ELECTRICAL & COMPUTER ENGINEERING
SUMMER RESEARCH INTERNSHIP PROGRAM

FACULTY MENTOR
Michael Yip

PROJECT TITLE
AI-assisted Robotic Surgery for Lung Cancer

PROJECT DESCRIPTION
1.8 Million people died of lung cancer last year. Most people die from late-stage diagnosis, and better screenings could drastically reduce this number by hundreds of thousands of lives saved annually. Currently, lung cancer screening requires clinicians to manually insert needles through the chest and into the lung cavity to grab samples of tissues they may suspect are cancerous and check them under histology. This process is remarkably done completely manually without any real-time image guidance -- instead, patients are placed in the CT scanners while the physician steps out of the room, gets scanned, and then the physician eye-balls the location to place the needle based on the 3D CT scan and does a partial insertion. With the needle partially inserted into the chest, the patient is fed back into the CT scanner, and this process repeats until the target is confirmed reached in the image. This can take up to 45 minutes, and there is a 15% chance of lung collapse (and emergency scenario). The procedure itself is done hundreds of thousands of times each year in the US, and lung cancer is the leading cancer killer in the US.

We have built a robot that can live inside the CT scanner for precision placement of needles to hit cancer targets. This robot is highly dexterous and has many degrees of freedom. The goal of this project is to find the optimal way to hit the target that avoids hitting sensitive anatomical targets that could cause injury (e.g., heart). The technical approach combines robot manipulation, computer vision (for close-loop feedback), motion planning and control, and even haptics (force feedback). No one student can take on all of these tasks, but a collection of students will work together as a team under the PI's direct mentorship to achieve the goal.

This project will be in person.

INTERNS NEEDED
- 5

PREREQUISITES
- Advanced coursework in at least one of the following topics: robotics, computer vision, linear systems/control, sensing, and estimation
- If you have taken ECE276A or CSE276A, that is a big plus.

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PROJECT TITLE
Neural Methods for Dynamic and Deformable Surgical Scene Reconstruction

PROJECT DESCRIPTION
Neural Radiance Field (NeRF) has emerged as a new approach to encode 3D environments implicitly and continuously, enabling more precise representation. However, it is still not accurate enough when handling dynamic and deformable environments, including surgical scenes. Specifically, the presence of texture-less tissue and instrument surfaces makes it challenging for existing NeRF models to converge. To address this problem, current surgical scene reconstruction techniques require monocular or stereo-depth supervision techniques for seamless 3D reconstruction. The absence of depth maps leads to geometric inconsistencies. The objective of this project is to develop self-supervised techniques, drawing inspiration from approaches like SPARF. The aim is to design methodologies that eliminate the necessity for existing techniques to rely on reference depth maps.

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

INTERNS NEEDED
- 2

PREREQUISITES
- Python and PyTorch.
- Should have taken some machine learning courses.
- Good to have some CV experience.

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PROJECT TITLE
Dust-Fragment Classification

PROJECT DESCRIPTION
Laser lithotripsy is a treatment procedure that uses lasers to break kidney stones into tiny pieces. Currently, the surgeons need to manually adjust the laser setting (e.g., intensity of laser beams) to achieve the desired performance - break kidney stones into either fine dust or fragments. However, manual laser setting adjustment is tricky and relies heavily on surgeons' experience. The goal of this project is to develop a framework for autonomous laser setting adjustment and kidney stone remover. As the first step toward this goal, we aim to investigate recent representation learning algorithms to extract good features from ureteroscopy videos to pinpoint the time and location of the presence of the stone, fragment, and dust.

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

INTERNS NEEDED
- 2

PREREQUISITES
- Python and PyTorch.
- Should have taken some machine learning courses.
- Good to have some CV experience.

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PROJECT TITLE
Machine Learning Augmented Deformable Object Simulation

PROJECT DESCRIPTION
Physics simulations are extremely useful for the control and manipulation of deformable objects. Despite that, simulated dynamics are inevitably different from the true object dynamics due to modeling and discretization errors. This project will explore different learnable parameterized functions (gaussian mixture, neural network of different architectures), offline learning vs. online adaptation, and ways of acquiring real-time visual observation to be incorporated into a physics-based deformable simulation framework.

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

INTERNS NEEDED
- 2

PREREQUISITES
- Experience with machine learning and optimization.
- Fluent in Python and PyTorch.
- Optional: prior knowledge in physics simulation.

FACULTY MENTOR
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PROJECT TITLE
Model and Policy Adaptation for Deformable Object Manipulation

PROJECT DESCRIPTION
Dynamic models are important in control and planning for robot manipulation. In deformable object manipulation, there is always a tradeoff between model accuracy and speed, as deformable systems are infinite-dimensional. This project is intended to explore the following aspects:

1. developing error and uncertainty estimation to quantify the reliability of a model;
2. actively adapting the policy and the erroneous model to improve accuracy;
3. intelligently reducing a model's dimensionality based on the manipulation objective for real-time performance.

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

INTERNS NEEDED
- 2

PREREQUISITES
- Python and Pytorch.
- Prior knowledge in robot manipulation and control

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Simulation, Control, Learning for Robotic Manipulation of Deformable Objects

PROJECT DESCRIPTION
Autonomously manipulating deformable objects, like soft tissue or ropes, presents challenges due to their unpredictable, time-varying nature. Leveraging simulation for real-world applications allows tracking of robot-object interactions, offering valuable insights for control and planning in practical scenarios. However, traditional physical simulations—mesh-based and mesh-free methods—encounter obstacles due to mismatches between perception data (such as images or point clouds) and simulation information.

The objective is to create a model-based framework that integrates perception, control, and learning to devise optimal autonomous manipulation plans. The proposed approaches will be assessed based on physical accuracy, computational stability, and real-time performance. This involves:

1. constructing a physical simulation environment for deformable objects,
2. connecting simulations to real-world setups using model-based or model-free methods and
3. devising a simulation-in-loop controller for real-world manipulation.

These approaches can utilize advanced simulators like NVIDIA Omniverse, Isaac Gym, employing reinforcement learning, imitation learning, or image-based techniques such as NeRF rendering. Furthermore, students will have hands-on experience with experimentation using 7-DOF Panda robotic arm, Baxter arm, and the da Vinci Research Kit (dVRK), a surgical robot, within the lab.

This project will be in person.

INTERNS NEEDED
- 4

PREREQUISITES
- Coding skills with Python and C++.
- Experience with deformable, rigid dynamics simulation and animation is 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
Michael Yip

PROJECT TITLE
Data-driven Approaches for Modeling, Control, Learning of Catheter Like Soft/Continuum Robots

PROJECT DESCRIPTION
Continuum or soft robots, resembling catheters, possess adaptive capabilities owing to their continuously deformable and compliant structure. They find extensive use in surgical, natural exploration, and industrial grasping applications. However, their high-dimensional nature leads to under-actuation, while unpredictable uncertainties like friction and hysteresis make modeling and control challenging. Despite advances in soft sensor technologies in literature, integrating normal sensors into millimeter-sized catheter-like robots remains a difficulty. Instead, leveraging data-driven algorithms that extract information from experimental setups, whether online or offline, can enhance accuracy by characterizing and identifying system behavior.

The goal is twofold: 1) to develop algorithms that blend model-based and data-driven techniques for modeling the shape, kinematics, and dynamics of these robots, and 2) to devise an online, real-time controller capable of handling uncertainties and disturbances, such as external contacts.

These approaches can utilize cutting-edge data-driven methods (Jacobian estimation, Gaussian Process) or model-based techniques (Cosserat rod, constant curvature, polynomial curvature). Students will evaluate these methods using a real catheter robot and soft-material robots designed in the lab.

This project will be in person.

INTERNS NEEDED
- 2

PREREQUISITES
- Coding skills with Python or Matlab.
- Experience with real robots/hardware motors and sensors.
- Experience with ROS and soft robotics is preferable.
- Interested in math formulation of control, planning, etc.