Reinforcement Learning

Some slides were adapted/taken from various sources, including Prof. Andrew Ng's Coursera Lectures, Stanford University, Prof. Kilian Q. Weinberger's lectures on Machine Learning, Cornell University, Prof. Sudeshna Sarkar's Lecture on Machine Learning, IIT Kharagpur, Prof. Bing Liu's lecture, University of Illinois at Chicago (UIC), CS231n: Convolutional Neural Networks for Visual Recognition lectures, Stanford University, Dr. Luis Serrano, Prof. Alexander Ihler and many more. We thankfully acknowledge them. Students are requested to use this material for their study only and **NOT** to distribute it.

Outlines

- What is Reinforcement Learning?
- Markov Decision Processes
- Q-Learning
- Policy Gradients

Supervised Learning

Data: (x, y)
x is data, y is label

Goal: Learn a *function* to map

Examples: Classification, regression, object detection, semantic segmentation, image captioning, etc.

Cat

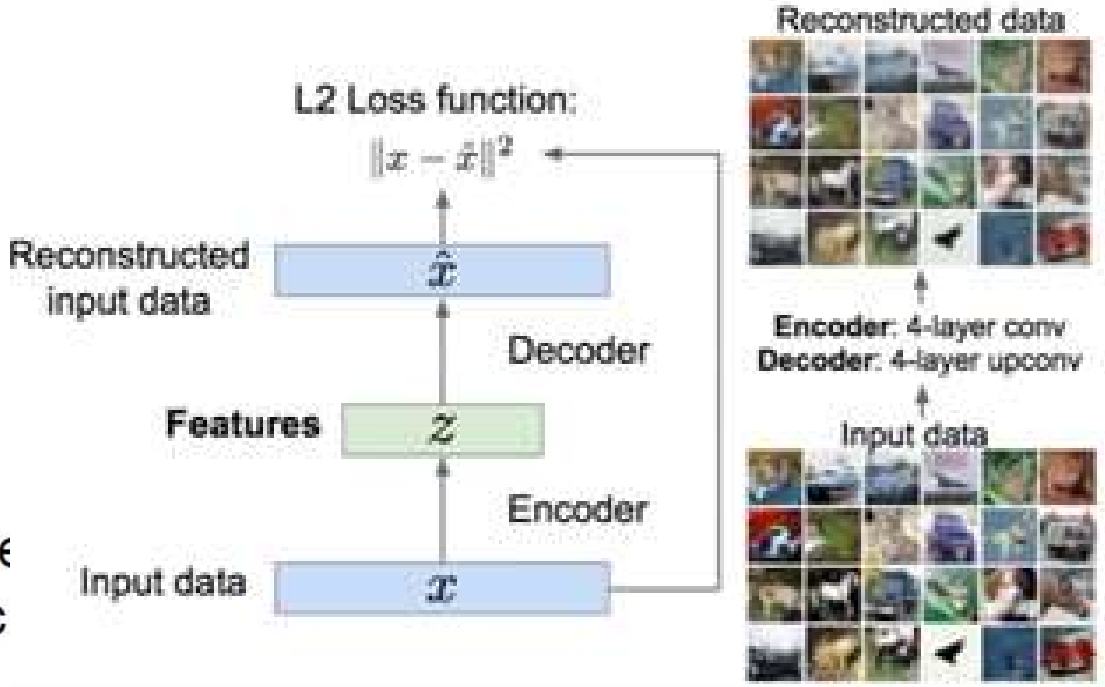
Classification

Un-Supervised Learning

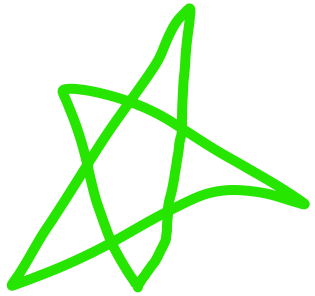
Data: x
Just data, no labels!

Goal: Learn some underlying hidden *structure* of the data

Examples: Clustering, dimensionality reduction, feature learning, density estimation, etc

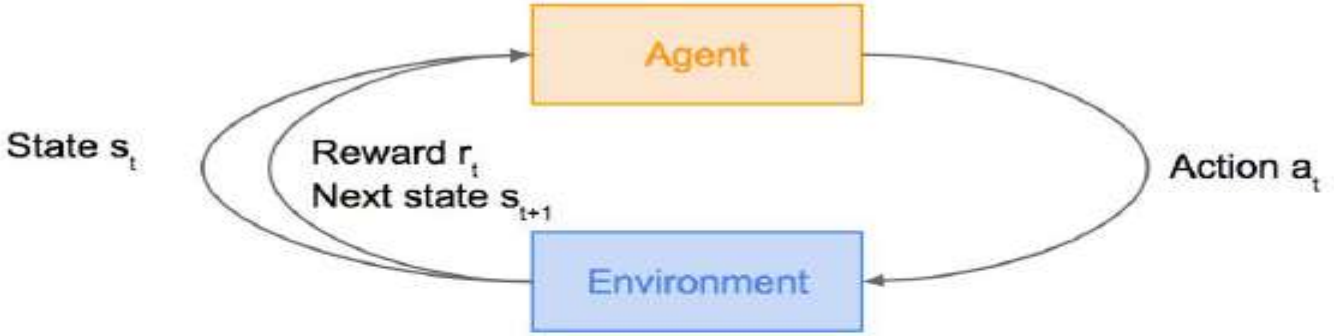


Reinforcement Learning



Problems involving an **agent** interacting with an **environment,** which provides numeric **reward** signals

Goal: Learn how to take actions in order to maximize reward



Reinforcement Learning

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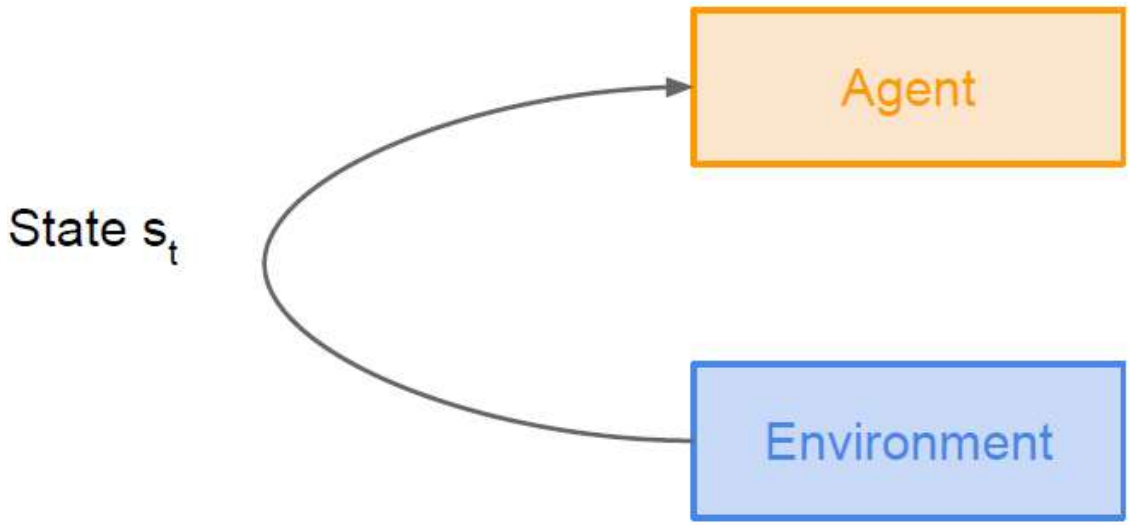
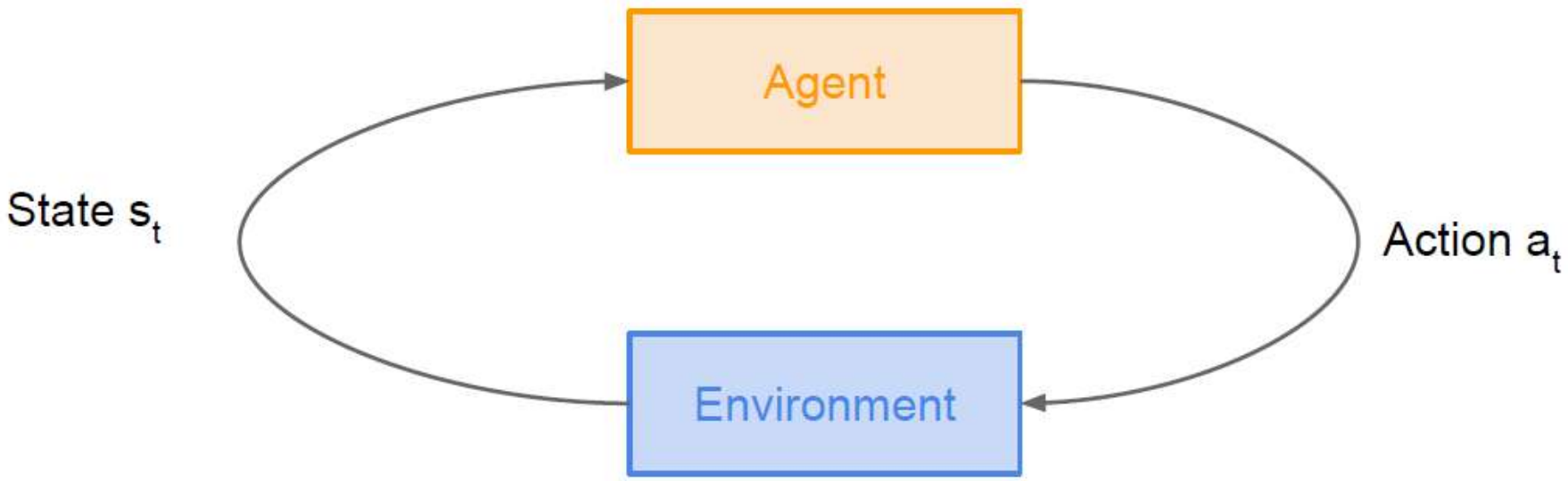
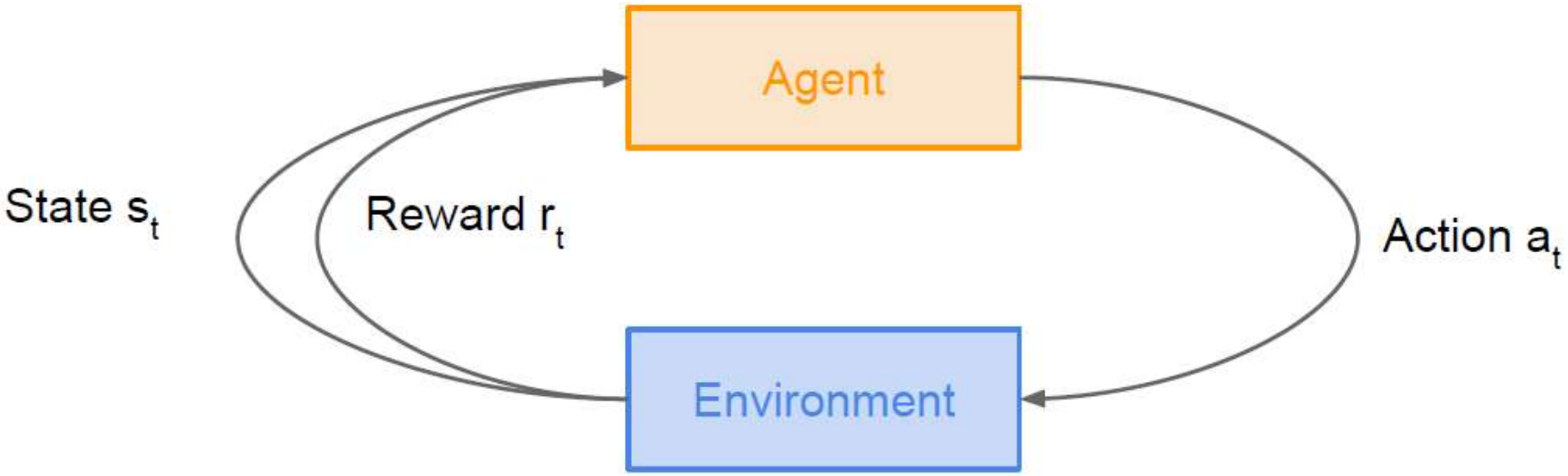


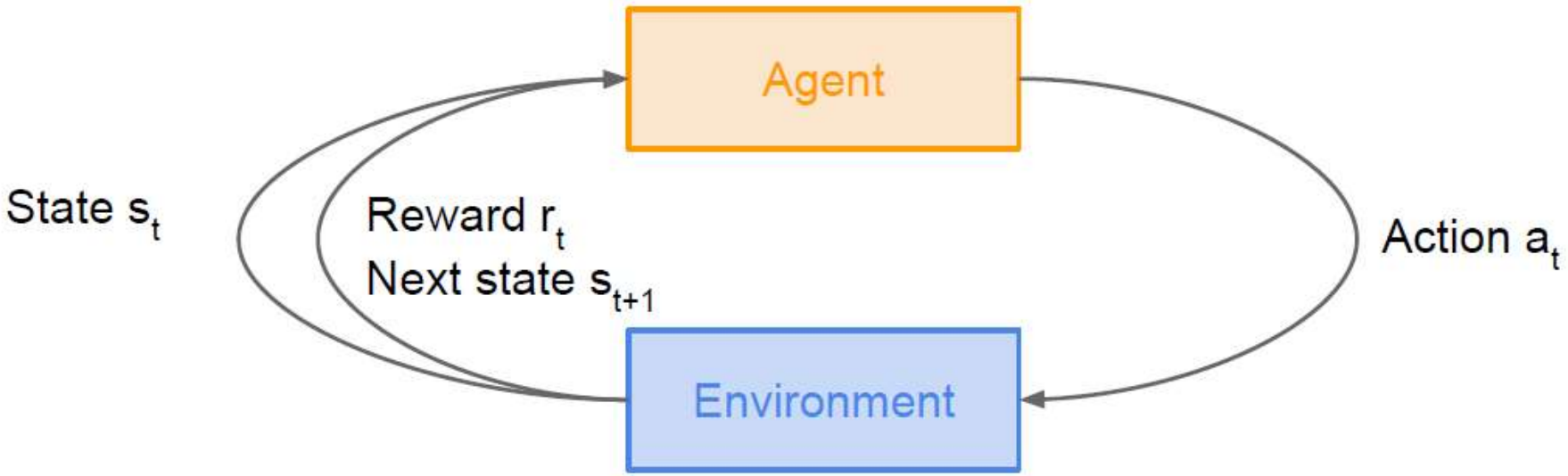
Reinforcement Learning



Reinforcement Learning

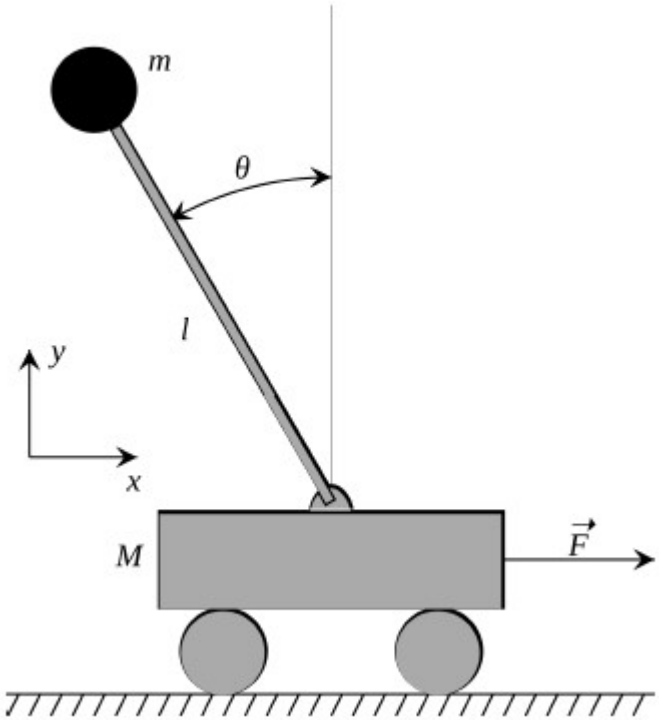


Reinforcement Learning



Cart-Pole Problem

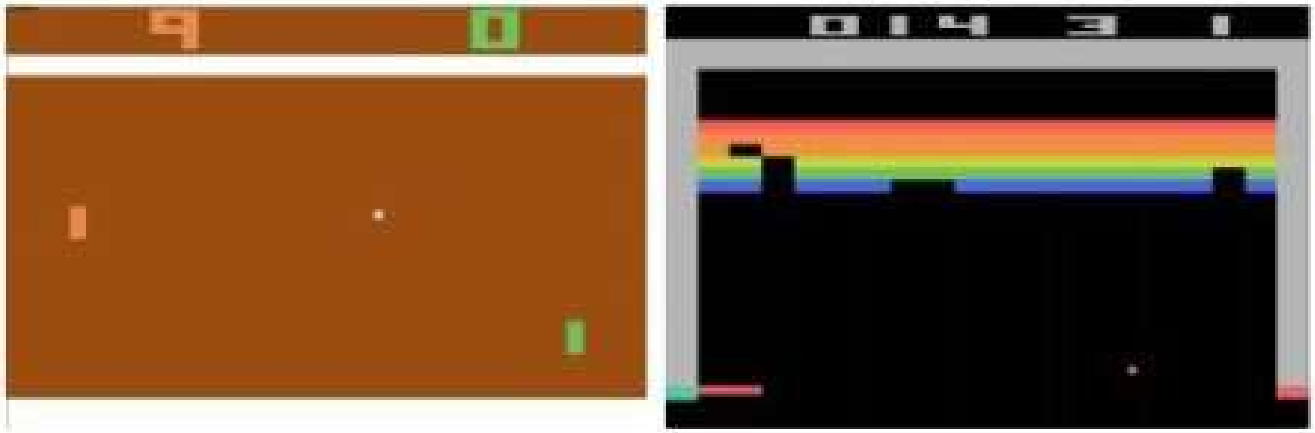
Objective : Balance a pole on top of a movable cart
State : angle, angular speed, position, horizontal velocity
Action : horizontal force applied on the cart
Reward : 1 at each time step if the pole is upright



Robot Locomotion

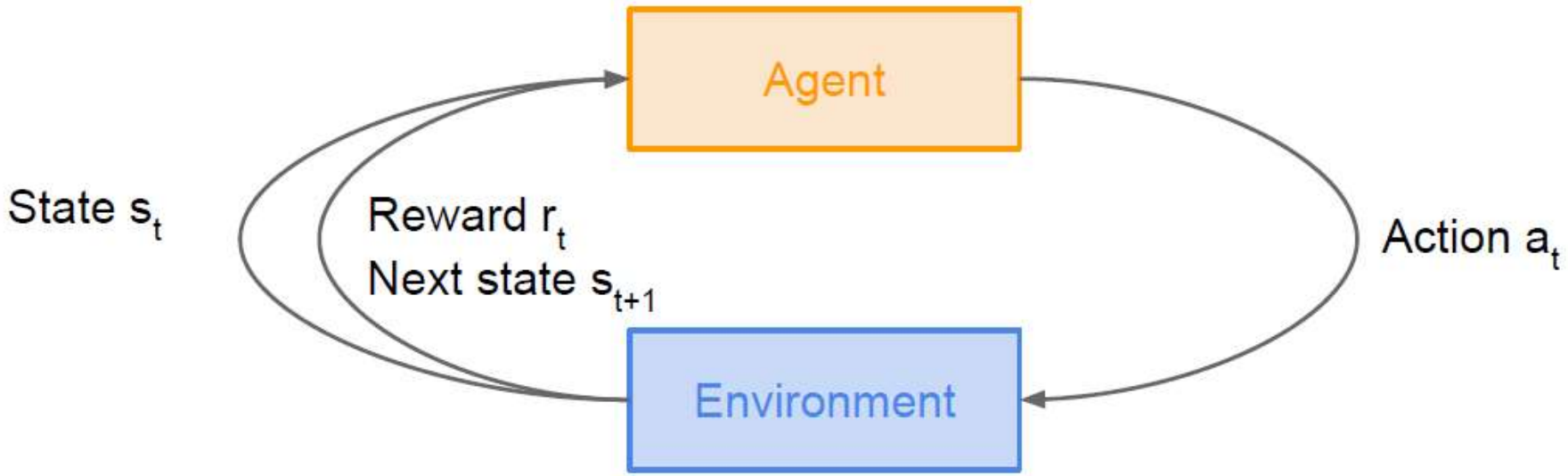
Objective: Make the robot move forward State: Angle and position of the joints
Action: Torques applied on joints
Reward: 1 at each time step upright + forward movement

Atari Games



Objective : Complete the game with the highest score
State : Raw pixel inputs of the game state
Action : Game controls e.g. Left, Right, Up, Down
Reward : Score increase/decrease at each time step

RL: Mathematical Formulation



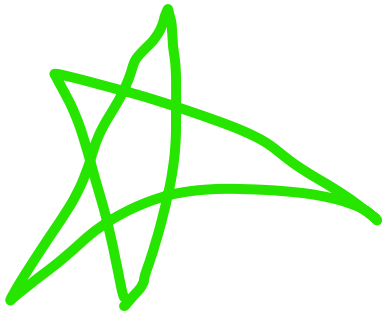
Markov Decision Process

- Mathematical formulation of the RL problem
- **Markov property**: Current state completely characterises the state of the world

Defined by: $(\mathcal{S}, \mathcal{A}, \mathcal{R}, \mathbb{P}, \gamma)$

$\mathcal{S}$: set of possible states
$\mathcal{A}$: set of possible actions
$\mathcal{R}$: distribution of reward given (state, action) pair
$\mathbb{P}$: transition probability i.e. distribution over next state given (state, action) pair
γ : discount factor

Markov Decision Process



S is a set of a finite state that describes the environment.

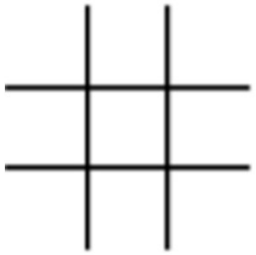
A is a set of a finite actions that describes the action that can be taken by the agent

P is a probability matrix that tells the probability of moving from one state to the other.

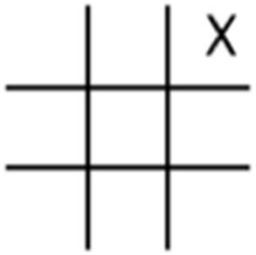
R is a set of rewards that depend on the state and the action taken. Rewards are not necessarily positive, they should be seen as outcome of an action done by the agent when it is at a certain state. So negative reward indicates bad result, whereas positive reward indicates good result.

γ is a discount factor, that tells how important future rewards are to the current state. Discount factor is a value between 0 and 1. A reward R that occurs N steps in the future from the current state, is multiplied by γ^N to describe its importance to the current state. For example consider $\gamma = 0.9$ and a reward $R = 10$ that is 3 steps ahead of our current state. The importance of this reward to us from where we stand is equal to $(0.9^3)*10 = 7.29$.

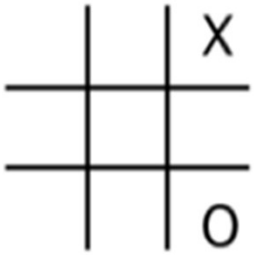
Example: Tic-tac-toe



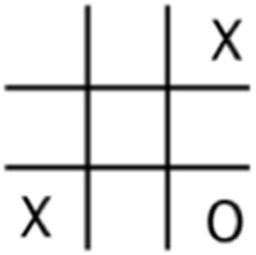
Before game begins



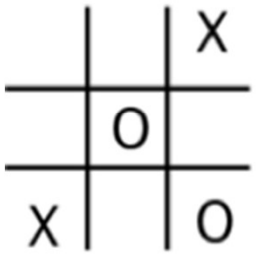
X's first move



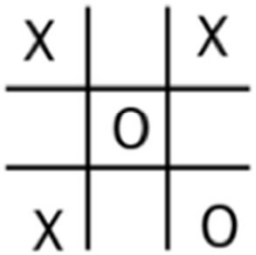
O's first move



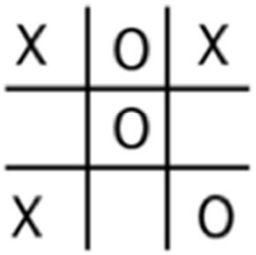
X's second move



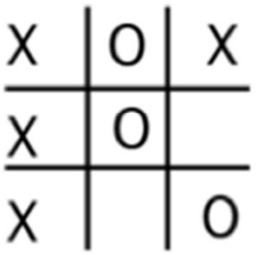
O's second move



X's third move



O's third move



X wins on X's fourth move

Man Vs Machine

Deep Blue
IBM Super Computer

Garry Kasparov
World Chess Champion

First match February 10, 1996: took place in Philadelphia, Pennsylvania
Result: **Kasparov**–Deep Blue (4–2)
Record set: First computer program to defeat a world champion in a *classical game* under tournament regulations

Second match (rematch)
May 11, 1997: held in New York City, New York
Result: **Deep Blue**–Kasparov (3½–2½)
Record set: First computer program to defeat a world champion in a *match* under tournament regulations

Thanks