Carnegie Mellon University
The Robotics Institute

RI Summer Scholars Program
Summer 2021 Undergraduate Research
With DAAD Scholarships Opportunities
https://www.daad.de/rise/en/rise-worldwide/
riss.ri.cmu.edu

Table of Contents

Behavioral Planning for Autonomous Vehicles with John M. Dolan, Ph.D.

What will you do?

Explore autonomous vehicles through a variety of approaches around behavioral planning.

Recent Undergraduate Internship Projects Have Included:

FG-GMM based Social Behavior Estimation for Autonomous Driving Vehicle in Ramp Merging Control: Social behavior is important for autonomous driving vehicles, especially for scenarios like ramp merging which require significant social interaction between autonomous driving vehicles and human-driven cars. Previous intern projects have worked towards enhancing the lab's previous Probabilistic Graphical Model (PGM) work merging control model for the social behavior of autonomous driving vehicles. To better estimate the social behavior for autonomous driving cars, a Factor Graph (FG) is used to describe the dependency among observations and estimates of other cars' intentions. Real trajectories are used to approximate the model instead of human-designed parameters. Forgetting factors and a Gaussian Mixture Model (GMM) are also applied in the intention estimation process for stabilization, interpolation, and smoothness. The advantage of the factor graph is that the relationship between its nodes can be described by self-defined functions, instead of probabilistic relationships as in PGM, giving more flexibility.

Functional Trajectory Forecasting and Consistency Guarantees for Self-Driving Cars in Social Settings: Self-driving cars will be required to navigate urban scenarios such as intersections, ramp merges, and lane changes. These are all highly social environments that require accurate estimates of the intentions of other cars. Increasingly, this problem is being tackled by learning a behavior model from data. A previous intern worked with the lab to develop a new learning-based method which is based on non-parametric regression in Reproducing Kernel Hilbert Space. The method provided three important contributions:

- The use of a prediction function class which can account for the interactions between all relevant vehicles, both autonomous and human-driven.
- A novel prediction function where the output is a smooth trajectory over time, rather than a series of discrete points.
- A bound on how our estimated trajectory will vary as a function of the time at which it is calculated

Artificial Intelligence for Impact with Artur Dubrawski Ph.D. & the Auton Lab

What will you do?

Explore how AI is changing the world through a number of application areas.
Examples of recent projects:
Predicting Acute Renal Failure
Providing Earlier Diagnosis to Save Lives
Combating Human Trafficking

Carnegie Mellon's Auton Lab develops new approaches to statistical data mining, artificial intelligence, and machine learning algorithms for critical real-world problems. We apply new techniques and tools to massive and complex data. We have built and successfully launched large-scale deployments of very highly autonomous self-improving systems for partners government, industry, not-for-profit, and the scientific community. The Auton Lab is led by Dr. Artur Dubrawski and Dr. Jeff Schneider, renowned leaders in the field.

The Auton Lab's core research areas include fairness, explainability, and safety. Critical application areas include health care, national security, and countering human trafficking.

FAIRNESS
Machine learning can help improve decision-making. Optimizing overall system performance is not enough. At the Auton Lab, we are conducting research to characterize and mitigate fairness-related risks of algorithmic decision support.

EXPLAINABILITY
Interpretable AI systems are critical as machine learning continues to be applied more broadly and have a significant impact on decision making.

HEALTH CARE
We use machine learning tools to build various types of practical models of data that empower providers with new tools and insight to dramatically improve patient outcomes. This can range from predictive models that aim to identify some interesting aspect of patient data (e.g. is a monitor alert real or artifact, are there signs of disease or not), explanatory models (e.g. what differentiates one cohort from another, or one state from another), forecasting and trending models (e.g. what is going to happen in the future, will a patient become unstable), and grouping (or clustering) entities (e.g. these patients are similar to those ones).

RADIATION SAFETY
We develop algorithms for both detection and decision support in nuclear threat identification. Using our flagship Bayesian Aggregation method for source detection and characterization we are developing fast and efficient tools for situational awareness and safety applications. Our work focuses on robust methods, multi-sensor and multi-modal data fusion, and decision support infrastructure for rapidly processing alerts.

FOOD SAFETY
The Auton Lab partners with government agencies to keep us safer. The Centers for Disease Control and Prevention (CDC) estimates that "each year in the United States, 1 in 6 Americans (or 48 million people) gets sick, 128,000 are hospitalized, and 3,000 die of foodborne diseases." To fight against the outbreak, and fast, it requires collaboration across agencies and a powerful data analytic platform with ultra-low latency.

PREDICTIVE MAINTENANCE
The Auton Lab develops machine learning approaches to optimize large scale maintenance operations with a focus on reducing risks of unforeseen issues, forecasting failures, and business impact.

COUNTER HUMAN TRAFFICKING
Digital advertisements are a significant part of the modern commercial sex industry, many of which are thinly veiled ads for prostitution. Unfortunately, some of the people represented therein are victims of human trafficking. The volume and pace of this activity is beyond the ability of traditional investigative methods to consume and process. To address these challenges, the Auton Lab works directly with law enforcement and NGOs in this space to develop intelligence-based tools to meet the needs of those on the front lines combating human trafficking.

THE LEARNING ENVIRONMENT: The Auton Lab scaffolds a dynamic learning environment where undergraduate develop through active research, collaboration, and mentoring. The lab blends one-on-one mentorship & deep project focus with exposure to a broad range of related projects that are applying similar methods to different application areas. Through this approach, interns share progress, contribute ideas, better understand the context of their research, and are inspired by others.

The Auton Lab partners with Carnegie Mellon’s Robotics Institute Summer Scholar’s Program to extend mentorship & professional development opportunities and provide a broader exposure to robotics & artificial intelligence.

Robot Localization, Mapping & State Estimation with Michael Kaess, Ph.D.

What will you do?

The Robot Perception Lab performs research related to localization, mapping and state estimation for autonomous mobile robots. One of the first problems encountered when robots operate outside controlled factory and research environments is the need to perceive their surroundings. Our research focuses on efficient inference at the connection of linear algebra and probabilistic graphical models for 3D mapping and localization. Applications of our research span a wide range from underwater robots to aerial robots and handheld systems for mapping.

Learn more about the lab: https://rpl.ri.cmu.edu/

Here is a selection of our research: https://rpl.ri.cmu.edu/research/ and recent intern projects:
https://riss.ri.cmu.edu/wp-content/uploads/2019/08/2019-RISS-poster-SI-Zilin-KAESS.pdf
https://riss.ri.cmu.edu/wp-content/uploads/2018/11/2018-RISS-Poster-ZHOU-Yang.pdf

Machine Learning and AI for Robotic Manipulation with Oliver Kroemer, Ph.D.

What will you do?

Recent projects have explored developing manipulation strategies for arrays of cooperative robots, and learning to visually identify the kinematics of different doors using deep learning.

We explore a wide range of research topics related to machine learning and AI for robotic manipulation. Our goal is to develop autonomous robots capable of performing complex manipulation task in everyday environments, such as homes, hospitals, restaurants, and stores. You'll engage in a project that is scientifically meaningful and builds upon your skills and areas of interest.

Research key words: Manipulation, Robot learning, Multimodal sensing

Learn more about the lab: https://labs.ri.cmu.edu/iam/

Perception and Planning for Aerial Robotics with Maxim Likhachev, Ph.D.

What will you do?

Carnegie Mellon's Search-based Planning Laboratory researches methodologies and algorithms that enable autonomous systems to act fast, intelligently and robustly. Our research concentrates mostly on developing novel planning approaches, coming up with novel heuristic searches and investigating how planning can be combined with machine learning. Our work spans graph theory, algorithms, data structures, machine learning and of course robotics. We use our algorithms to build real-time planners for complex robotic systems operating in real-world and performing challenging tasks ranging from autonomous navigation and autonomous flight to multi-agent systems and to full-body mobile manipulation.

Learn more about the lab: http://www.sbpl.net/

Our goal is to develop planners that work in real-time and deal with complex real-world environments. We are also actively pursuing planning approaches that "learn from experience". Such guarantees help dramatically users to analyze and anticipate the behavior of autonomous systems which is crucial for safe autonomy alongside people. The lab is home to several robots including PR2 robot, segbot robot, hexarotor aerial vehicle, quadrotor aerial vehicles, and few other smaller aerial vehicles. In addition, we build planners for a number of large-scale robotic systems such as humanoid robots and a full-scale helicopter.

Here is a selection of our recent intern projects:

- https://youtu.be/o_oqWLKxAtc
- https://www.youtube.com/watch?v=0WJa5XJRtlY&feature=youtu.be

https://youtu.be/JYaHQulo0gA

Perception and Planning for Aerial Robotics with Sebastian Scherer, Ph.D.

What will you do?

The Air Lab advances state-of-the-art aerial autonomy. Explore some of the topics we explore.

Exploiting Physical Interactions to Increase the Understanding of Dynamics and Environment Properties for Enhanced Autonomy Project:
We propose to enhance the autonomy of intelligent robots by actively learning the physical common sense and dynamic models of complex objects. This will enable these robots to automatically identify, understand and avoid difficult situations in adversarial environments, by learning physical models and robust skills in unstructured environments.

Real-time Fault Detection for Autonomous Aerial Vehicles Project:
The recent increase in the use of aerial vehicles raises concerns about the safety and reliability of autonomous operations. There is a growing need for methods to monitor the status of these aircraft and report any faults and anomalies to the safety pilot or to the autopilot to deal with the emergency situation.

Learn more about the lab: https://theairlab.org/

We have online modules to help you learn essential skills. Learn about critical skills that Air Lab interns must have or develop. http://theairlab.org/summer2020/

Here is a selection of our recent intern projects:

- https://www.youtube.com/watch?v=YQFMzPyLyEk&feature=youtu.be
- https://www.youtube.com/watch?v=qZ9T4dw6xUg&feature=youtu.be
- https://www.youtube.com/watch?v=5oCGDthR9-4&feature=youtu.be