FACULTY MENTOR
Atanasov, Nikolay

PROJECT TITLE
Motion Planning and Reinforcement Learning for Robot Manipulation

PROJECT DESCRIPTION
Description: This project focuses on motion planning and reinforcement learning techniques for robot manipulation. The objective is to develop algorithms that compress visual or tactile observations into an environment model and plan or learn robot arm and end-effector motions to achieve a desired task. The project involves learning manipulation policies in a physics simulator, such as MuJoCo or ManiSkill, and transfer of the learned policies to a real robot arm.

References:
Cross-Embodiment Robot Manipulation Skill Transfer using Latent Space Alignment:
https://arxiv.org/abs/2406.01968

Safe Bubble Cover for Motion Planning on Distance Fields: https://www.arxiv.org/abs/2408.13377

Neural Configuration Distance Function for Continuum Robot Control:
https://arxiv.org/abs/2409.13865

This project will be in person.

INTERNS NEEDED
- 2

PREREQUISITES
- Experience with motion planning (e.g., A*, RRT) or reinforcement learning (e.g., Q learning or policy gradient) as well as proficiency in Python or C++ are required.

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PROJECT TITLE
Model Learning and Adaptive Control for Aerial Robots

PROJECT DESCRIPTION
Description: This project focuses on learning dynamics models for aerial robots from trajectory or visual data using physics-informed neural networks. The learned robot model will be used for control design to achieve autonomous flight and adaptation to disturbances. Being able to achieving autonomous flight also requires an understanding of visual-inertial odometry and geometric control techniques both in simulation and on the physical robot platform.

References:
Port-Hamiltonian Neural ODE Networks on Lie Groups For Robot Dynamics Learning and Control:
https://arxiv.org/abs/2401.09520

Adaptive Control of SE(3) Hamiltonian Dynamics with Learned Disturbance Features:
https://arxiv.org/abs/2109.09974

This project will be in person.

INTERNS NEEDED
- 2

PREREQUISITES
- Candidates are expected to have experience with robot hardware design (CAD software, soldering, 3D printing), C++ programming, and the robot operating system (ROS).

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PROJECT TITLE
Distributed Optimization with Consensus Constraints for Multi-Agent Reinforcement Learning

PROJECT DESCRIPTION
Description: This project focuses on distributed optimization problems defined over graphs, where each node has a local cost function and is able to communicate with its neighbors, subject to a consensus constraint that nodes agree on the same optimizer. Multi-agent reinforcement learning and game problems can be posed as consensus-constrained optimization problems in order to distribute and obtain control policies that respect the communication constraints of the graph. The objective is to study consensus-constrained optimization problems and use the insights to design novel policy gradient algorithms for multi-agent reinforcement learning and games that respect the connectivity structure of the robot team.

References:
DARL1N: Distributed multi-Agent Reinforcement Learning with One-hop Neighbors: https://arxiv.org/abs/2202.09019

Riemannian Optimization for Active Mapping with Robot Teams: https://arxiv.org/abs/2404.18321

Physics-Informed Multi-Agent Reinforcement Learning for Distributed Multi-Robot Problems: https://arxiv.org/abs/2401.00212

This project will be in person.

INTERNS NEEDED
- 1

PREREQUISITES
- Candidates are expected to have experience with graph theory and consensus algorithms for multi-agent estimation and control (e.g., at the level of MAE 247). Experience with multi-agent reinforcement learning (e.g., MADDPG) is preferred but not required.

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PROJECT TITLE
Neural Feature Fields for Robot Mapping and Task Planning

PROJECT DESCRIPTION
Description: This project focuses on using neural network features to model occupancy, distance, and semantic information in 3D robot mapping. Examples include deep-signed distance functions, occupancy networks, or neural radiance fields. The objective is to integrate such neural map representations in the optimization process of simultaneous localization and mapping (SLAM). An additional aspect of the project is to consider language features in the map representation that allow connecting objects in 3D space to language descriptions of robot tasks. Given a neural map model, the project will consider grounding and planning natural language tasks for manipulators or mobile robots.

References:
Learning Generalizable Feature Fields for Mobile Manipulation: https://arxiv.org/abs/2403.07563

Act3D: 3D Feature Field Transformers for Multi-Task Robotic Manipulation:
https://arxiv.org/abs/2306.17817

A Deep Signed Directional Distance Function for Object Shape Representation:
https://arxiv.org/abs/2107.11024

This project will be in person.

INTERNS NEEDED
- 2

PREREQUISITES
- Candidates are expected to have experience with deep learning for scene representation (e.g., SDF, NeRF, Gaussian Splatting) and open-vocabulary classification (e.g., CLIP). Proficiency in Python or C++ programming is required.

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PROJECT TITLE
Particle-Based Algorithms for Active Bayesian Inference

PROJECT DESCRIPTION
Description: Variational inference (VI) offers an optimization approach for computing posterior distributions in Bayesian estimation. While common techniques for VI are based on (stochastic) gradient descent, this project will explore a continuous-time particle-based formulation of gradient flow for Bayesian variational inference. The key idea is to propagate a set of particles from the prior distribution to the posterior distribution along the trajectories of a (stochastic) ordinary differential equation driven by the data likelihood term. Besides propagating particles to the posterior, the project may also consider controlling the particle motion to achieve a desired posterior, which is relevant in the context of active sensing and active learning. Application to camera pose estimation in the context of simultaneous localization and mapping may be considered.

References:
Particle Filtering with Invertible Particle Flow: https://arxiv.org/abs/1607.08799

Sampling via Gradient Flows in the Space of Probability Measures: https://arxiv.org/abs/2310.03597

Variational Inference via Wasserstein Gradient Flows: https://arxiv.org/abs/2205.15902

This project will be in person.

INTERNS NEEDED
- 1

PREREQUISITES
- Candidates are expected to have a strong background in probability theory (e.g., at the level of ECE 250) and optimization theory (e.g., ECE 273). Familiarity with Riemannian manifolds is preferred but not required.