state



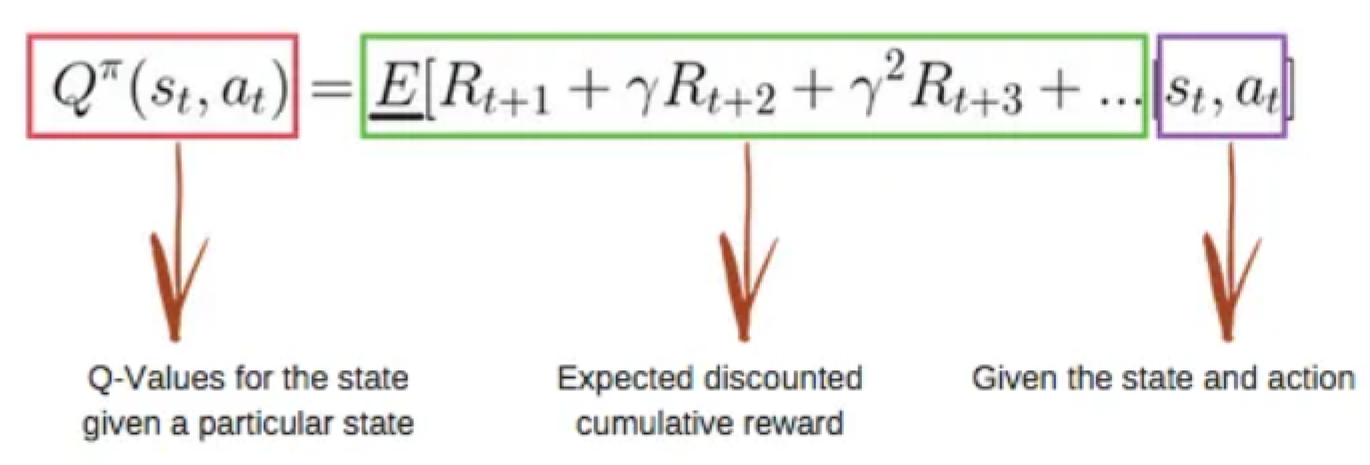
Actions :	↑	→	↓	←
Start				
Nothing / Blank				
Power				
Mines				
END				

Reward (scoring) points

- Lose 1 point at each step to reward the shortest path and reaching the goal as fast as possible
- Lose 100 points if the robot steps on a mine
- Gain 1 point if the robot steps on power
- Gain 100 points if the robot reaches the End goal.

Q-Function

- Belman equation



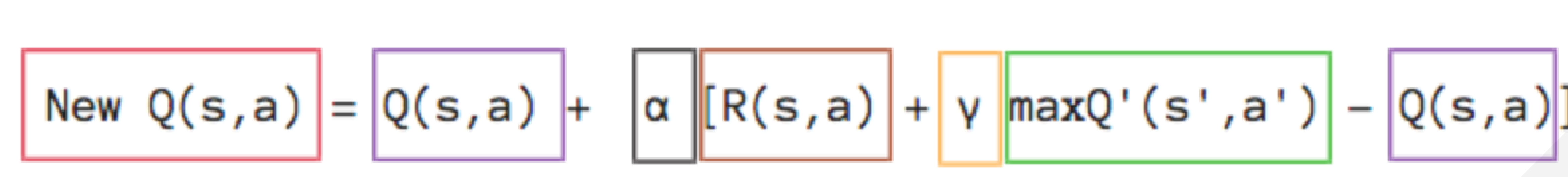
$$\boxed{Q^{\pi}(s_t, a_t)} = \boxed{\underline{E}[R_{t+1} + \gamma R_{t+2} + \gamma^2 R_{t+3} + \ldots} \boxed{s_t, a_t}]$$

Q-Values for the state given a particular state

Expected discounted cumulative reward

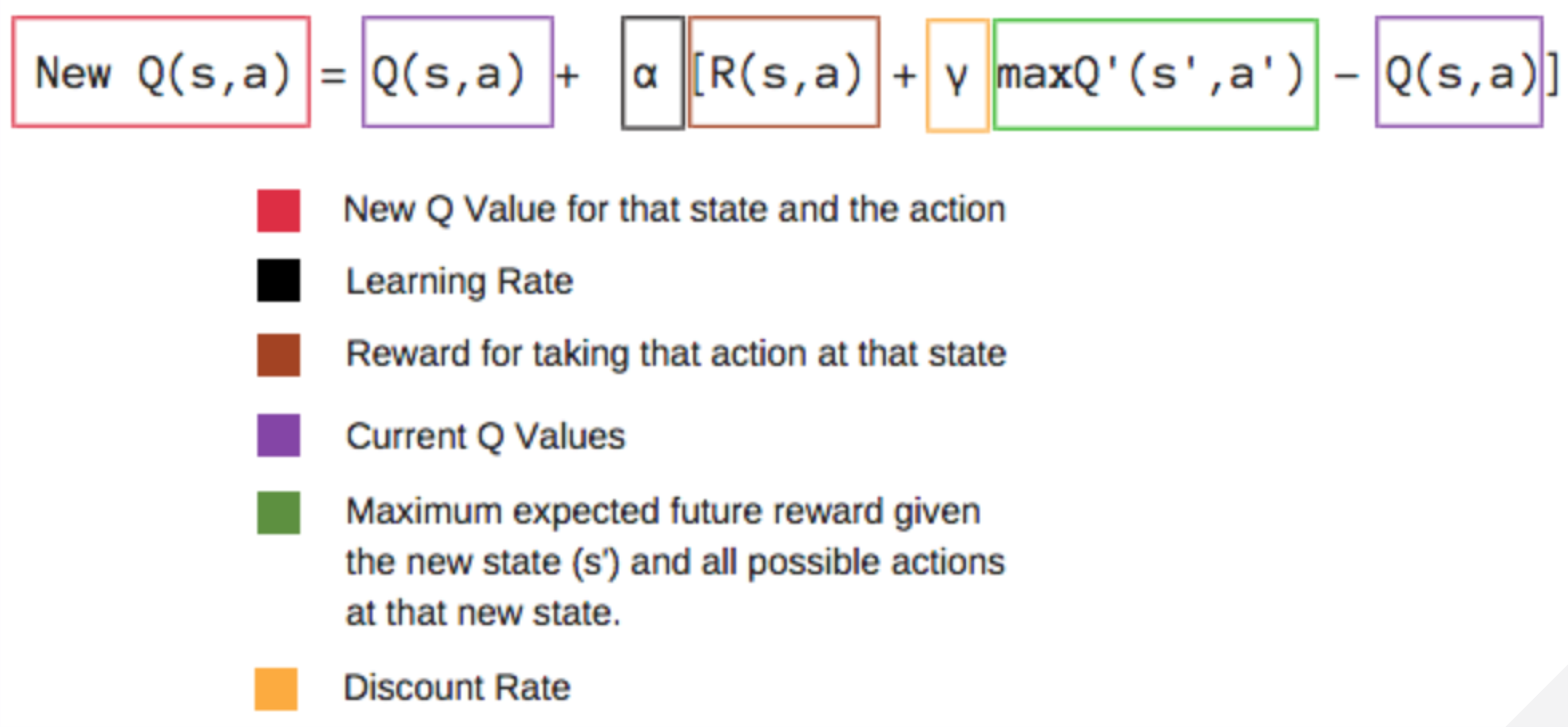
Given the state and action

- Q-value calculation



$$\boxed{\text{New } Q(s,a)} = \boxed{Q(s,a)} + \boxed{\alpha} \boxed{[R(s,a)} + \boxed{\gamma} \boxed{\max Q'(s',a')} - \boxed{Q(s,a)}]$$

New Q-value Calculation



$$\boxed{\text{New } Q(s,a)} = \boxed{Q(s,a)} + \boxed{\alpha}\boxed{[R(s,a)} + \boxed{\gamma}\boxed{\max Q'(s',a')} - \boxed{Q(s,a)}]$$

🟥 New Q Value for that state and the action

⬛ Learning Rate

🟫 Reward for taking that action at that state

🟪 Current Q Values

🟩 Maximum expected future reward given the new state (s') and all possible actions at that new state.

🟧 Discount Rate