CAREER: A Skill-Driven Cooperative Learning Framework for Cyber-Physical Autonomy

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Goal: The *goal* of this project is to advance foundational knowledge and scientific methodologies of reinforcement learning for generalization and scalability in cyber-physical systems (CPS).

Challenge

- The nature of many CPS is heterogeneous and high-dimensional, making the hand-coded functions and task-specific information hard to design.
- Large amount of training data is often required for achieving the desired performance which limits the generalization to other tasks.

Scientific Impact: This project advances the scientific foundations and methodologies of intelligent control design for CPS in high-dimensional and heterogeneous environment. The developed algorithms and associated architectures have provided critical insights and guidelines to foster autonomous learning and generalization in CPS.

Solution

Design secure neural-RL-based methods for CPS

- Develop intelligent guaranteed cost control methods for nonlinear multi-agent systems subject to unknown matched and mismatched perturbations;
- Transform the robust cooperative learning problem into a stabilization design.

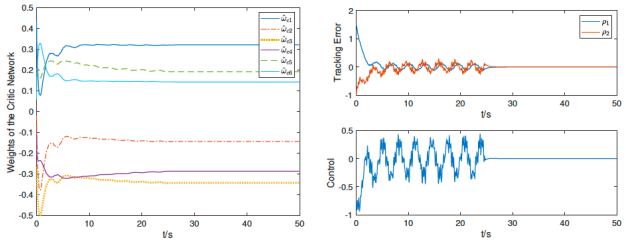

Fig. 1 Critic network weights trajectories and system response in learning phase.

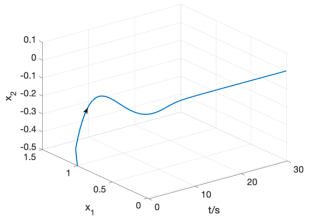

Fig. 2 State trajectory in robust control phase.

Establish cyber-physical robotics testbed

Fig.3 Autonomous wireless charging process with the designed on-board robotic vision system.

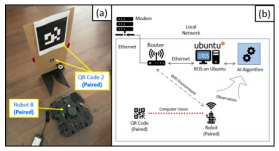

Fig.4 Low-cost wireless charging station.

Develop new RL algorithms for real-world CPS control tasks

- Develop deep Q-Learning algorithms with dynamic window approach and dynamic epsilon adjustment;
- Demonstrate the results on physical goal searching tasks.

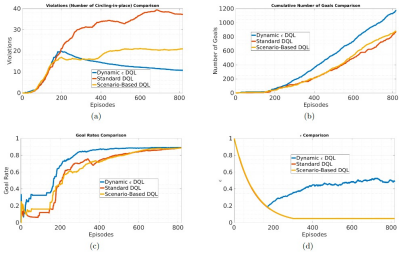

Fig. 5 Control performance comparison.

Broader impact

- Provide critical insights and guidelines to foster autonomous learning and generalization in CPS.
- Integrate research and education plan to enrich the participation of students with different backgrounds and prepare the future workforce in the fields of CPS, artificial intelligence, learning and control.
- Build connections between the CPS research, and minority groups (women and Hispanic students), K-12, and college students through various learning approaches.
- Establish learning models into the current curriculum and also integrate the project's cutting-edge research into new courses.