2025/02/20 회의 (RL 관련 공유)

Wise
AI Lab
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Contents

Preliminaries

Random variables

$X : \Omega \to E$

(Ω, Σ, P): 확률 공간 (Sample space Ω, Event space Σ, Probability measure P)

(with some assumptions), we also have

Probability density function

$\mathbb{E}_P[f(X)] := \int_\Omega f(X(\omega))dP(\omega) = \int_E f(x)p(x)dx =: \mathbb{E}_{x \sim p(x)}[f(x)]$

> Note
>
> E might be complex..

Monte Carlo estimation

Goal: Calculate $\mathbb{E}_{x \sim p(x)}[f(x)]$

(Hint: Law of Large Numbers)

Overview of RL

- Agent
- Environment
- $\mathcal{S}$: a finite set of states (상태 집합)
- $\mathcal{A}$: a finite set of actions (행동 집합)
- Policy $\pi : \mathcal{A} \times \mathcal{S} \to [0, 1]$
    - Optimal policy
        - $\pi^* = \arg\max_\pi \mathbb{E}_{s_0 \sim p_0(s)}[V_\pi(s_0)]$
        - $V_{\pi^*}(s) \geq V_\pi(s)$ $(\forall x \in \mathcal{S}, \forall \pi)$
- Reward $R : \mathcal{A} \times \mathcal{S} \to \mathbb{R}$
- Value function $V : \mathcal{S} \to \mathbb{R}$
- Q-function $Q : \mathcal{S} \times \mathcal{A} \to \mathbb{R}$

Overview of RL

Terminologies

- Advantage function $A : \mathcal{S} \times \mathcal{A} \to \mathbb{R}$
  - $A(s, a) := Q(s, a) - V(s)$
- Generalized advantage estimation (GAE)
  - Advantage function을 계산하려면 state와 action 값이 필요하다.
  - 그런데 이러한 state, action은 (policy와 initial state의 확률분포에 depend하는) random variable이다.
  - 따라서 Advantage function의 evaluation 결과 $A(s, a)$도 random variable
  - 이 random variable을 estimate하기 위해 R, V를 통해 Monte Carlo estimate을 하는데 그 estimation의 variance를 줄이기 위해 나온 방법이 GAE

GAE

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GAE

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Objective function of RL

$$L(\theta) = \mathbb{E}_{s_0 \sim p_0(s)}[V_{\pi_\theta}(s_0)]$$

- policy를 neural network의 parameter θ를 도입하여 위의 목적함수를 최대화하도록 훈련해서 optimal policy를 얻고자 하는 것이 RL의 목표

Overview of RL

- Value-based RL
  - Q functiond을 학습하여 $\pi(s) = \arg\max_{a \in \mathcal{A}} Q(s,a)$를 policy로 사용
  - 단점
    - function approximation (such as neural networks)
    - bootstrapped value function estimation (TD-like method)
    - off-policy learning
    - This combination : `the deadly triad`
    - RL 알고리즘 불안정함
- Policy-based RL
  - Policy search method
  - 대부분 policy gradient 방법론 사용
- Model-based RL (MBRL)

Overview of RL

Classification of RL

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Policy Gradient Theorem

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Policy Optimization

REINFORCE

- Monte Carlo version
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- 단점: estimation G_t의 분산이 큼
  - 해결책: baseline을 사용

Policy Optimization

- PPO

Reinforcement Learning with LLMs

- InstructGPT

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RL with LLMs

- ChatGPT

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RL with LLMs

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RL with LLMs

- DeepSeek-R1-Zero
  - RL on the Base Model

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Reinforcement Learning with Verifiable Rewards

RLVR

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RLVR

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