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Multi-agent evaluation for energy management by practically scaling α -rank

Key words: Energy management; Multi-agent deep reinforcement learning; Strategy evaluation; Power grid system

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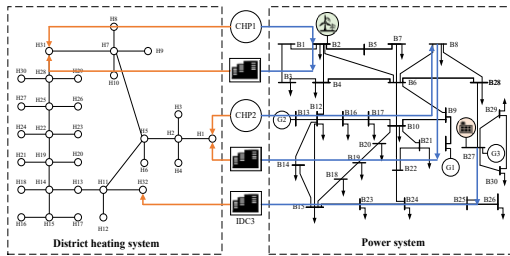
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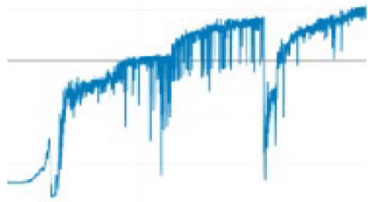
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Motivation

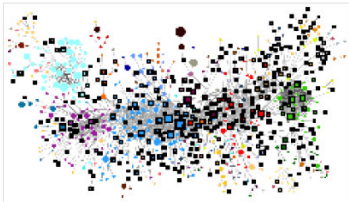


Currently, the increasing number of photovoltaic units being distributed into distribution networks may result in voltage issues. Multi-agent reinforcement learning (MARL) methods have shown great potential in energy management systems to alleviate these issues.

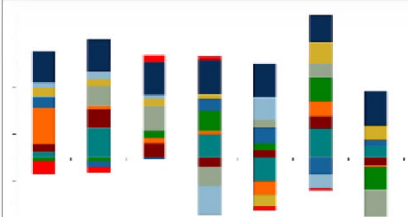
Problem



Most MARL algorithms have difficulty in guaranteeing the efficiency of each agent's strategy, which needs to be evaluated.



The existing strategy evaluation methods applied to MARL have high sampling complexity and are costly when applied to distributed network systems.

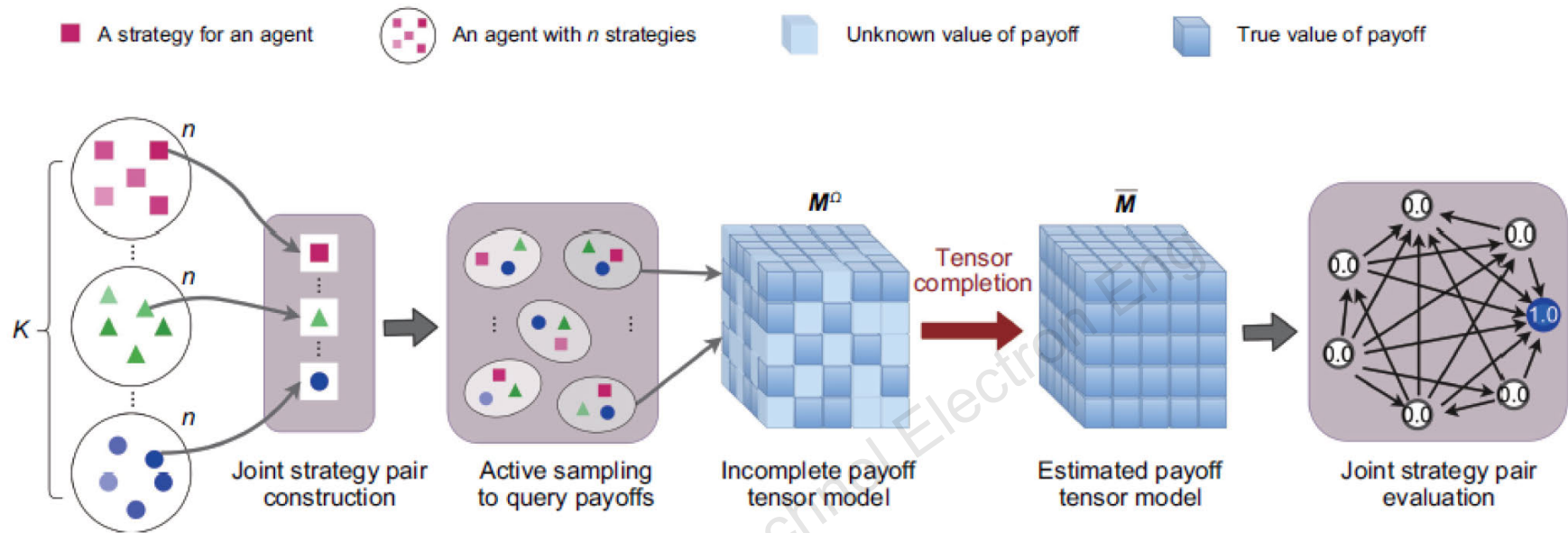


There is a practical problem with using strategy evaluation for the multi-agent system due to noisy payoffs.

Main idea

- ❑ The α -rank-based evaluation method to obtain the ranking of all reconstituted joint strategies at both the building and system levels is proposed.
- ❑ Unlike existing evaluation methods that require all joint strategy payoffs, we propose an approach to accurately estimate complete payoffs from a subset of key observed payoffs. This approach alleviates the problem of high sampling complexity during evaluation.
- ❑ Considering the treatment of observed payoffs with noise in real scenarios, a payoff prediction model is presented in TcEval-AS to accurately predict the real payoff in an energy management task with few interactions.

Method



The overview of the proposed TcEval method

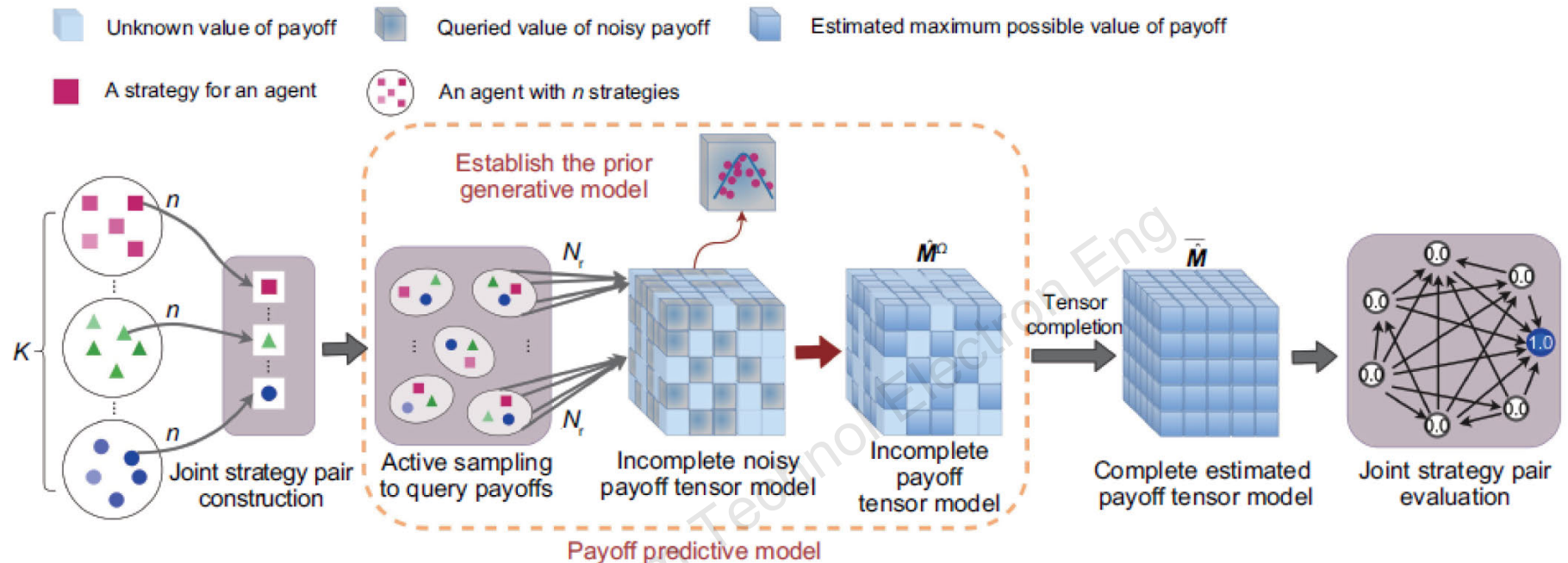
Pipeline:

- (1) Use the active sampling method to select key observed payoffs with the maximum information gain.
- (2) Estimate the complete payoff tensor based on the PS-HOSVD tensor completion algorithm with the selected rank.
- (3) Obtain the steady-state strategy distribution for the joint strategy set and calculate the ranks of all joint strategies.

Key point:

The TcEval method is proposed to precisely evaluate all joint strategies through a small portion of joint strategies.

Method (Cont'd)

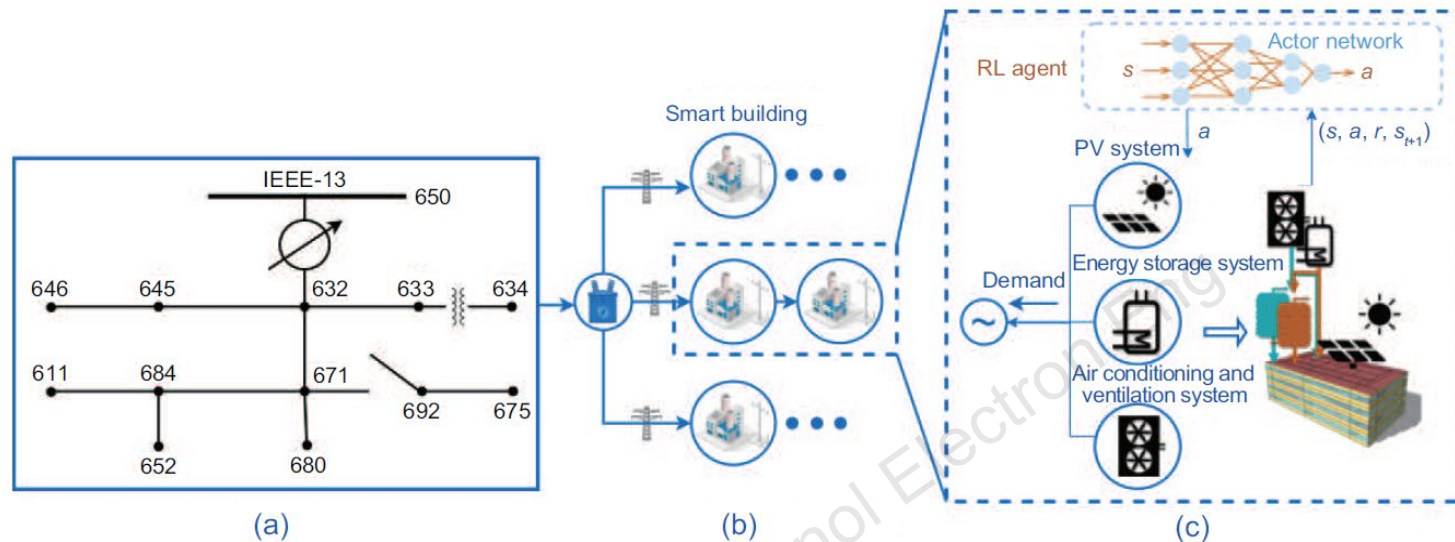


The overview of the proposed TcEval-AS method

Key points:

- ❑ To solve the problem of accessing only noisy payoffs, the payoff probabilistic predictor can be represented based on the mathematical prior model.
- ❑ The proposed payoff prediction model presented in TcEval-AS aims to accurately predict the real payoff in an energy management task with a few interactions. Additionally, an interaction complexity analysis based on the theory of tensor completion with noisy terms is proposed.

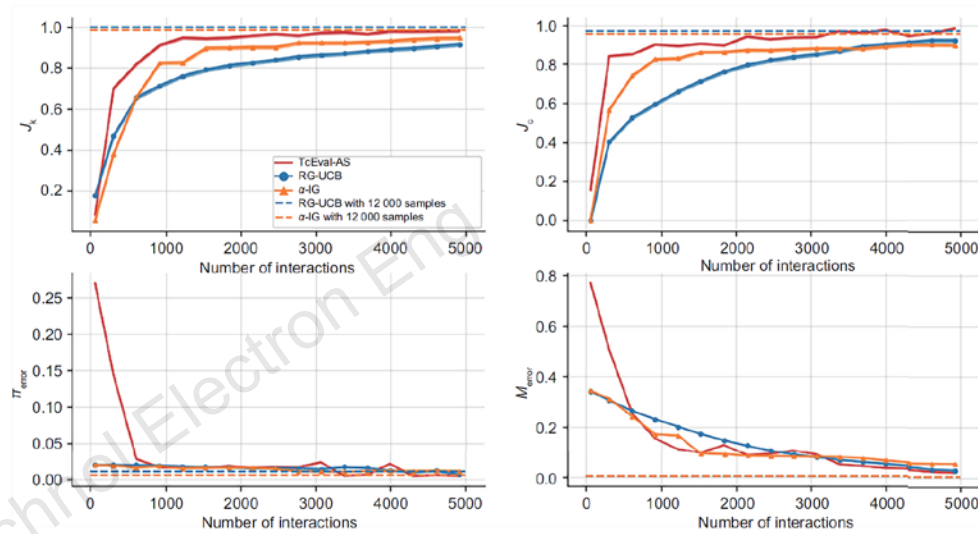
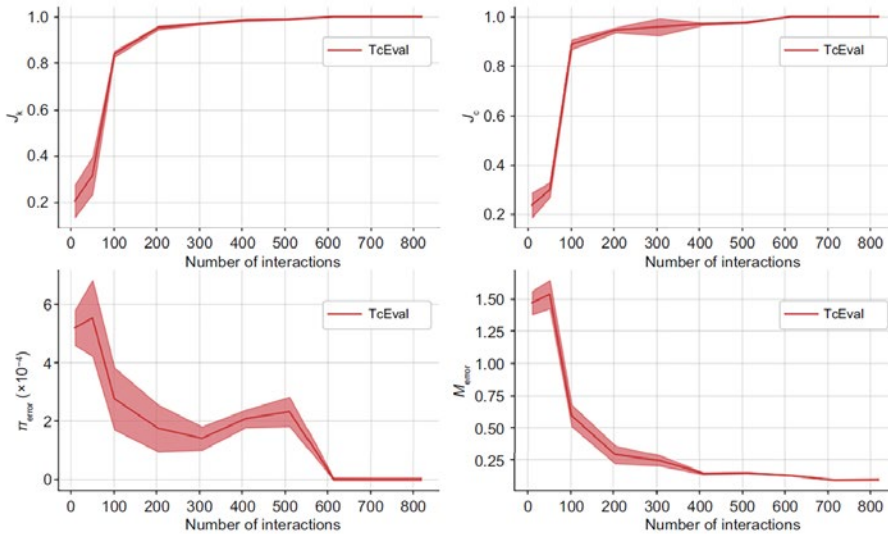
Constructed environment



Structure of the EnergyGrid environment

- ❑ EnergyGrid is developed as an adaptation of the GridLearn environment, as shown in the figure.
- ❑ The IEEE-13-bus network is selected as the grid model, and building microgrids based on the data from the prototype buildings provided by the U.S. Department of Energy are developed to connect to it.
- ❑ The purpose of the energy management task is to achieve the rational strategy, further preserving building occupants' comfort while pursuing system-level objectives.

Major results: Evaluation performance



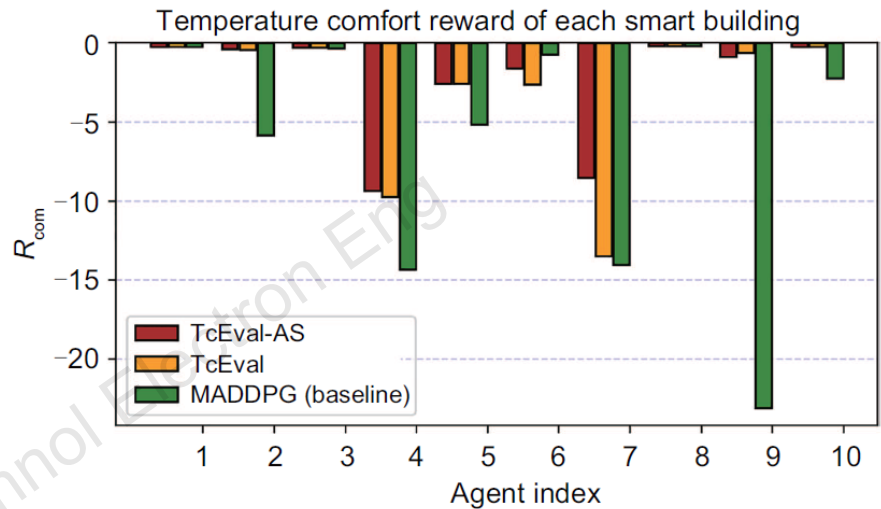
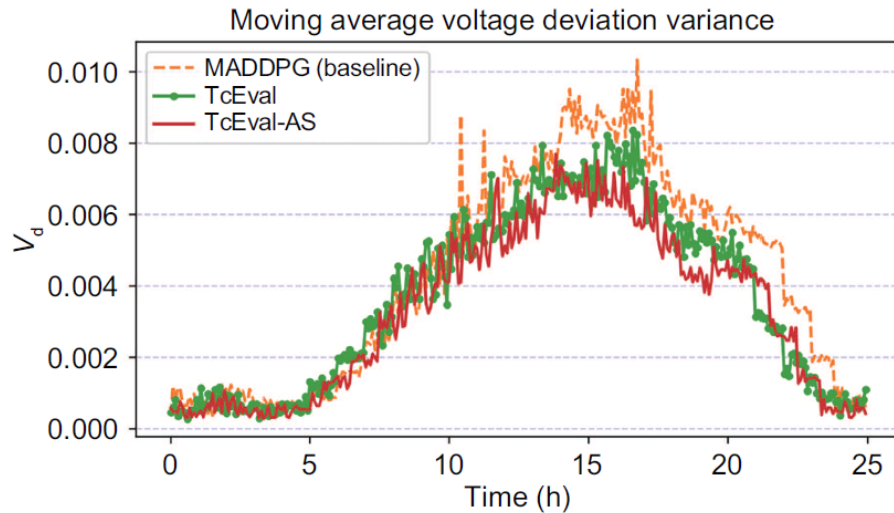
(a) Evaluation performance with precise payoffs

(b) Evaluation performance with noisy payoffs

Evaluation performance comparison in case study 1 with state-of-the-art evaluation methods

- The proposed TcEval obtains accurate rankings with as few as about 400 interactions, reducing the number of interactions by over 60% compared to the original α -rank.
- TcEval-AS achieves better performance in terms of all metrics compared to RG-UCB and α -IG, with the same number of interactions. These results prove that the proposed method is feasible.

Major results: Control performance of the top-rank joint strategy



Control performance in case study 2 with strategies obtained from different methods

- ❑ The top-rank joint strategy evaluated by TcEval-AS usually effectively reduces the overall voltage deviation, especially during high deviations, which ensures the stability of the power system at the system level.
- ❑ The baseline joint strategy does not perform well on some agents, possibly because all agents converge on similar control strategies.
- ❑ The combination of MARL methods with the strategy evaluation algorithm is an effective roadmap toward trustworthy MARL.

Conclusions

- ❑ In this paper, two algorithms, namely, TcEval and TcEval-AS, are proposed for the energy management task in a simulated power grid system.
- ❑ The TcEval method is developed to achieve large-scale strategy evaluation by estimating the α -rank with tensor completion.
- ❑ Considering the noise prevalent in practice, the proposed TcEval-AS adds a noise processing module based on TcEval, using a mathematical model to fit the noisy payoff distribution and predict the real payoff.
- ❑ Joint strategy evaluation is performed in two case studies, and it is shown that the proposed algorithms can achieve better performance than the RG-UCB and α -IG methods while reducing the number of interactions.



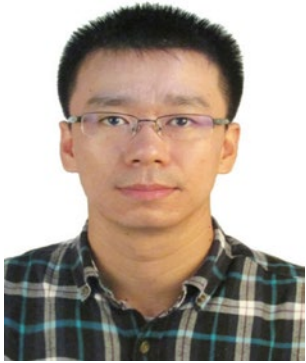
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