Lecture 1.1: Basic Machine Learning

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Basic Machine Learning

Category of machine learning

- **Supervised learning:** learning from samples with labels
- **Unsupervised learning:** learning from samples without labels
- **Semi-supervised learning**: augment supervised learning with unlabeled data
- **Reinforcement learning:** learning through the interaction with environment

Supervised Learning

Image classification via supervised learning

Deep neural network (DNN) $h : \mathbb{R}^{k \times k} \to \mathbb{R}$

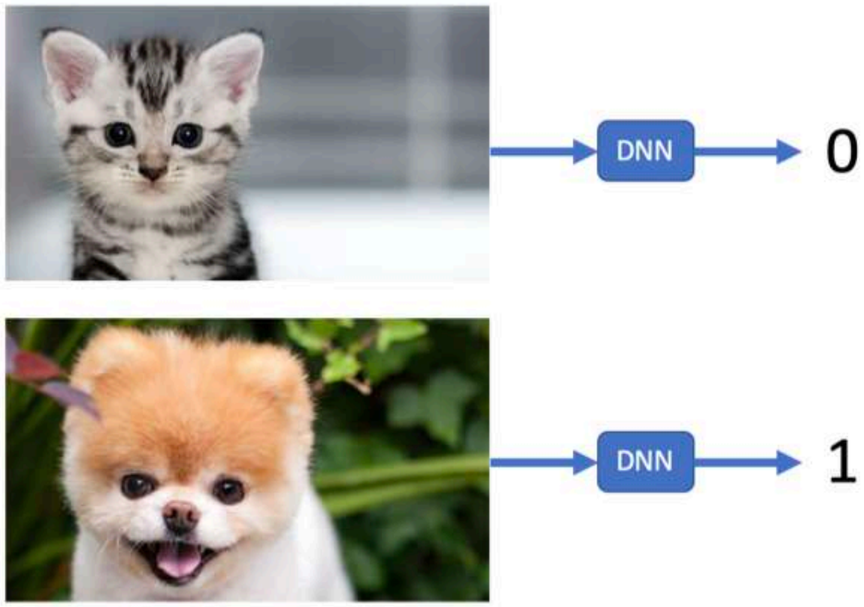

Image classification via supervised learning

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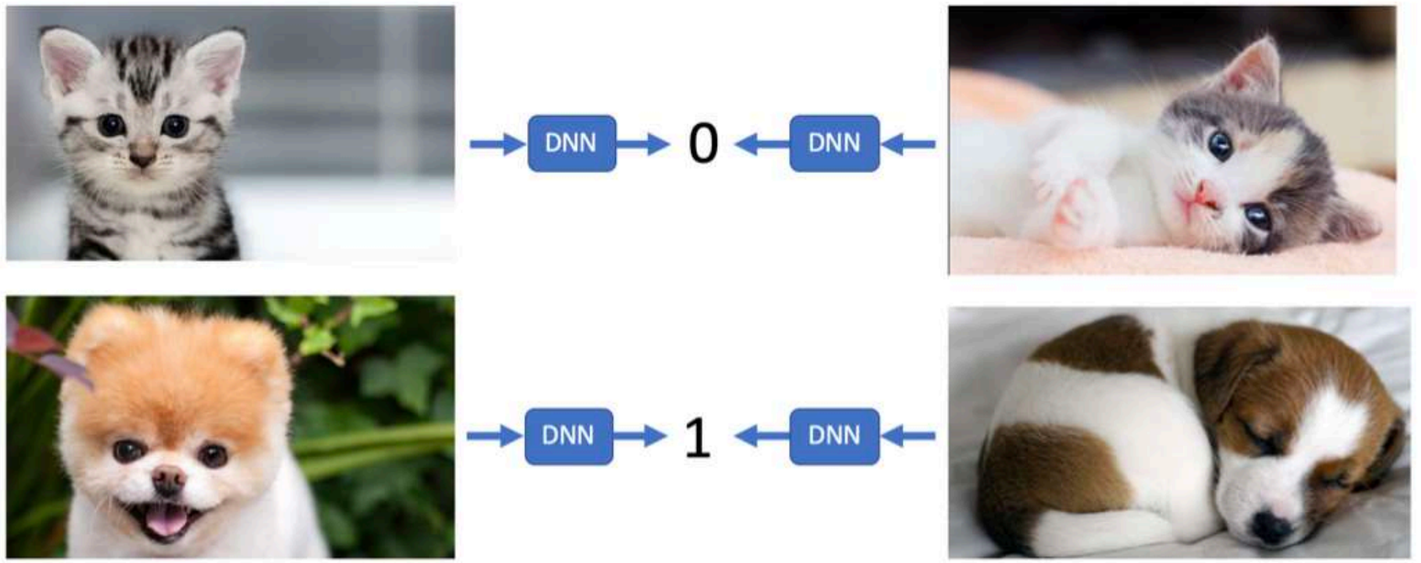


Mathematical Formulation of Supervised Learning

- **Unknown target:** a map $f : \mathbb{R}^d \to \mathbb{R}^k$
- **Training data:** samples $\{x_i\}_{i=1}^n$ and labels $\{y_i\}_{i=1}^n$
- **Learning goal:** find a model (e.g., a network $h(x;\theta) \approx f(x)$)
- **One solution**: $\min_\theta \frac{1}{n} \sum_{i=1}^{n} | h(x_i;\theta) - f(x_i) |^2 = \frac{1}{n} \sum_{i=1}^{n} | h(x_i;\theta) - y_i |^2$

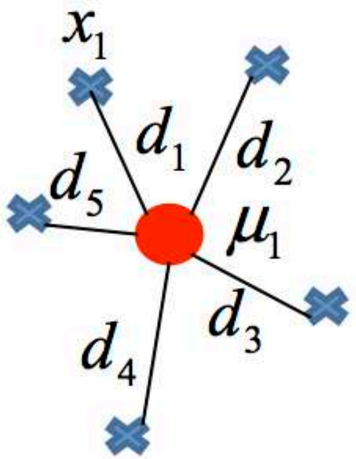
Unsupervised Learning

Common Problems

- **Clustering**
- **Dimension reduction**
- **Principle component analysis**
- **Autoencoder**

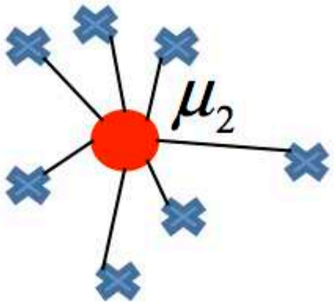
K-Means Clustering

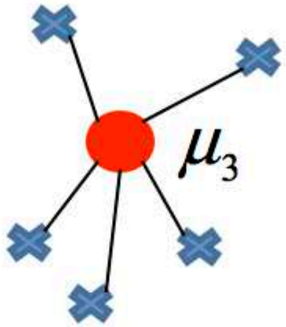
Centroid
Sample



$$\sum_{x_j \in S_1} d_j^2 = d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2$$

$$\sum_{x_j \in S_2} d_j^2$$



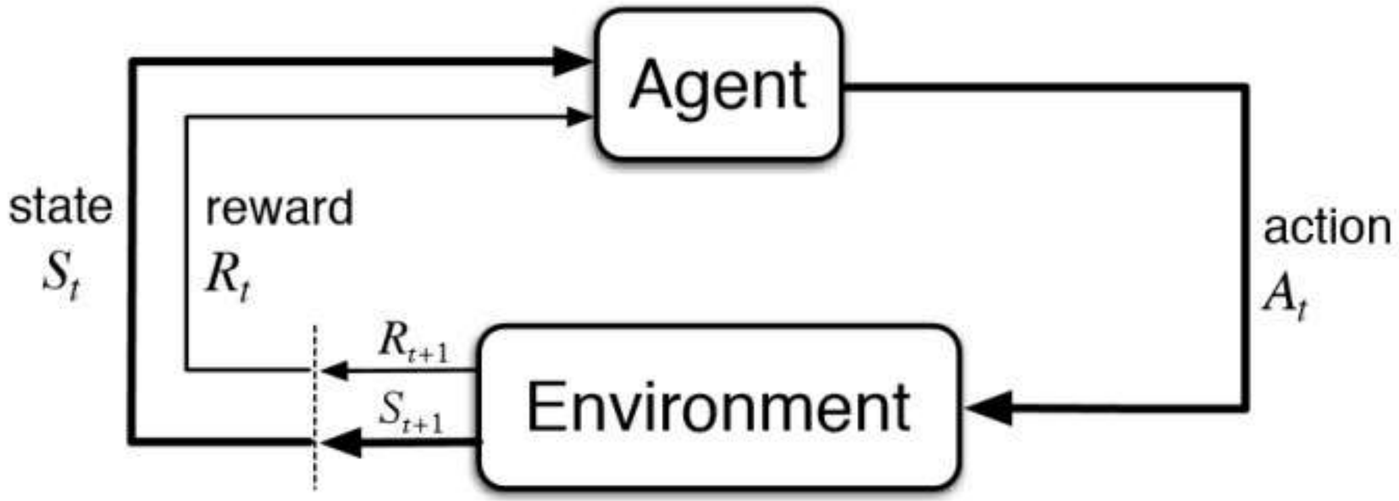


$$\sum_{x_j \in S_3} d_j^2$$

$$\min_S E(\mu_i) = \sum_{x_j \in S_1} d_j^2 + \sum_{x_j \in S_2} d_j^2 + \sum_{x_j \in S_3} d_j^2$$

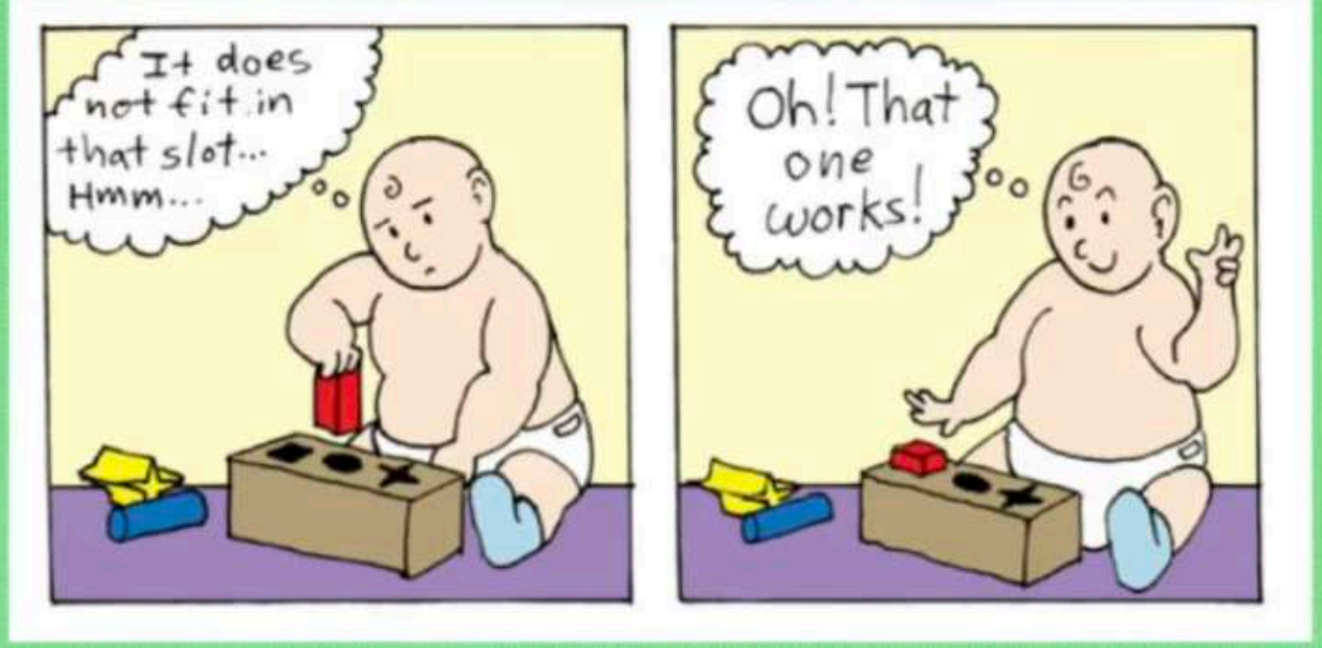
Reinforcement Learning

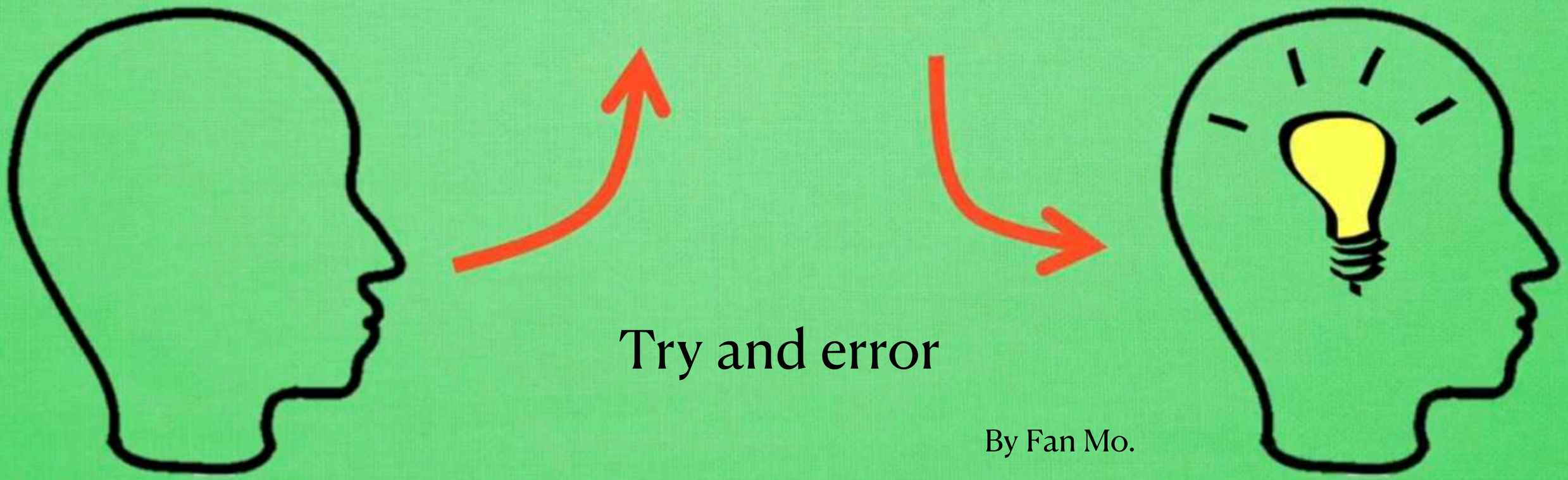
Introduction to RL



By Richard S. Sutton and Andrew G. Barto.

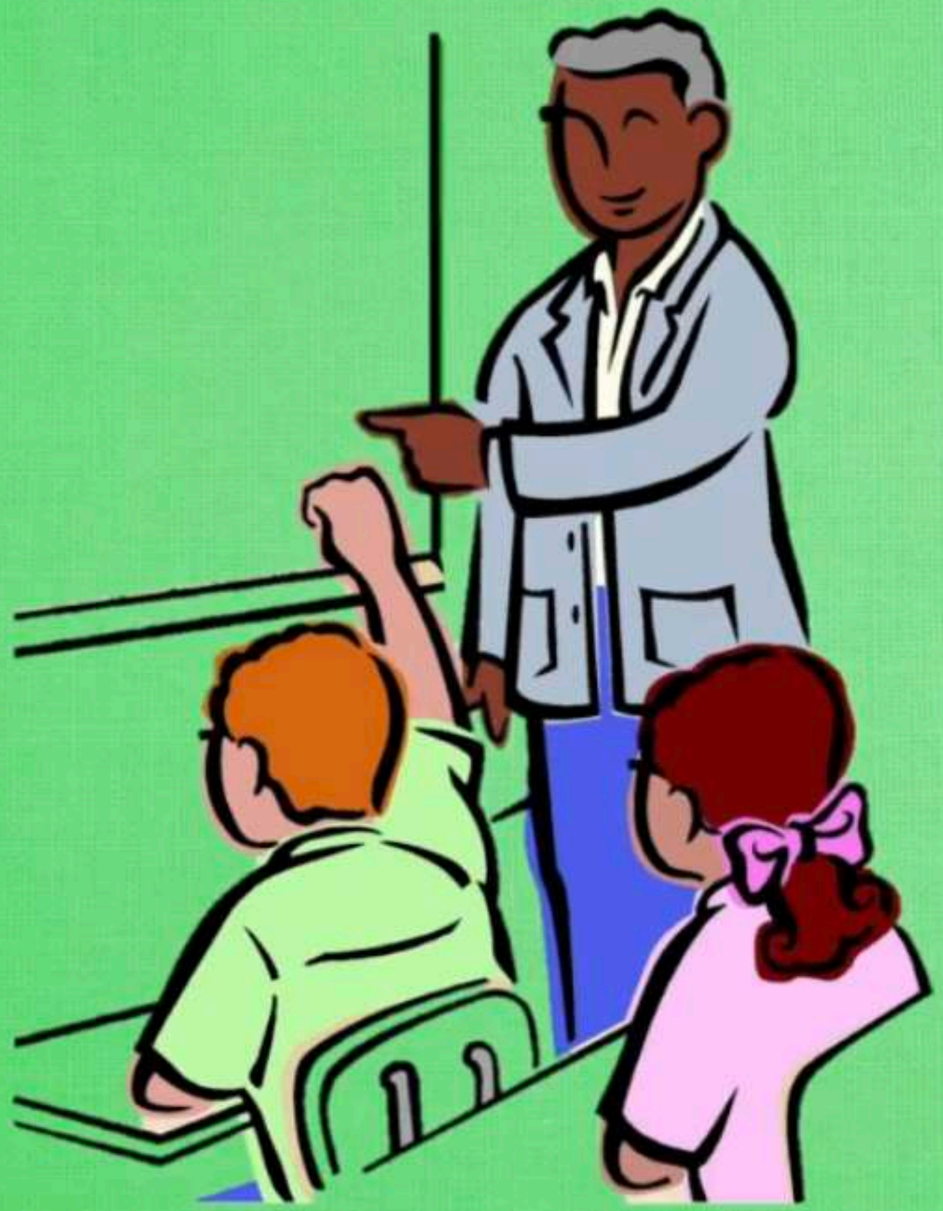
- **Goal:** Learn how to take actions in order to maximize reward via iteraction
- **Components:** agent, environment, etc
- **Interaction:** action, state, reward, etc





Try and error

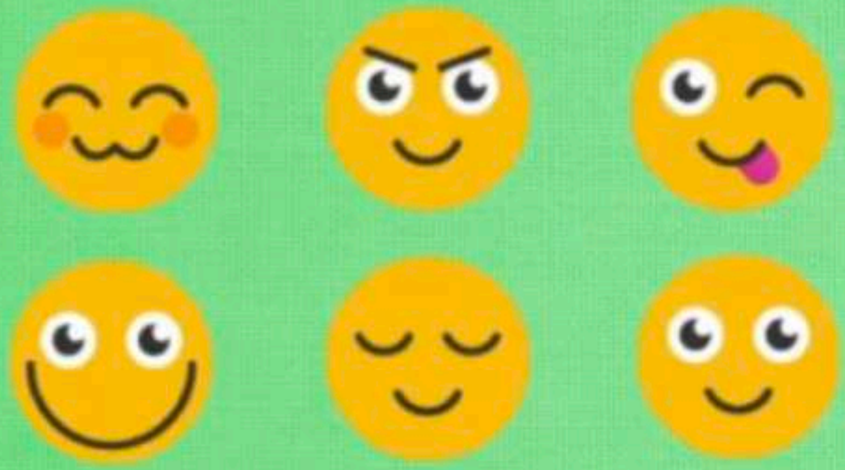
By Fan Mo.



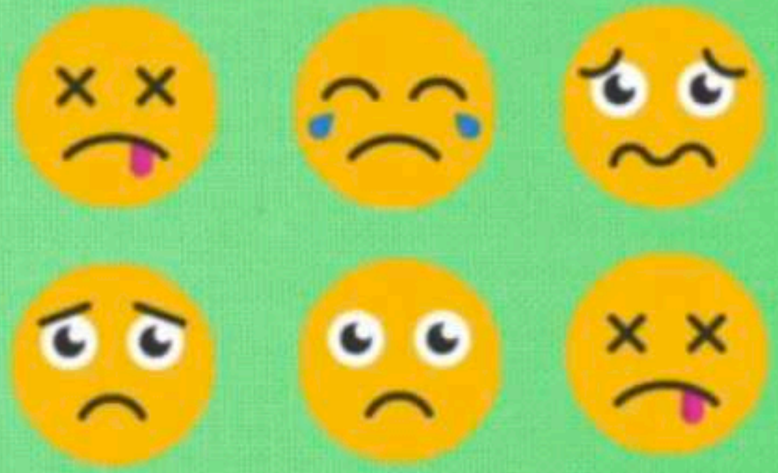
Instruction through evaluation

By Fan Mo.

High Grade



Low Grade

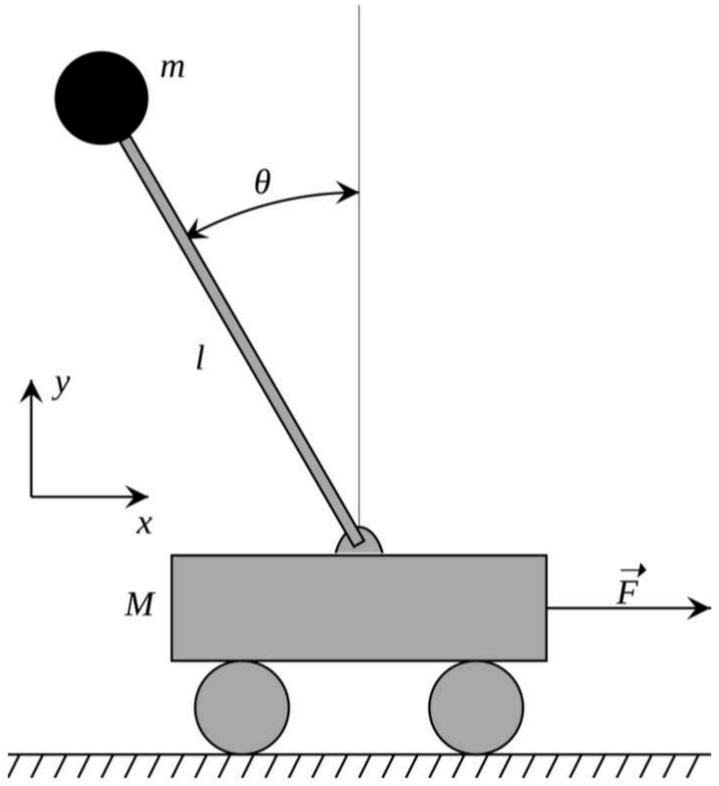


Learn to be optimistic via interaction

$$A_0, R_0, A_1, R_1, \ldots, A_n, R_n, \ldots$$

By Fan Mo.

Cart-Pole Problem



By Fei-Fei Li et al.

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

$$A_0, S_0, R_0, A_1, S_1, R_1, \ldots, A_n, S_n, R_n, \ldots$$