CRII: CPS: Towards a Model-Based Reinforcement Learning Approach for Safe Operation of Distributed Energy Systems

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Reinforcement Learning and Safety

- Reinforcement Learning (RL) addresses the problem of learning to control *unknown* systems by explicitly considering their inherent *dynamical* structure
- Control policy for any real-world systems should maintain some necessary safety criteria to avoid undesirable outcomes
  - Avoid collisions, avoid falling down, avoid blackouts

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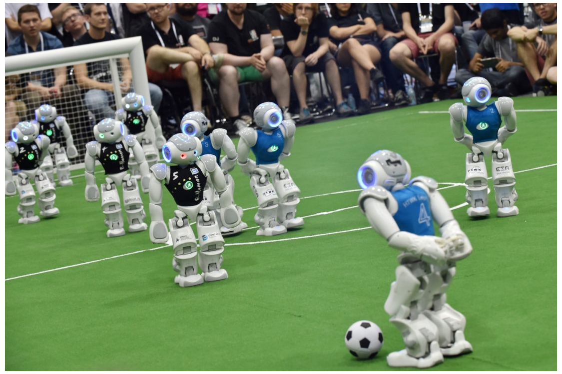

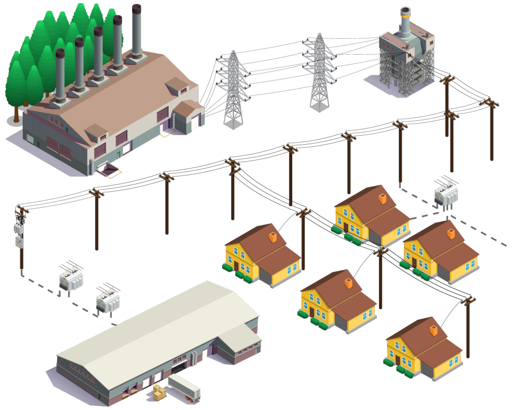

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- Standard RL algorithms typically focus on a single objective of maximizing the value function (expected cumulative reward)
- Standard RL algorithms may violate the necessary safety constraints and can lead to disastrous consequences
- How do we learn RL algorithms that maximize the objective while satisfying the safety requirements?

Safe RL Algorithms with Provable Guarantess

- Objective: Learn a safe policy with minimum number of online samples, with provable guarantees on performance
- Contributions:
  - RL algorithms that minimize the safety constraint violations while learning the optimal safe policy
  - Provable guarantees on the performance, characterized in terms of the sample complexity of the algorithms

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Theorem 1 (Sample complexity of Generative Model-Based CRL). [HasanzadeZonuzy et al, 2020a]
Let π_{safe} be the policy obtained from the Generative Model-Based CRL Algorithm with

$$n_o \geq \frac{256}{\epsilon^2} |S| H^3 \log \frac{24|S||A|H}{\delta}$$

Then, $\mathbb{P}(V_{\pi_{safe}} \geq V_{\pi^*} - \epsilon \ \ and \ \ C_{\pi_{safe}} \leq \bar{C} + \epsilon) \geq 1 - \delta.$

Publications

• Safe Reinforcement Learning

1. A. HasanzadeZonuzy, A., Bura, D. Kalathil, S. Shakkottai, ``Learning with safety constraints: Sample complexity of reinforcement learning for constrained MDPS'', AAAI Conference on Artificial Intelligence, February, 2021
2. A. HasanzadeZonuzy, A., Bura, D. Kalathil, S. Shakkottai, ``Model-Based Reinforcement Learning for Infinite-Horizon Discounted Constrained Markov Decision Processes'', International Joint Conference on Artificial Intelligence (IJCAI), August, 2021

• Reinforcement Learning for Power Systems

1. Dongqi Wu, Xiangtian Zheng, Dileep Kalathil, Le Xie, "Nested Reinforcement Learning Based Control for Protective Relays in Power Distribution Systems", IEEE Conference on Decision and Control (CDC), December, 2019
2. Rayan El Helou, Dileep Kalathil, Le Xie, " Communication-free Voltage Regulation in Distribution Networks with Deep PV Penetration", Hawaii International Conference on System Sciences (HICSS), January, 2020
3. Dongqi Wu, Dileep Kalathil, Miroslav Begovic, Le Xie, "Deep Reinforcement Learning-Based Robust Protection in DER-Rich Distribution Grids", submitted to IEEE Transactions of Smart Grid, May, 2021
4. Rayan El Helou, Dileep Kalathil, Le Xie, "Fully Decentralized Reinforcement Learning-based Control of Photovoltaics in Distribution Grids for Joint Provision of Real and Reactive Power", IEEE Open Access Journal on Power and Energy, May, 2021