FACULTY MENTOR
Michael Yip

PROJECT TITLE
Learning Key-points For Deformable Robotic Manipulation

PROJECT DESCRIPTION
Description: Surgical task automation often requires the robot agent to be able to handle the soft tissue. We are interested in developing machine learning algorithms for manipulating deformable objects. To achieve this, we need an object representation which the motion planner can reason about the geometric information and desired configuration. We want to explore how to learn a set of descriptive key-points on the deformable object. We will use a physical simulator to generate data of deformation for learning. Through sim-to-real transfer, the key-points then can be inferenced from raw sensor input (RGB, RGB-D images, point-clouds,), and utilized for motion control and planning. The work package will include : 1) modeling and building of a simulated deformable environment; 2) a learning-based framework to train and detect key-points features for deformable objects; 3) sim-to-real transfer applications on real-time robotics platforms in the lab, i.e., da Vinci Research Kit/Baxter/Panda robots etc.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Python, C++
2. Knowledge on Deep Learning and Computer Vision etc.

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Combing Model-based and Learning-based Control for Automation in Surgical Robotics

PROJECT DESCRIPTION
Description: It has been shown the learning approaches will advance the control and automation for robotics in the past years. However, it is still a challenge for accurate complex motion of robots, which is difficult to represent without a physical model. In this research project, the model-based and learning-based control approach will be combined for advanced control. The physical model can be deployed as prior knowledge for neural layers. The goal is to develop a framework by combining physical models and learning methods, in order to generate optimal autonomous manipulation plans. The accuracy, computational stability, and real-time performance should be evaluated for the proposed approaches. It should break down the problems by 1) integrating a physical simulation environment for surgical robotics, 2) proposing a modeling approach for model-based or model-free robotic control, 3) performing automation of sub-tasks (such as tensioning, grasping, etc.) on field robotic platform in the lab, i.e., a surgical robot platform of da Vinci Research Kit (DVRK), 7-DOF Baxter and Panda collaborative robotic arms etc.

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

INTERNS NEEDED
4 Students

PREREQUISITES
1. Python, C++, MS
2. Prefer with knowledge of robotics, control, or machine learning.

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Simulation of Advanced Multibody Physical Environment for Real-to-Sim Robotics Control and Planning

PROJECT DESCRIPTION
Description: The simulation is a key component for control and modeling in robotics, especially when dealing with learning-based approaches. However, most of the existing physical simulators in robotics can only handle rigid-bodies, such as Gazebo, Mu oCo etc. Other types of objects such as deformable objects, fluids, are also important when performing specific robotic applications. For example, it is a key issue to model the tool-tissue interaction for autonomous surgical operations. In this research project, the advanced simulation of multibody objects will be investigated. The coupling model between multi-bodies should be considered. The goal is to develop a simulation framework which is able to do real-to-sim transfer applications for control and planning. The work package includes 1) modeling and representing different types of objects (i.e., deformable, rigid, articulated, fluid) with mesh-based or mesh-free physical methods; 2) simulation of the kinematics and dynamics of the coupled multibody objects; 3) interfacing for real-to-sim control and planning with the existed robotic platform in the lab, i.e., a surgical robot platform of da Vinci Research Kit (DVRK), 7-DOF Baxter and Panda collaborative robotic arms etc.

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

INTERNS NEEDED
4 Students

PREREQUISITES
1. Python, C++, MS
2. Prefer with knowledge of computer graphics, animation or robotics

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Sim-to-Real Instrument Tracking For Surgical Robot

PROJECT DESCRIPTION
Description: Precise instrument tracking is essential for the surgical automation application as the agent needs to know its location before any planning can be executed. Previously, we have proposed an algorithm for real-time surgical tool tracking utilizing point features and a particle filter. However, one of the major challenges for deploying the tracker is the complexity of the surgical environment, due to poor lighting conditions and occlusion. A better point feature detector is necessary for improving the robustness of the tracker. In this project, we will develop a learning-based point feature detector that maximizes the performance in various environments. As collecting and labeling the surgical data is non-trivial, we want to use simulation/rendering software to generate photo-realistic images for neural network training and sim-to-real transfer. Finally, we will integrate the point feature detector into the tool tracker and make a complete package for real-time surgical instrument tracking. Furthermore, we will also explore more interesting topics on pose estimation with sim-to-real techniques.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Python, C++, MS
2. Knowledge of Computer Vision, simulation, and rendering software

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Fast Collision Detection with Point Cloud via Machine Learning for Robotic Manipulators

PROJECT DESCRIPTION
Description: Collision Detection is an operation that will be repeated hundreds of thousands of times to compute a safe trajectory for robotic manipulators, and thus, a major bottleneck of real-time motion planning. Machine learning-based methods have been proposed recently to provide orders-of-magnitude speedup over classical collision detection algorithms. However, these methods assume perfect knowledge of the shapes of the objects in the environment, limiting their application in the real world since recognizing geometric shapes from real-time point clouds is itself a very challenging problem. This project aims to explore the possibility of applying machine learning-based collision detection algorithms in the wild, especially an end-to-end method to convert point clouds into collision detection models, removing a major barrier for real-time robotic motion planning in the real world. The outcome of this project will be an easy-to-use ROS package for ML-based collision detection.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Efficient coding skills in Python and C++
2. Project experience/courses taken in Machine Learning
3. Previous experience with ROS/FCL/OMPL is preferred but optional

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Interactive Perception and Planning in Dense and Deformable Environments

PROJECT DESCRIPTION
Description: To operate in the real world, robots must learn to reason about complex environments. Real world environments often consist of multiple objects interacting with one another in an unstructured manner. These environments can also have non-rigid obstacles that undergo complex deformations when handled by the robot. As humans we often leverage our interactions with the environment to uncover crucial structure, such as how objects will deform, how their motions are constrained and how they will interact with the surrounding environment when manipulated. We use our understanding of this structure in complex environments to plan and accomplish tasks ranging from minimally invasive robotic surgery to navigating through a cluttered room.

Our goal in this project is to develop a method that enables robots to learn a structural and dynamic model of the environment that they refine through interaction. This will involve learning an uncertainty aware structure of complex environments, learning their dynamics, and updating our belief on the structure and dynamics before using them for planning. We will deploy this method in both simulation and on real robot arms.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Efficient programming skills, Python
2. Basic probability, Basic machine learning and reinforcement learning
3. Robotics experience is preferred

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Bimanual Planning for Deformable Object Manipulation

PROJECT DESCRIPTION
Description: Implement existing bimanual planning methods and test them on deformable object manipulation. Improve existing methods for better efficiency and more safety.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Be familiar with C++ and Python
2. Has some background knowledge in motion planning algorithms

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Benchmarking Learning-Based Motion Planners for Robot Manipulators

PROJECT DESCRIPTION
Description: In recent years various learning-based planners have been developed for manipulation systems. Much of these algorithms have been tested on simulations rather than real world robots. In this work, the student would create a benchmark for multiple learning-based algorithms for the Baxter robot. The work will focus but not be limited to the following learning-based algorithms:

- Motion Planning Networks [1]
- Neural Exploration-Exploitation Trees [2]
- Graph Neural Networks for Planning. [3]

References

1. Qureshi, A. H., Miao, Y., Simeonov, A., & Yip, M. C. (2020). Motion planning networks: Bridging the gap between learning-based and classical motion planners. IEEE Transactions on Robotics, 37(1), 48-66.
2. Chen, B., Dai, B., Lin, Q., Ye, G., Liu, H., & Song, L. (2019). Learning to plan in high dimensions via neural exploration-exploitation trees. arXiv preprint arXiv:1903.00070.
3. Yu, C., & Gao, S. (2021). Reducing Collision Checking for Sampling-Based Motion Planning Using Graph Neural Networks. Proceedings of the 35rd International Conference on Neural Information Processing Systems.

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

INTERNS NEEDED
2 Students

PREREQUISITES
1. Coding proficiency in C++, Python and Pytorch
2. Experience with ROS, OMPL and MoveIt libraries is preferred but not required

FACULTY MENTOR
Michael Yip

PROJECT TITLE
ViP-SuPer: A Vision and Physics-Based Surgical Perception Framework for Robotic Tissue Manipulation

PROJECT DESCRIPTION
Description: To improve outcomes of minimally invasive surgery, a timely awareness of soft tissue deformation, as well as the relative positions between surgical instruments and target anatomy is critical for providing accurate guidance to surgeons. However, most commercial surgical navigation systems still provide navigation on preoperative scans that are fixed throughout procedures. This project aims to build a surgical perception framework for real-time tracking and 3D reconstruction of tissue deformation. The proposed framework will be an integration of vision-based and physics simulation methods, aiming to achieve occlusion-robust deformation tracking by leveraging the advantages of these two types of methods. 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
1. Programming experience with Python and/or C++
2. Knowledge or project experience in machine learning
3. Experience in physics simulation methods such as FEM/MPM/PBD is preferred but not required

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Tissue Deformation Prediction and Future Video Frame Synthesis for Robotic Tissue Manipulation

PROJECT DESCRIPTION
Description: The goal of this project is to predict tissue deformation and synthesize future video frames of surgical scenes given a sequence of controls and previous video frames. The success of this project will lay the foundation of intelligent robotics systems that can provide efficient assistance by foreseeing the next surgical stage and potential risks. Existing prediction methods include pure vision-based and physics model-based methods. While having achieved promising performance, vision-based methods that predict based on motion trends in the past frames still suffer from hysteresis. On the other hand, physics model-based methods that provide accurate predictions may be slow. In fact, when conducting tissue manipulation, we may not need to achieve the same accuracy on the whole surgical scene. More specifically, we can allow more intensive computation on regions that are close to the surgical instruments while accepting lower prediction accuracy in other regions. Therefore, a key challenge of this project will be developing an algorithm that efficiently iterates between vision-based and physics model-based methods to achieve real-time forecasting.

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
1. Programming experience with Python and/or C++
2. Knowledge or project experience in machine learning
3. Experience in physics simulation methods such as FEM/MPM/PBD is preferred but not required

FACULTY MENTOR
Michael Yip

PROJECT TITLE
Handheld Robotic Catheter Development and Deployment with School of Medicine and San Diego Zoo

PROJECT DESCRIPTION
Description: Refine a manufacturing process for a robotic catheter prototype to be used in surgical procedure relevant to lung cancer diagnosis as well as IVF with the San Diego Zoo Rhino Rescue Project.

This project will be in person.

INTERNS NEEDED
2 Students

PREREQUISITES
1. Must have experience with building devices, CAD, machining, i.e. significant mechanical experience. Python as well
2. Some experience with control is beneficial but not essential
3. Experience with hardware testing