ECE SRIP

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Learning Safe Surgical Manipulation

PROJECT DESCRIPTION
Motivated by the use case of autonomous manipulation during surgery, in this project, we seek to manipulate deformable objects in a manner that is cognizant of the unknown, varying safety constraints in the environment. This project involves online learning and adaptation to actively and safely explore an environment while manipulating deformable objects. The project also involves aspects of representation learning to better model the deformable environment to plan in and motion planning to actively manipulate the environment. Students will be able to get experience with developing novel learning algorithms and getting them to work on real robots.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
2 Students

PREREQUISITES
- Strong python skills
- Background in probability
- Background in developing and training Neural Networks
- Experience with simulation environments: Pybullet and NVIDIA omniverse preferred
- Experience with ROS preferred
- Experience using real robots preferred
- PyTorch experience preferred
- In-person availability preferred

FACULTY MENTOR

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PROJECT TITLE

Sim-to-Real Control, Planning, for Robotic Manipulation of Deformable Objects

PROJECT DESCRIPTION

It is difficult for autonomous manipulation of deformable objects (such as tissue, ropes, toys, bread, etc.) due to the time-varying and unpredictable structures. Taking the advantage of the simulation for sim-to-real setups, one can track the robot-object interactions, which can be useful for control and planning in real scenarios. Physical simulation has been studied in the past decades and can be divided into mesh-based and mesh-free methods. However, it cannot be directly employed in real robotic tasks regarding the mismatch between the perception (such as images, point cloud, etc.) and simulation data. The goal is to develop a model-based framework for interleaving perception, control, and learning approaches that generate optimal autonomous manipulation plans. The physical accuracy, computational stability, and real-time performance should be evaluated for the proposed approaches.

The tasks:
1) building a physical simulation environment for deformable objects,
2) bridging the simulation to real setups by model-based or model-free approaches;
3) proposing a simulation-in-loop controller for manipulation in real setups.

The proposed approaches can rely on state-of-art simulators, such as NVIDIA Omniverse, Isaac Gym, etc., by applying reinforcement learning, imitation learning, or image-based (such as NeRF rendering) methods. Meanwhile, the students will be able to have chances to do real experiments on 7-DOF Panda robotic arm, Baxter arm, and da Vinci Research Kit (dVRK, a surgical robot) inside the lab.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

4 Students

PREREQUISITES

- Coding skills with Python, C++
- Experience with deformable, rigid, dynamics simulation and animation is a preferable
- Experience with machine learning, deep learning, robotic manipulation, and computer graphics is a plus.
- Interested in math formulation of control, planning etc

FACULTY MENTOR
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PROJECT TITLE
Data-Driven Approaches for Modeling, Control, and Learning of Catheter-Like Soft/Continuum Robots

PROJECT DESCRIPTION
"The catheter-like continuum or soft robots can adaptively interact with the environment due to their continuously deformable and compliant nature. It has been intensively used for many applications, such as surgical, natural exploration, and industrial grasping. However, the high dimensional nature renders under-actuated of this kind of robot. Meanwhile, the unpredictable uncertainties (such as friction and hysteresis) result in the modeling and control being more challenging. There have been many advances in soft sensor technologies (such as shape and force) in the literature. However, it is difficult to deploy normal sensors into catheter-like robots whose diameters are usually at the millimeter level. Instead of solely relying on body-integrated sensors on the continuum shape robots, the data-driven algorithms that extract information from online or offline experimental setups can benefit the improvements in accuracy. It can be viewed as characterizing and identification of system behavior.

The tasks:
1) develop algorithms combining model-based with data-driven techniques for modeling of shape, kinematics, and dynamics of the robots,
2) propose an online real-time controller dealing with uncertainties and disturbances (such as external contacts).

The proposed approaches can rely on state-of-art data-driven (Jacobian estimation, Gaussian Process) or model-based (Cosserat rod, constant curvature, polynomial curvature) methods. The students will evaluate their methods on a real catheter robot and the soft-material robots designed in the lab.

This project can accommodate both remote and in-person students.

INTERNS NEEDED

2 Students

PREREQUISITES

- Coding skills with Python, Matlab
- Experience with real robots/hardware motors and sensors
- Experience with ROS, soft robot is preferable
- Interested in math modeling and control

FACULTY MENTOR
Michael Yip

PROJECT TITLE
ARCSnake - Screw-Propelled Snake Robots

PROJECT DESCRIPTION
We are developing a novel screw-propelled snake robotic system that is intended for exploration through a wide range of terrains, such as land, water, ice, and even extraterrestrials, through our collaboration with NASA's JPL. We are building the snake robot in-house, along with test beds that allow us to collect performance data of mobility in controlled environments. The electrical sub-system uses CANBus communication to send commands to the motors and read out from sensors (e.g., accelerometers and pressure sensors). Finally, higher-level software will be developed such that the robot can be controlled via the Robot Operating System (ROS).

For summer, we are looking for students who are interested in exploring the following topics: mechanical design to vary and optimize screw parameters, modeling of screws in multiple terrains, and using learning techniques to develop and solve complex motion planning for the snake robot in water, gravel, and climbing scenarios.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
2 Students

PREREQUISITES
- Python coding, mechanical design experience, electro-mechanical design experience, path planning
- PyTorch experience preferred
- In-person availability preferred

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PROJECT TITLE
Robot Design from the Wild

PROJECT DESCRIPTION
Animals in nature can perform agile motion beyond human limitations. Inspired by this, we will try to optimize the robot design by observing animal motion in the wild. This includes extracting agile animal motion using a computer vision algorithm and estimating a rough structure of the animal. Finally, taking the estimated structure as a reference, we will build a robot to imitate animal motion.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
2 Students

PREREQUISITES
- Python, knowledge of robotics, computer vision, and optimization.

FACULTY MENTOR
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PROJECT TITLE
Robotic Perception for Manipulation

PROJECT DESCRIPTION
Vision sensors can provide rich information to guide robotic control. In this project, we will develop algorithms for vision-based robot manipulation. We will explore a broad topic on computer vision and robotics, including but not limited to pose estimation, representation learning, and deformable manipulation.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
2 Students

PREREQUISITES
- Python, PyTorch, and knowledge of computer vision and deep learning.

FACULTY MENTOR
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PROJECT TITLE
Modeling and Planning for Bimanual Deformable Object Manipulation

PROJECT DESCRIPTION
Manipulating deformable objects with dual arms is critical in many robotic tasks, including garment folding, rope disentangling, and tissue grasping. However, bimanual deformable object manipulation is known to be challenging since it requires models for soft objects and coordination between two arms in non-static environments. In this project, we will investigate these challenging aspects to achieve robust and efficient bimanual manipulation on deformable objects. The goal is to develop a framework that (1) models a given non-rigid object with physical and mathematical methods and then (2) generates a strategy for two arms to coordinate and achieve a given goal.

The students joining this project will gain hands-on experience to:
1. Learn and implement classic and advanced modeling methods for deformable objects.
2. Given the models and a task, propose and implement planning methods for a bimanual robot to complete the task requirements.
3. After verifying the above two goals in a simulation environment, evaluate the method on a real robotic platform.

This project will be in person.

INTERNS NEEDED
2 Students

PREREQUISITES
- Familiar with coding in C++ and Python.
- Project experience in robotics is preferred but not required.
- Knowledge of physic simulators, motion planning, or ROS is preferred but not required.

FACULTY MENTOR
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PROJECT TITLE
Vision-Based Robotic Soft-Tissue Dissection

PROJECT DESCRIPTION
Dissection of tissue, tumors, or other polyps is a fundamental operation in surgery, and the goal of this project is to automize this process. This project consists of two parts:

I. Perception. Previously, developed a surgical perception framework that can track soft tissue deformation from endoscopic videos. Yet, it does not have the function to deal with cutting, and we are recruiting one intern to work on this part of the project.

II. Deploy the perception framework to a surgical robot, da Vinci Research Kit (dVRK), and control the robot to dissect the target tissue based on the perception feedback. We will recruit two interns for this part of the project.

In this project, you will explore computer vision, deep learning, and gain experience in controlling a surgical robot. Working on this project will also help you build up strong engineering experience.

This project will be in person.

INTERNS NEEDED
3 Students

PREREQUISITES
- We require programming experience with Python and/or C++ and knowledge in control.
- Knowledge/project experience in machine learning is preferred but not required.

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PROJECT TITLE
Learning to Implicitly Track Deformation in the Surgical Scene

PROJECT DESCRIPTION
The neural radiance field (NeRF) is a neural network that learns the representation of 3D scenes in an implicit way and can generate novel views of the scenes. NeRF has become an extremely hot topic since it was proposed two years ago. Compared to its applications on other tasks, the studies of NeRF on the surgical scene are still relatively limited. A major reason is that the surgical scenes are highly dynamic, which requires the model to be able to adapt quickly to changes in the scene. Several recent works have proposed promising solutions to dynamic scenes. The goal of this project is to investigate these methods, i.e., study their advantages and drawback when applied to surgical scenes, and then develop a new NeRF-based model for surgical scenes to deal with domain-specific difficulties. In this project, you will explore computer vision, deep learning, and physics simulation, among others.

This project can accommodate both remote and in-person students.

INTERNS NEEDED
2 Students

PREREQUISITES
- Programming experience with Python and/or C++.
- Knowledge or project experience in machine learning.