THE UNIVERSITY OF BRITISH COLUMBIA

Mechanical Engineering

2023

CREATE-U

PROJECTS

What makes a Good Demonstration for Robot Learning and Generalization?

Laboratory Name CARIS
Faculty Supervisor: Machiel Van der Loos
Graduate Student Mentor: Maram Sakr

General Area of Research:

Robotics

The Project:

Robots are increasingly being used in many areas in our daily life, from industrial and social robots to robots used in medicine and space. Thus, it is crucial to have effective methodologies for robot programming and customization. Robot Learning from Demonstration (LfD) is the branch of robotics research that is concerned with programming robots to perform tasks by observing demonstrations from humans without the need for any robot programming experience. It has been shown that robot learning efficiency is significantly affected by the quality of the demonstration data. By having high-quality demonstration data, we accelerate a robot's learning process.

The term "poor quality demonstrations" has been used loosely in the literature to refer to different issues in the demonstrations data itself. These issues include undesired motions, failed demonstrations, and ambiguous demonstrations. However, the explicit definition and measurements for the demonstration's quality is still an open question. In this project, we propose recovering the underlying cost functions form both experts' and novices' demonstrations. Then, a comparison between the recovered cost functions will be made to explore the important functions that the expert considers, and the novice overlooked. In order to do that, we have collected a dataset of demonstrations from participants with different levels of expertise in robotics.

What You Will Do:

The student will use an inverse optimal control code on MATLAB for recovering the cost functions. A model for the robot (UR5) is needed for running the code. The student will also be involved in selecting the cost functions for each task. Finally, data analysis for the resulting cost functions will be conducted.

Supervision Received:

This project will be carried out under the supervision of Prof. Mike Van der Loos and a Ph.D. student, Maram Sakr. The supervision will be daily with the mentor while the student will meet the supervisor weekly. In addition, we have a weekly group meeting at which we discuss and present our work, allowing the student to learn more about other work in the lab and seeking help from other lab members if needed.

Skills for Success:

Student should be generally familiar with robot kinematics and programming. Specifically, our system uses ROS. A knowledge of Matlab or Python will be required. Basic knowledge of Machine Learning will be an asset.

Metal AM for X

Laboratory Name: TBC
Faculty Supervisor: Adam Clare
Graduate Student Mentor: TBC

General Area of Research:

AM, Manufacturing technology, design, materials processing

The Project:

The Department of Mechanical Engineering is shortly to make significant investments in new manufacturing apparatus which will include state-of-the-art Laser DED technology. This project will support two aspects of our work i) benchmarking a new piece of hardware and ii) supporting an innovative research activity to deploy DED in a new high value application. The project will allow the create Student to develop technical skills across a range of areas and take responsibility for specific activities of their own design. Development opportunities across a range of competencies will be provided as we commission and exploit a new manufacturing capability in BC.

What You Will Do:

The CREATE-U student will undertake design and experimental work to support the foundations of a new research activity. The student will have some flexibility in terms of what areas of focus will be pursued within broad limits.

Supervision Received:

The student will join a small but growing team around metal AM at UBC. There will be interaction with two ongoing PhD projects who will likely be interested in this project. The student can expect to meet in person with the supervisor on one occasion per week.

Skills for Success:

- *Enthusiasm to learn about and apply new AM technology*
- *Ability to see problems as challenges*
- *Comfortable with problems which stretch across engineering domains*
- *Professional approach to tackling projects and working with others*

Non-Newtonian Liquid Jet Impingement

Applied Fluid Mechanics Laboratory
Faculty Supervisor: Sheldon Green
Graduate Student Mentor: Omid Mohammadi

General Area of Research:

Fluid Dynamics

The Project:

The project is a fairly fundamental fluid mechanics problem – understanding how a free surface liquid jet interacts with a moving surface. The equivalent interaction with which you are likely familiar is what happens when a car drives through the jet of water coming from a hose, although we are interested in things at a much smaller scale.

In addition to being a fairly fundamental fluid mechanics problem, whose understanding will improve our overall understanding of fluid mechanics, this problem also has industrial relevance. Liquid jets are used to cool incandescent metal plate during production. They can also be used to apply liquid friction modifier (LFM) to train tracks from a moving train. LFM is known to reduce the train fuel consumption and track wear.

What You Will Do:

The CREATE-U student will carry out tests on an existing apparatus, and modify the apparatus for additional tests. They will then, with the assistance of the faculty supervisors, analyze the results of the trials.

Supervision Received:

The student will receive direct supervision from Omid Mohammadi, who is a Ph.D. student in Professor Green's group. Professor Green collaborates with Professors Stoeber and Balmforth, and weekly meetings are held with the students. The CREATE-U student will give weekly presentations to the faculty supervisors, in addition to meeting more frequently with the graduate student

Skills for Success:

The key skill needed for this project is attention to detail, to ensure that each trial is done carefully and the results reported thoroughly. Good hand skills (e.g., acquired in the machine shop or as part of a student design team) would be an asset, as would a certain comfort level around moving equipment.

Design and Prototyping of a Novel Kinematically Redundant Parallel Robot

Laboratory Name: Advanced Robotics Laboratory
Faculty Supervisor: Dr. Kefei Wen
Graduate Student Mentor: TBD

General Area of Research:

Robotics, mechanism design, robot kinematics

The Project:

Different from open-loop serial robotic manipulators, a parallel robot is a closed-loop kinematic chain mechanism whose end-effector is linked to the base by several independent kinematic chains (see Fig. 1 for an example). Parallel robots are widely used as flight simualtors, precision devices, and machine tools. However, the rotational ability of the end-effector of a common parallel robot is limited to relatively small ranges due to singularities. The goal of this project is to design and build a novel kinematically redundant parallel robot which exploits kinematic redundancy to avoid singularities, thereby enlarging the useful rotational workspace.

Fig. 1. A 6-degree-of-freedom parallel robot

What You Will Do:

The structure of the novel parallel robot will be provided by the supervisor, while the student will conduct CAD modelling using SolidWorks. The student is also expected to build a prototype in the end of the CREATE-U project.

Supervision Received:

The student will meet the supervisor weekly to report the progress and discuss the following work. The student will also receive a day-to-day supervision under a Ph.D. student who is expected to join the lab in early 2023.

Skills for Success:

- *Intermediate 3D modelling skill using SolidWorks*
- *Basic knowledge in mechanism design such as gears, bearings.*
- *Interested in hands-on work*

Image-based Cell Separation

Laboratory Name: Multi-scale Design Laboratory
Faculty Supervisor: Hong Ma
Graduate Student Mentor: Pan Deng

General Area of Research:

Biomedical Engineering, cell separation, cell image analysis, laboratory automation

The Project:

Cell separation is an important capability for many biological studies. We are developing a technology for image-based cell separation, which involves using a microscope to observe single cell behaviour, identify target cells, and then isolate specific cells for subsequent testing. We will use this approach to observe the behaviour of cancer cells, immune cells, as well as cell-cell interactions. The CREATE-U student joining this project will help to improve and validate this cell separation process by performing cell separation experiments, developing software to analyze cell behaviour, as well as program robotic liquid handlers to automate sample transfer.

What You Will Do:

- *Grow cells in culture*
- *Acquire cell images using a microscope*
- *Perform wet-lab chemistry to fabricate experimental substrates*
- *Develop software to analyze cell behaviour*
- *Perform biological assays to assess cell properties (e.g. live/dead)*
- *Perform cell separation experiments*
- *Measure system performance (e.g. purity and throughput) and devise methods for improvement*
- *Program robotic liquid handlers to automate sample transfer*

Supervision Received:

Day-to-day supervision will be provided by Pan Deng, a graduate student in Dr. Ma's group. The CREATE-U student will meet weekly with the faculty supervisor.

Skills for Success:

- Enjoy experimentation and troubleshooting experimental problems.
- Willingness to learn and conduct chemical and biological experiments involving cellular samples.
- Willingness to learn bioengineering research techniques including experimental protocol development, data analysis, and data presentation.
- Familiarity with general purpose programming languages, such as C, C#, MATLAB, Python.
- Ability to present and discuss experimental plans and results with colleagues.

An Investigation of Fabrication Techniques for New Multi-material Density Gradients for Biomedical Applications of Soft Robotics

Laboratory Name: Microelectromechanical Systems Laboratory
Faculty Supervisor: Mu Chiao
Graduate Student Mentor: Hiroshan Gunawardane

General Area of Research:

Soft Robotics, Soft Materials, Biomedical Applications of Soft Robotics

The Project:

At the Microelectromechanical Systems Laboratory at the department of mechanical engineering, we are focused on developing new soft (i.e., flexible) materials for soft sensors and actuators targeting future medical applications. With the collaboration of our inter-departmental (Dr. John Madden's Group from the ECE Department, Dr. Feng Jiang from the Department of Wood Science) and overseas partners (Dr. Gursel Alici's group from the University of Wollongong, Australia) we are focused on developing and testing new soft material technologies. In the coming summer, we are planning to go beyond the boundaries and limitations of the traditional materials that we normally use to fabricate these robots, and we are planning to investigate the potential avenues of developing new material technologies for soft robotics. The potential candidate will assist our team to investigate new fabricating technologies to develop new multi-material density gradients using 3D printing and molding and casting techniques.

What You Will Do:

You will be mainly involved in assisting us to investigate new material fabrication technologies using,

a). Molding & Casting

You will assist us to develop PDMS, EcoFlex, DragonSkin, & PDMS-based density gradients using spin coating technology. The process involves experiments in the spin coating of polymer materials with sacrificial particles and mechanically characterizing them after post-processing.

b). 3D Printing Technology

You will assist us to create (programming) custom CAD files using an open-source CAD programming language and assist us in printing these files on a customized 3D printer with multiple extruders. The successful prints will be mechanically characterized after post-processing.

Supervision Received:

The day-to-day mentoring will be carried out by the graduate student at the MEMS laboratory and the student will be meeting the faculty supervisor weekly basis to deliver the progress. In case of unavailability, the zoom meetings will be arranged to deliver the progress and clarify any issues related to the project. Moreover, WhatsApp will be used as a communication platform to stay connected during the day and connect with other members of the team. The training fill cover following aspects,
Supervision & Training

i. An overview of the MEMS lab and its main research aspects.
ii. Necessary laboratory safety training and orientations (include Chem safety and laser safety).
iii. In-person training from the supervisor, graduate students, and other local and international research associates.
iv. An overview of robotics, soft robotics, and their biomedical applications.
v. Hands-on experience/ training in programming robot manipulators for different tasks.
vi. Hands-on experience/ training in soft sensors and actuators.

Connections & Professional Development

i. The student will be invited to participate in relevant online workshops, training sessions, invited talks, and meetups.
ii. The student will be encouraged to work as a team and encourage them to learn from their peers.
iii. The student will be encouraged to actively engage in brainstorming to solve engineering problems.
iv. The student will be guided to learn how to think outside the box to solve engineering problems.

Skills for Success:

One or more of following skills would be helpful to be successful in this project.

i. Being enrolled in 2nd year or higher in mechanical, mechatronics, engineering physics or computer engineering steams.
ii. Having previous experience in programming languages (i.e., Python, C++, MATLAB).
iii. Having previous experience in 3D printing technologies.
iv. Having previous experience in computer aided drafting software.
v. Having previous experience in sensors and actuators (a general understanding of their function and circuit implementation, and signal processing).
vi. Willingness to learn new skills and readiness to go for an extra mile to achieve project goals and milestones.
vii. Excellent communication, organization, and time management skills and ability to work with teams.