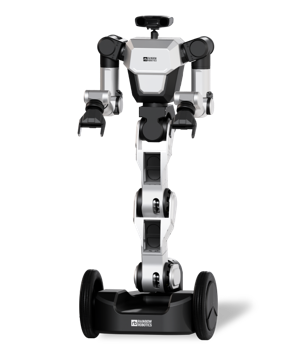
**Data-Efficient Learning for Physical AI Systems**

**Abstract:**

The integration of AI with physical systems—Physical AI—requires data-efficient learning techniques to mitigate expert data scarcity while enhancing robustness, adaptability, and interpretability in control systems and robotics. This seminar presents key technical advancements from MLCS in expert imitation, reinforcement learning (RL), and group-equivariant learning, driving more robust and efficient AI-driven physical autonomy. First, we introduce an inverse Model Predictive Control (iMPC) framework for expert imitation in racing, where track-dependent MPC cost functions are learned via Gaussian process regression. This method generates expert-like driving trajectories and outperforms standard MPC in trajectory optimization. Additionally, we discuss AI driving tutoring using Large Language Models (LLMs), where AI-driven racing agents provide personalized driver feedback to enhance human driving performance. For robotic learning, we first explore Distributional and Hierarchical RL (DHRL), which models reward distributions to improve robustness against uncertainty. Next, we introduce explainable AI (XAI) in RL through Hierarchical Primitive Composition (HPC), focusing on enhancing interpretability and trustworthiness by recursively decomposing complex tasks into simpler sub-tasks. While XAI improves transparency, HPC still requires significant data and computational resources, presenting challenges for data efficiency. To address data efficiency, we present SE(3)-equivariant learning for visual robotic manipulation, including Equivariant Descriptor Fields (EDFs) and Diffusion-EDFs, which significantly enhance data efficiency, generalization, and real-time inference. Together, these advancements improve learning efficiency, interpretability, and robustness in AI-driven control and robotics, paving the way for more efficient and robust Physical AI solutions.

A robot with arms and legs and arms holding a red cube

Description automatically generated with medium confidenceA group of people in helmets driving a race car

Description automatically generatedA white robot with a white background

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