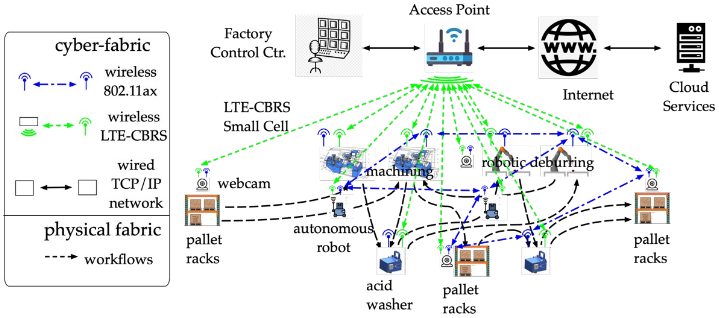
# Learning How to Control

## a meta-learning approach for the adaptive control of cyber-physical systems

Michael Lemmon, Yuying Duan, Shabnam Rafieisangari – University of Notre Dame

https://www3.nd.edu/~lemmon/Projects/NSF-21-551/

**OVERVIEW:** Internet-of-Things (IoT) enabled manufacturing systems form an important class of cyber-physical system whose physical fabric is woven from machines on the factory floor and whose cyber fabric is formed from the wired and wireless communication networks managing the flow of material across the factory floor. This project is developing a meta learning framework for controlling the cyber and physical fabric of an IoT manufacturing system.

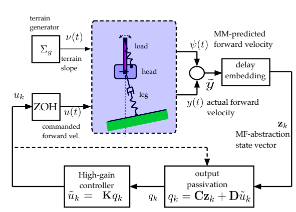


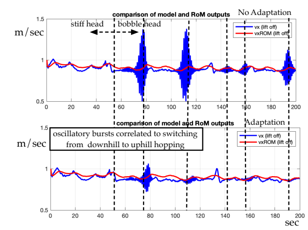

### CHALLENGES and KEY PROBLEMS

- Reinforcement Learning (RL) generates policies that empirically enforce state constraints over finite time intervals. There are, however, no formal safety and stability guarantees when these policies are used in a real-world test environment.
- The challenge is to take an RL action policy that was developed in a virtual training environment and adapt it in real-time to be safe and stable in a physical test environment.
- The objective is to show that such adaptive control of RL-based action policies provides a practical approach for the coordinated control of the cyber/physical fabrics found in IoT-enabled manufacturing systems.

### APPROACH and PRELIMINARY RESULTS

- Preliminary results demonstrated how heuristic control policies for robotic and flow-control systems could be adapted to unmodeled dynamics and time-varying exogeneous environments.




- Building on this prior work, we developed a first-step analysis of the agent's local neighborhood to determine the likelihood of successfully reaching the hood's border without catastrophic episode reset. We then used a sensitivity analysis to select local action policies that minimize the likelihood of episode reset. By reducing the number of episode resets, we improve the learning speed and provide a basis for safe sim2real transfer of learned policies.

- Multi-robotic model of an IoT-enabled factory floor will be used to experimentally validate the proposed approach.

### BROADER IMPACTS

- This project addresses open issues regarding the robust safety/stability of RL policies
- The project will demonstrate safe/stable management of IoT-enabled factory floors
- Educational opportunities between Notre Dame and Saint Mary's College.

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