**Autonomous Systems Lab (ASL) M.Eng and Undergraduate Project Openings**
**Fall 2020**

The Autonomous Systems Lab seeks a small group of students (undergrad and/or MEng) to work with our PhD students on robotics applications and research. A list of potential project topics and background is given below. Students are expected to sign up for 3-4 credits of (…CS/ECE/MAE Independent study courses or MEng courses) during the semester, and thus commit at least 9-12 hours per week. Most projects are virtual, but we may be able to work out a small number of hands on robotics projects.

**How to apply:** Send an email with the subject heading "[Fall 2020 ASL application] <Your Name>" to Professor Mark Campbell, mc288@cornell.edu, with the following information:

1) Name, contact information
2) Experience in programming, robotics, sensors, control systems (or a resume with similar information is fine)
3) List up to your top three projects of interest

**Project #1: Next-Best View Planning via Geometric Reasoning**

Description: This project is about planning paths for a mobile robot in presence of uncertain maps. The goal is to develop a suite of C++ functions for evaluating how good a candidate robot pose might be in reducing the uncertainty of some given cells of an occupancy 3D grid. The functions will consider the likelihood of those cells being visible and their current uncertainty, and output a number representing the quality of that particular pose.

*Preferred background experience:* basic computer vision knowledge, C++, basic knowledge of ROS

**Project #2: Next-Best View Planning via 3D ConvNet**

Description: This project is about path planning in presence of uncertain maps. The goal is to develop a 3D convolutional neural network for estimating how good a candidate robot pose might be in reducing the uncertainty of some given cells of an occupancy 3D grid. The network will take as input a portion of the current 3D grid, the cells that the robot needs to get an estimate of, and a candidate pose. The output will be the estimated entropy reduction of those cells from that particular pose. Part of the project will be devoted to the collection of a suitable dataset.

*Preferred background experience:* working knowledge of Neural Networks including theory and training, basic knowledge of ROS, Python. MEng preferred.

**Project #3: Planning with Ordinal Information**

Description: This project aims to use ordinal information (relative positions) of obstacles in an image to develop a path planner. A big portion of the project will be developing a dataset possibly including semantic segmentations, instance segmentations, and instance ordinality.

*Preferred background experience:* Python, Computer Vision coursework, previous experience with Machine Learning/Deep Learning

**Project #4: Planning with Image Inpainting Experiments**

Description: This project is about urban outdoor path planning. Our group has developed a path planner, currently only working on a custom simulator, able to reason about unseen portions of a map by treating it like a bird's-eye view image whose unknown parts can be filled in by applying an image inpainting neural network. There are three tasks:

1. Build a ROS node that annotates 3D lidar scans with semantics by applying RangeNet++ or a similar off-the-shelf neural network
2. Set up the ROS navigation stack with 3D lidar mapping on the Jackal robot (possibly starting from a ROS/Gazebo simulation)
3. Port our current planner (or some simplified variant) in ROS by developing a custom global planner for the ROS navigation stack

*Preferred background experience:* C++ or Python, ROS experience preferred, Basic Machine Learning/Deep Learning experience

**Project #5: Tracking and Intent Recognition in Autonomous Driving**

Description: The goal of this project is to develop a framework which tracks the kinematics and behavior of an agent from a moving vehicle. This work can be accomplished via behavior in the loop Bayesian tracking or through a machine learning approach depending on the student's preference. Example tasks include:

1. Developing a suitable dataset.
2. Implementation of off-the-self detection and recognition models.
3. Building behavior dependent motion models.
4. Implementation of baseline tracker
5. Incorporating motion models from 3 to improve baseline tracking performance.

*Preferred background experience:* Basic understanding of probability and linear algebra. Strong skills in python or C++ are required. Experience with particle filters and machine learning preferred but not required. Best suited as an MEng project.

**Project #6: Amodal dataset**

Description: The goal of this project is to create a dataset for deep learning models for A-modal segmentation (multiple labels per pixel) for varying weather, lighting and environment conditions. We have been collecting a longitudinal dataset (Winter to Summer) of car driving data (images, LiDAR, and GPS), along a consistent route.

Tasks include:

1. Developing and managing the dataset from our data collections.
    a. Labeling images using Amazon turk.
        i. Sandbox testing of annotation tool
    b. File management, Input and Output scripts
2. Image alignment
    a. Images at select points along the route must be align to transfer annotation labels
3. Implementation of baseline model
    a. Model development can occur in parallel (on Kitti dataset) while Ithaca dataset is being developed

*Preferred background experience:* Python, Computer Vision (Image processing), Basic Machine Learning/Deep Learning experience

**Project #7: Unreal Engine Simulations for Robotics Research**

Students will use the Unreal video game engine to build a virtual simulation environment, containing:

- Multiple pedestrians walking around in an outdoor scene, and
- Multiple mobile camera-equipped robots which can be commanded to move around the scene.

Autonomous Systems Lab researchers will use the designed simulation to test methods for vision-based scene understanding by teams of robots. The project will involve:

1. Creating models for robots with a camera sensor. Writing Python/C++ code to get sensor data and send velocity commands to move them.
2. Setting up an Unreal Engine environment to simulate the motion of multiple pedestrians as per a given motion model.
3. Working with neural networks and estimation techniques for person detection and tracking.
4. Writing detailed documentation for the code and the simulation environment.

*Preferred background experience:*

- Programming experience, ideally in Python and C++.
- Prior experience with Unreal Engine is good to have but not required.
- Completion of one or more of the following courses, or other closely related courses, is a plus:
    - CS 4670/5670 Intro to Computer Vision
    - CS 4780/5780 Machine Learning for Intelligent Systems
    - MAE 2030 Dynamics
    - MAE 4180/5180 Autonomous Mobile Robots

**Project #8: Search and Rescue Simulator**

Your goal is to build a 3D environment in Gazebo based on an approximate floor plan, integrating ground + aerial robots and an outside planner (given) for simulations. You will also develop a user interface to human interaction, and set it up remotely for online experiments.

*Preferred background experience:* familiarity with Python and ROS/Gazebo

**Project #9: Virtual Framework for Remote Experiments**

Your goal is to develop a virtual environment, allowing the user to explore it by navigating and interacting with a robot. This will be used to conduct experiments using Amazon Mechanical Turk. You will: (1) explore how simulation engines (Unreal, Unity 3D or ROS/Gazebo) can connect to Turk and suggest one to work with (2) build a simple environment (3) integrate a ground robot (4) develop a user interface and (5) set this framework up online.

*Preferred background experience:* programming language Python, C++, JavaScript (one or more); familiarity with the engine itself is a plus

**Project #10: 3-D detection in night-time for autonomous driving**

This project will involve working with a PhD student on developing detectors for cars driving at night. 3-D detection using stereo images has gained a lot of success recently. However, most existing methods for 3-D detection are designed for daytime scenes under good weather conditions. The goal of this project is to develop a 3-D detector for more challenging scenarios, e.g., night time or poor weather conditions.

*This project may involve:*

1. Literature review, i.e., reading and discussing relevant papers.
2. Preparing and preprocessing the data.
3. Implementing and evaluating baseline network models (benchmarking), and analyzing their strength and weakness.
4. Developing our own method.

*Preferred background experience:*

1. Strong programming skill in Python is required.
2. Solid maths, i.e, comfortable with reading papers.
3. Basic knowledge in machine learning.
4. Basic knowledge in Pytorch is a plus.

**Project #11: Point cloud completion**

The aim of this project is to develop a network to estimate the complete 3-D point cloud from a partial one, which is a key problem in many robotics tasks.

*This project may involve:*

1. Literature review, i.e., reading and discussing relevant papers.
2. Preparing and preprocessing the data.
3. Implementing and evaluating baseline network models (benchmarking), and analyzing their strength and weakness.
4. Developing our own method.

*Preferred background experience:*

1. Strong programming skill in Python is required.
2. Solid maths, i.e, comfortable with reading papers.
3. Basic knowledge in machine learning.
4. Basic knowledge in Pytorch is a plus.

**Project #12: Localization on a Jackal robot**

The Jackal robot from Clearpath is a common robotics platform, and ASL has several. The goal of this project is to survey the current best SLAM based localization algorithms in ROS using lidar or stereo camera sensors. These will be compared to a combination of IMU+GPS+high precision GPS fixes. The project will be virtual to start, with a survey of ROS based SLAM algorithms. Then move to collecting data outdoors comparing the top several approaches.

*Preferred background experience:* Python, ROS. A good MEng project for students interested in estimation and robotics.

**Project #13: Trajectory Prediction in Autonomous Driving**

Description: Trajectory prediction is of vital importance in autonomous driving for many reasons, for example, it enables potential risk assessment and avoids collision with other vehicles. The goal of this project is to develop a neural network model for vehicle trajectory prediction, with consideration of the interactions between vehicles and the interactions between vehicle and environment.

**This project may involve:**

1. Literature review, i.e., reading and discussing relevant papers.
2. Preprocessing data
3. Implementation of baseline models
4. Develop our own approach.

**Preferred background experience:**

1. Python programming skills
2. Basic knowledge of neural networks
3. Basic knowledge of pytorch or tensorflow