CPS Small: Uncertainty-aware Framework for Specifying, Designing and Verifying Cyber-Physical Systems

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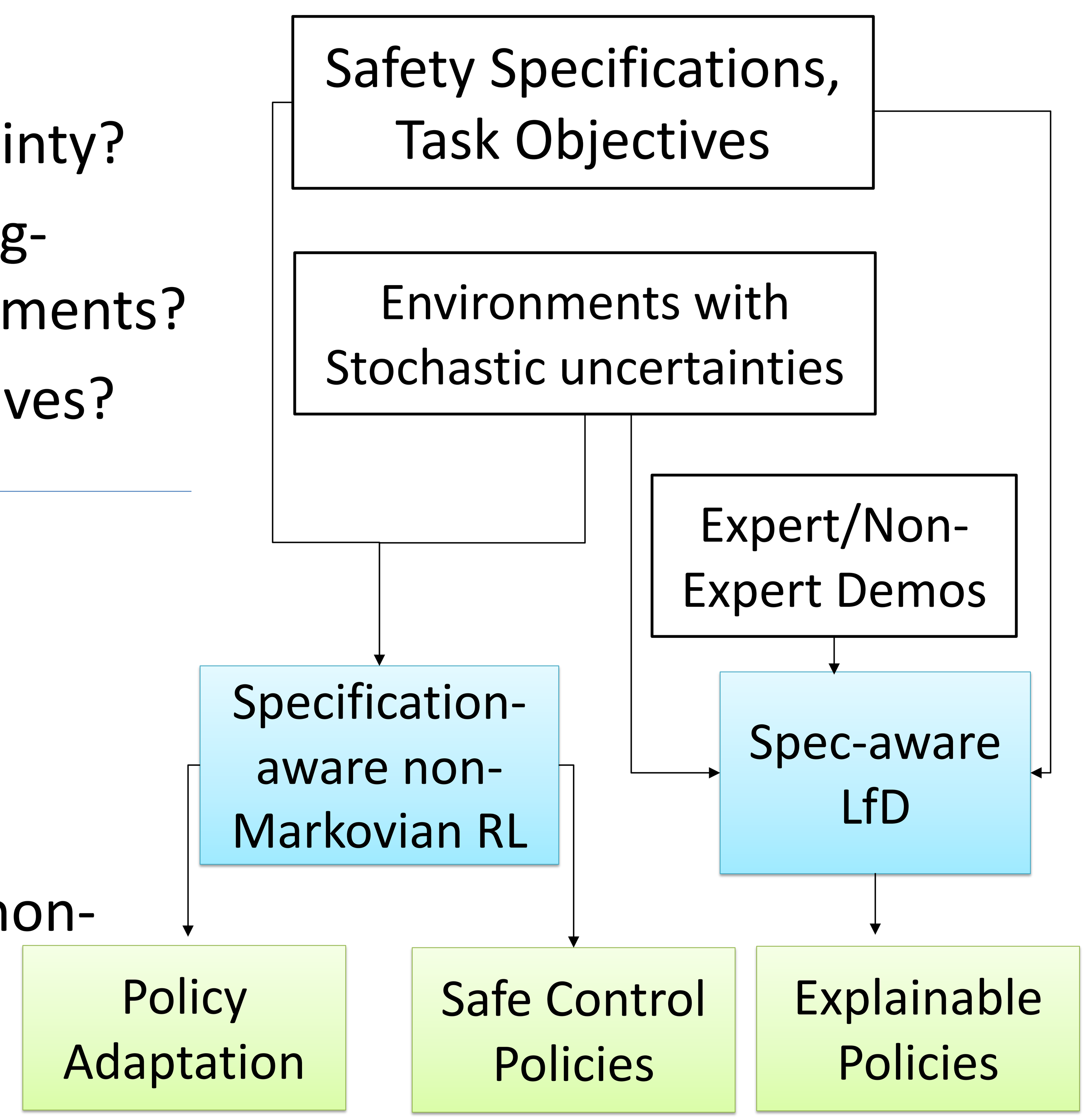
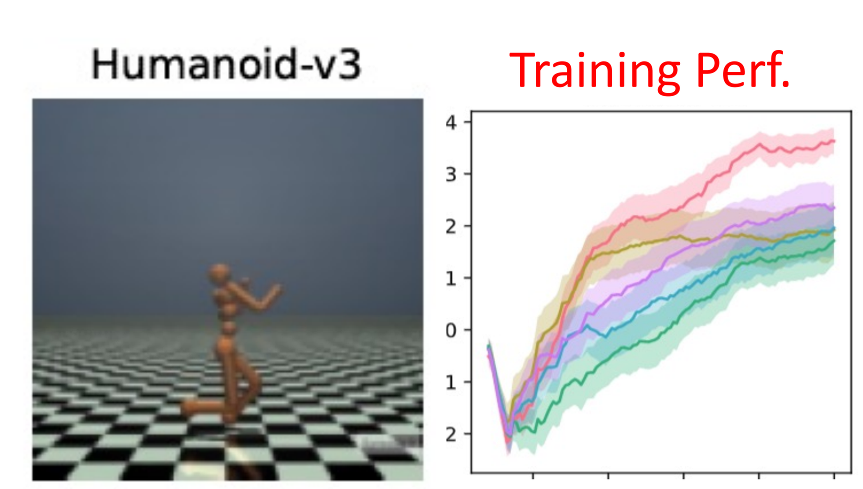
Challenges:

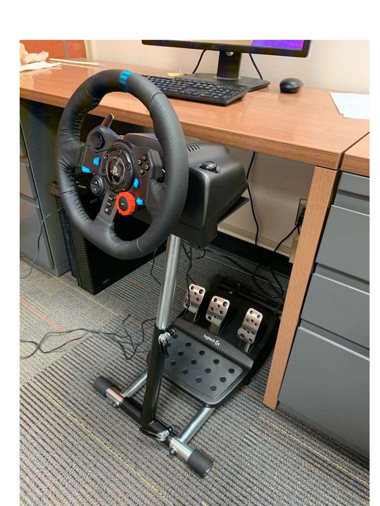
- How can we safely control CPSs under uncertainty?
- How do we enhance interpretability of learning-enabled CPS that operate in uncertain environments?
- How do we optimize for multiple goals/objectives?

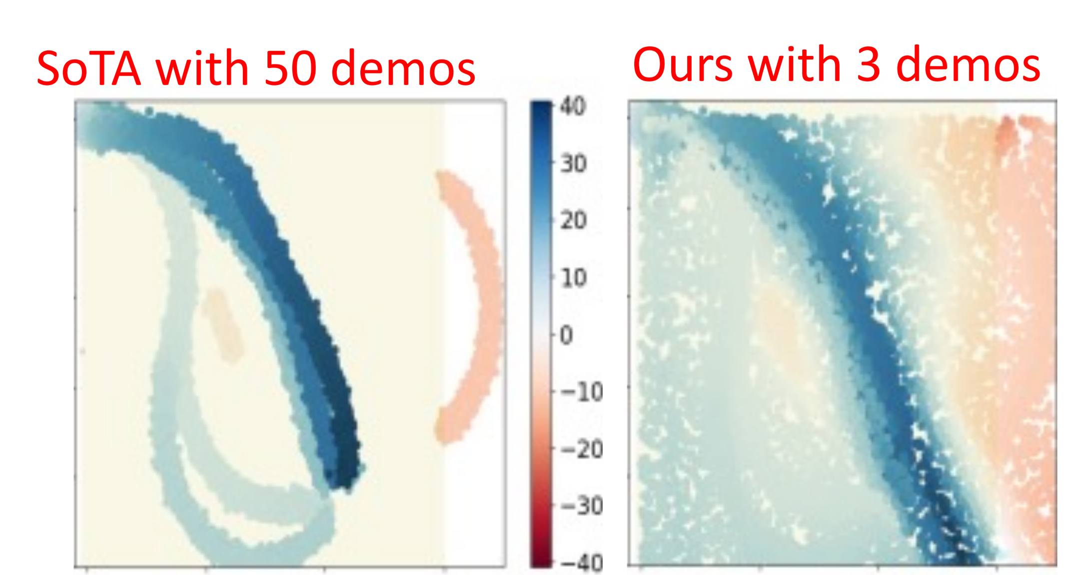
Solutions:

- Technical approach: Combine Learning-from-Demonstrations (LfD) approaches with formal specifications, Investigate multi-objective Reinforcement Learning (RL) approaches and non-Markovian environments
- Key Innovations
  - Algorithm to learn control policies from expert demonstrations
  - Policy Adaptation algo to properly optimize multiple objectives
  - Algorithm for non-Markovian RL for fractional dynamical systems
  - LfD-STL paradigm to learn control policies from non-expert and sub-optimal demonstrations in stochastic environments
  - Reward representation using explainable specification graphs for multi-objective LfD methods









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Scientific Impact:

- Learning safe control policies in uncertain environments that scale linearly in the dimension of the state (expert demos) and with orders of magnitude lower sample complexity (non-expert demos)
- New Multi-objective RL method compatible with SoTA RL solvers
- Enhanced explainability in policies generated for multi-objective settings

Broader Impact:

- Safe CPS applications will improve public trust in safe autonomy
- Opens applications such as robot therapeutics, human service robots, learning from driving demonstrations
- Formal specifications and LfD + Formal Specs in courses included in courses at USC
- Safe control design for systems with highly nonlinear, history-dependent uncertainties