Optimal Electric Vehicle Charging Strategy based on Deep Reinforcement Learning

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ABSTRACT

We propose a twin-delayed deep deterministic policy gradient (TD3) based deep reinforcement learning (DRL) algorithm to handle with the electric vehicle (EV) charging problem.

The proposed method can minimize the charging cost of EV users while satisfying their desired energy requirements.

INTRODUCTION

With the **increasing penetration of EVs**, the **charging power demand of large-scale EVs** has become a **crucial component** of the **electric power consumption**.

However, the **unscheduled** EV charging strategy will cause **great challenge to the operation of power systems[1]** as well as **damage the interests of EV users**.

To efficiently solve the EV charging problem, we formulate an **optimal EV charging strategy based on TD3[2]** algorithm.

TD3 algorithm is **an improved version of DDPG algorithm** and focuses on dealing with the **overestimation bias problem with the value function, which may lead to suboptimal policies[3].**

METHOD

- A knowledge-assisted TD3 algorithm with imitation learning for EV charging control
- **Knowledge-assisted**:

  constraining soc_t within the scope of the planner

  - Upper bound:
    - ✓ Charge at P_{max} directly it is parked

$$soc_t^{upper} = min\left\{\left(soc_{ini} + \eta\frac{P_{max}}{C}\cdot(t - t_{arr})\right), soc_{max}\right\}$$

    - ✓ Then discharge to expected value:

$$soc_{t_{dep}}^{upper} = soc^{target}$$

- **Knowledge-assisted**:
  - Lower bound:
    - ✓ Discharge at P_{max} directly it is parked

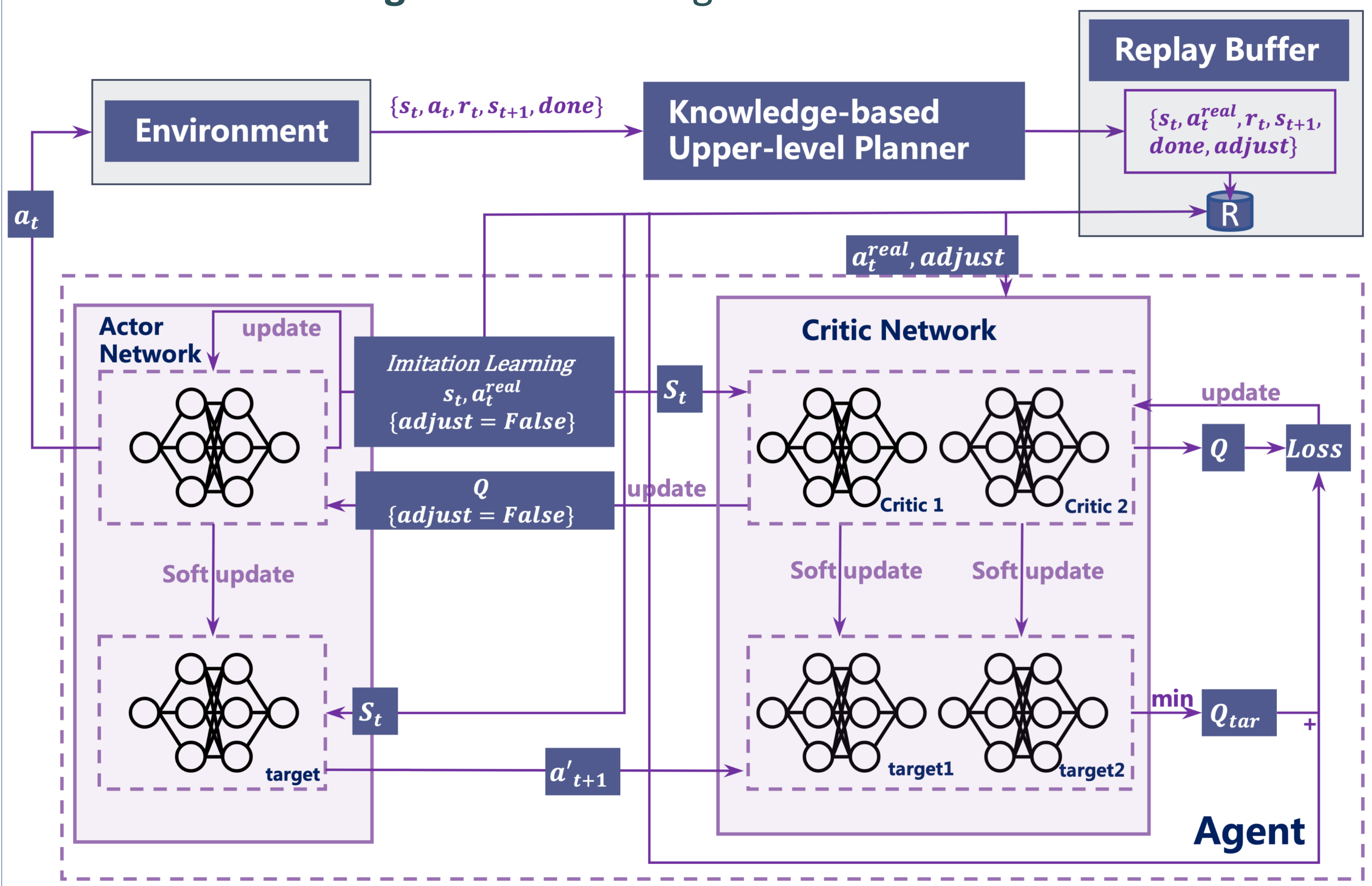
$$soc_t^{lower} = max\left\{\left(soc_{ini} - \frac{P_{max}/\eta}{C}\cdot(t - t_{arr})\right), soc_{min}\right\}$$

    - ✓ Then charge at P_{max} to expected value

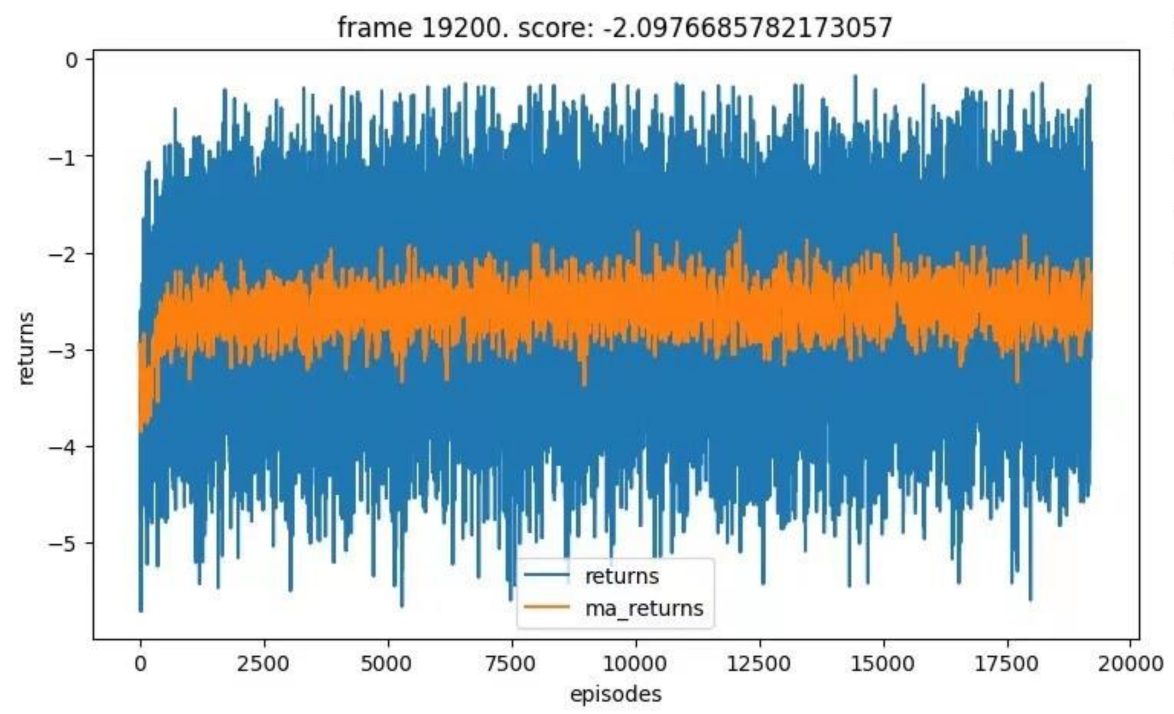
$$soc_t^{lower} = max\left\{\left(soc^{target} - \eta\frac{P_{max}}{C}(t_{dep} - t),\right), soc_{min}\right\}$$

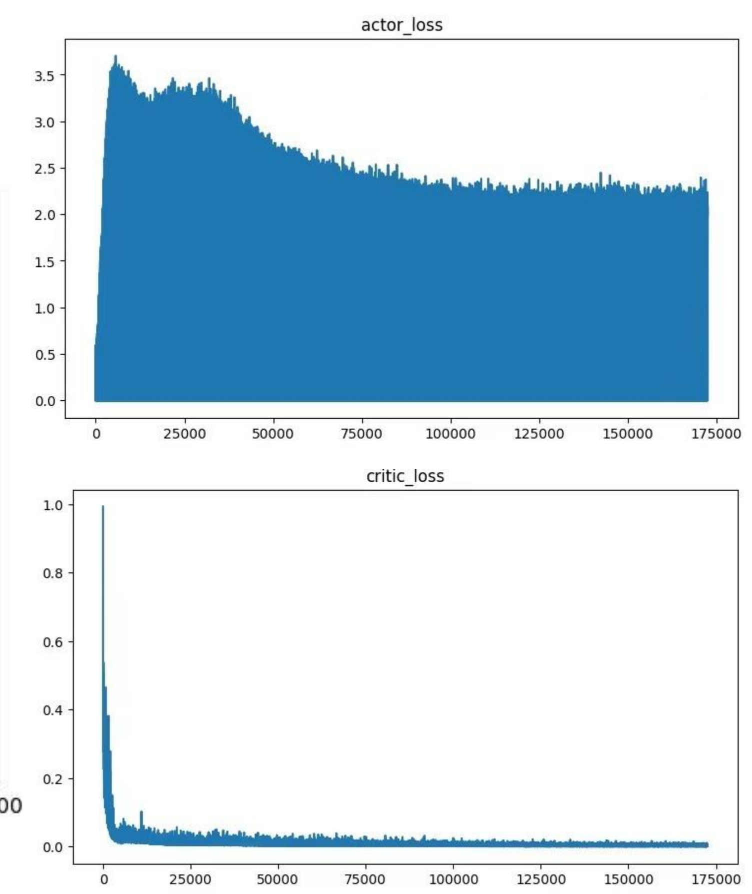
  satisfy the user's charging needs and protect the EV battery.

- **Imitation learning assisted TD3** algorithm:

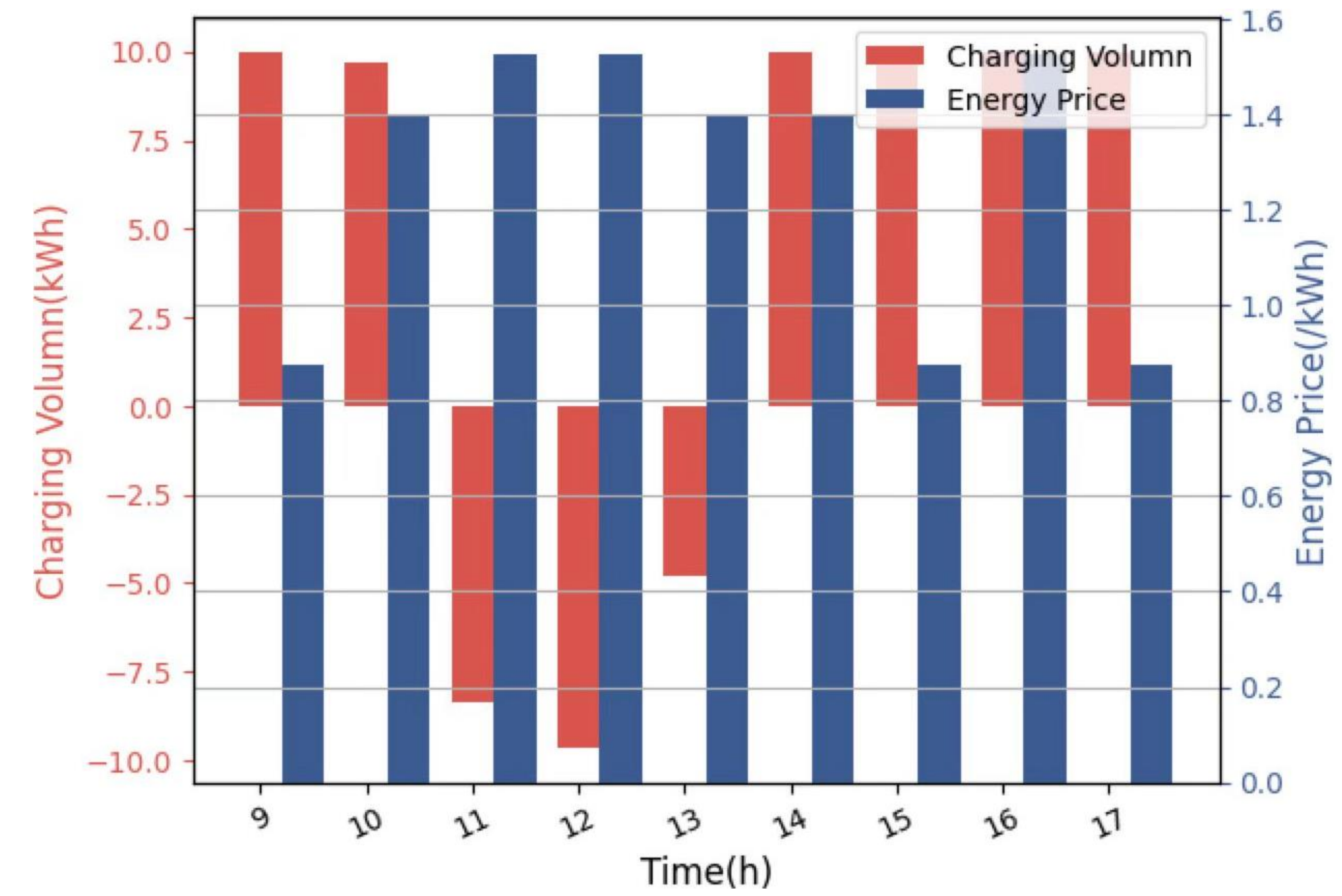


RESULT





Convergence process during training



Charging/Discharging volume and energy price of the 100thEV

	Traditional TD3	Proposed Method	Ideal Result
Average SoC	0.937	**0.95**	**0.95**
Maximum SoC	1.0	**0.95**	**0.95**
Minimum SoC	0.93	**0.95**	**0.95**
Average Cost	32.68	**25.09**	**22.356**

The results validate that the proposed method outperforms traditional TD3 algorithm in terms of economy and user satisfaction.

CONCLUSIONS

An optimal EV charging strategy based on TD3 algorithm is proposed to **reduce the charging costs of EV users while meeting with their energy requirements.**

Prior knowledge and imitation learning methods are **combined with the TD3 algorithm** to improve **the robustness and efficiency** of the charging strategy.

The numerical tests have demonstrated the effectiveness and advantages of the proposed method.

REFERENCES

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[3] Fujimoto S, Hoof H, Meger D. Addressing function approximation error in actor-critic methods[C]//International conference on machine learning. PMLR, 2018: 1587-1596.