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A home energy management approach using decoupling value and policy in reinforcement learning

Key words: Home energy system; Electric vehicle; Reinforcement learning; Generalization

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Motivation

1. Efficient home energy management (HEM) techniques are promising in optimizing electricity cost, comforting residents, and reducing carbon emissions, which are achieved by intelligently scheduling and controlling electric vehicles (EVs) and household appliances.

2. The scalability of model-driven approaches in different scenarios is poor, and re-established models are a prerequisite for excellent performance in new scenarios of HEM.

3. Standard deep reinforcement learning (DRL) algorithms usually use shared networks for the policy and value functions, which therefore limits the estimation accuracy of the value function.

Method

An improved mathematical model is designed to quantify EVs' energy demand more practically and completely, where driver's experience, unexpected events, and traffic conditions are integrated.

$$Z_{\mathrm{SoC}}(t)=\frac{k_1 k_3\left(\mathrm{e}^{-k_2(t-t_{\mathrm{a}})/(t_{\mathrm{d}}-t_{\mathrm{a}})}-1\right)}{\mathrm{e}^{-k_2}-1}$$

k_1, k_2, and k_3 are the shape parameters changing with driver's experience, unexpected events, and traffic conditions, respectively.

$$E_{t+1}^{\mathrm{SoC}}=\begin{cases}E_t^{\mathrm{SoC}}+\eta_{\mathrm{ch}}P_t^{\mathrm{EV}}\Delta t, & \text{if } P_t^{\mathrm{EV}}\geq 0,\\ E_t^{\mathrm{SoC}}+\eta_{\mathrm{dis}}P_t^{\mathrm{EV}}\Delta t, & \text{otherwise,}\end{cases}$$

$$-P_{t,\max}^{\mathrm{EV}}\leq P_t^{\mathrm{EV}}\leq P_{t,\max}^{\mathrm{EV}},$$

$$0\leq E_t^{\mathrm{SoC}}\leq E_{t,\max}^{\mathrm{SoC}},$$

$$\mathrm{SoC}_t=\frac{E_t^{\mathrm{SoC}}}{C}$$

Different EVs' battery capacities C are considered.

Method

A novel RL-based decoupled actor-critic (DA2C) approach is developed to alleviate the overfitting problem and enhance generalization performance by decoupling the policy and value networks.

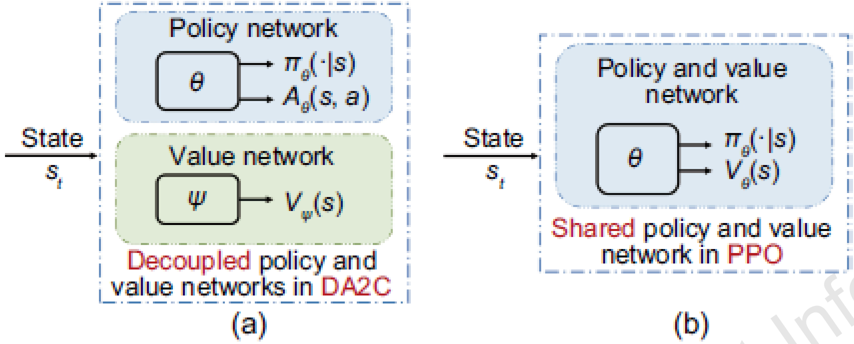


Fig. 2 Comparison of decoupled architecture in DA2C (a) and shared architecture in PPO (b) (DA2C: decoupled advantage actor-critic; PPO: proximal policy optimization)

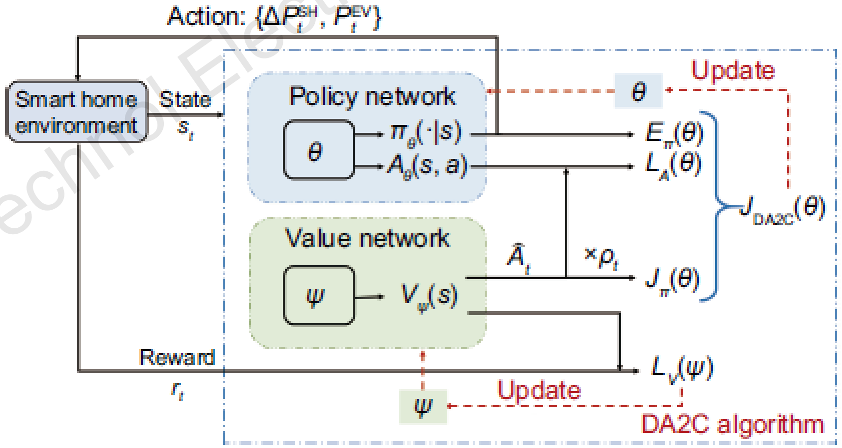


Fig. 3 Decoupled advantage actor-critic (DA2C) algorithm

Method

Table 2 Comparison of different methods and different Markov decision processes (MDPs) in terms of training and test performances on tasks from different residents

Method	Training cost ($\times 10^2$ A\$)			Test cost (A\$)		
	MDP	MDP_1	MDP_2	MDP	MDP_1	MDP_2
PPO	15.45±7.08	**9.31±6.40**	17.98±10.53	59.87±24.65	60.67±34.72	65.56±21.27
IDAAC	14.93±9.35	10.01±7.80	14.12 ± 7.67	62.57±25.38	51.70±23.76	**58.92±22.38**
APDAC	14.58±8.86	13.51±8.32	15.17 ± 6.63	64.13±21.25	43.33±18.01	68.32±23.20
DA2C	**13.31±7.40**	9.90±4.88	**13.90±7.72**	**58.33±25.72**	**42.76±18.80**	60.87±20.64

Results in bold and cells colored gray denote the best and the second best, respectively

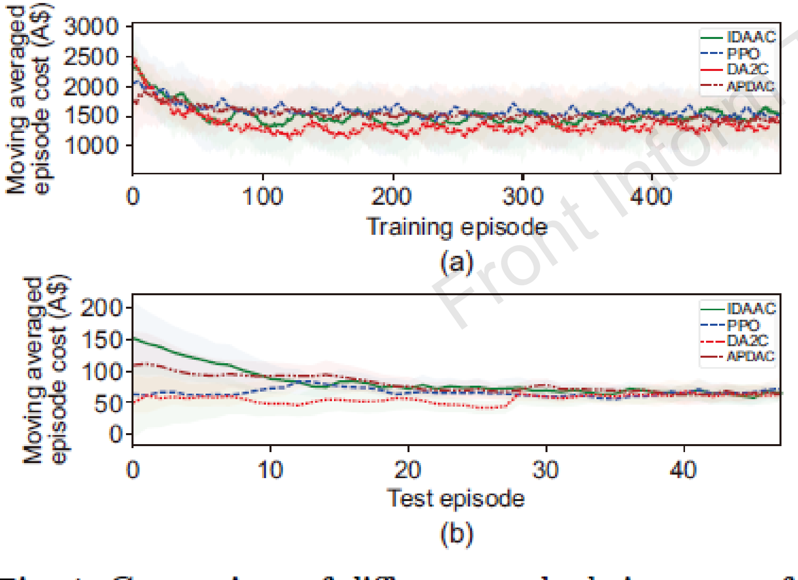


Fig. 4 Comparison of different methods in terms of training (a) and test (b) performances on tasks from different residents

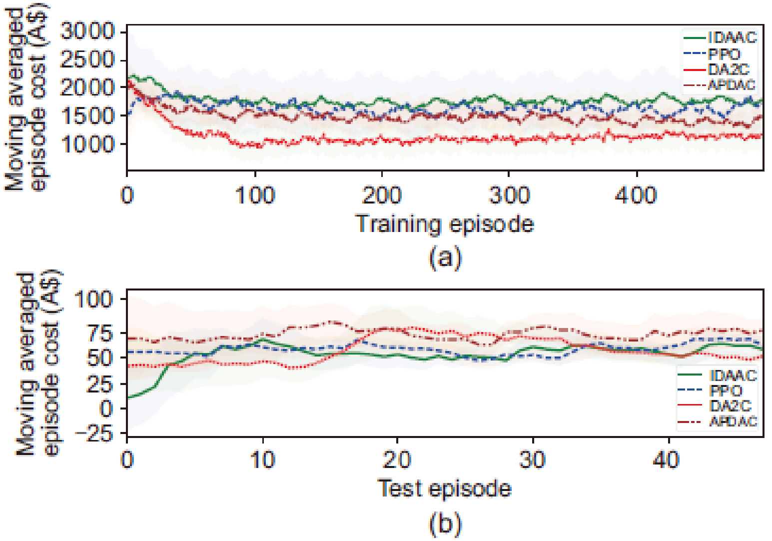
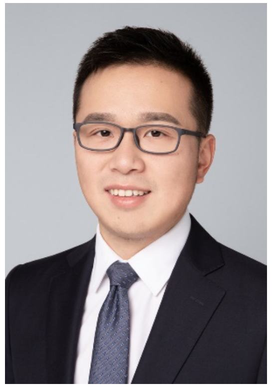


Fig. 6 Comparison of different methods in terms of different seasons: (a) training; (b) test

Conclusions

1. We proposed a data-driven intelligent optimization approach to achieve optimal energy management of smart home systems, by appropriately scheduling the charging operation of EVs and the energy consumption of household appliances.
2. An improved mathematical model is designed to quantify EVs' energy demand more practically and completely, where driver's experience, unexpected events, and traffic conditions are integrated.
3. A novel RL-based DA2C approach is developed to alleviate the overfitting problem and enhance generalization performance by decoupling the policy and value networks.

Luolin XIONG received her BS degree from the School of Control Science and Engineering, East China University of Science and Technology, Shanghai, China, in 2020, where she is currently pursuing her PhD degree. Her research interests include smart grids, microgrids, reinforcement learning, and their applications.



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