# Robert D. Leary

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Mechanical Engineer well versed in real-time, model-based state estimation of ground vehicles using the fusion of road map information and perception algorithms, as well as the development and testing of mechatronic systems.

## Education

### Doctor of Philosophy in Mechanical Engineering
2013 - 2019

The Pennsylvania State University, University Park, PA
Dissertation: "Real-time Vehicle State Estimation Using Previewed Map Information"

### Master of Science in Mechanical Engineering
2013 - 2018

The Pennsylvania State University, University Park, PA
Thesis: "Real-time Vehicle Pose Estimation Utilizing Monocular Vision and Lane Marker Maps"

### Bachelor of Science in Mechanical Engineering with Honors
2009 - 2013

The Pennsylvania State University, University Park, PA
Thesis: "Map-based Vehicle Occlusion Detection"

## Notable Projects

### Real-time Vehicle State Estimation Using Previewed Map Information (PhD Thesis)
2018 - 2019

Sponsor: National Science Foundation

Fused a vehicle motion model and mapped road information using a preview-horizon-based Kalman Filter framework to achieve 8.91 cm (1-$\sigma$) lane-level localization accuracy in real-time (50Hz).

- Developed immersive simulation-in-the-loop environment for real-time algorithm testing by integrating the Robot Operating System (ROS) and Unity.
- Investigated the influence of roadside infrastructure, such as signs and poles, with a vehicle pose estimator to improve position and orientation state estimates.

### Vehicle Pose Estimation Using Monocular Vision & Lane Marker Maps (Master's Thesis)
2014 - 2018

Sponsor: The Pennsylvania State University

Implemented a real-time (100 Hz) six degree-of-freedom vehicle pose estimation algorithm in ROS using monocular vision and a sparse map of lane markers. Achieved a precision of 6.0 mm in positioning and 0.04 degrees in orientation state estimation.

- Developed model-based analytical Jacobian from the pinhole camera model relating small perturbations in vehicle states to changes in pixel location of map features.
- Created reduced-order lane marker maps through the combination of camera, differential GPS, and laser rangefinder data.
- Used reduced-order lane marker maps to determine the position and orientation of the vehicle in real-time using a monocular camera.

### Map-based Shift Scheduler for Volvo SuperTruck
2015

Sponsor: Volvo Trucks

Improved Volvo SuperTruck truck fuel economy by 6% by incorporating previewed map terrain information into engine management system.

- Developed an SQL database backend for the mapped terrain inflection points.
- Incorporated GPS position and velocity in a Kalman Filter to estimate the vehicle station for data lookup in the database.
- Developed communication bridge between ROS and Simulink Real-Time over the User Datagram Protocol (UDP) for data transfer.

### Design & Build of a Mobile Mapping Vehicle

2013 - 2019

Sponsor: The Pennsylvania State University

Led a team of undergraduate engineers with the design and build of a Ford Transit Connect mobile mapping vehicle with LiDAR, multi-camera array, GPS/INS, and wheel encoder sensor systems.

- Integrated all sensors in ROS for real-time data fusion and post-processing data collection scenarios.
- Integrated uninterruptible battery power system with vehicle alternator for self-sustained battery power for powering sensors. Battery system could run for up to four hours without replenishing charge.
- Implemented GPS time synchronization for microsecond-accurate triggering of sensors.

### Design & Build of a Map Database System

2015 - 2019

Sponsor: The Pennsylvania State University

Created a PostgreSQL / PostGIS database to store terabytes of raw data collected from the mobile mapping vehicle and reduced raw data to obtain sparse lane marker feature maps for real-time state estimation.

- Collected and stored hundreds of miles of raw data from the mobile mapping vehicle.
- Implemented method for storing over one million images in folder tree structure for real-time retrieval.
- Developed Matlab, Python, and C++ APIs for querying the raw and post-processed datasets.
- Implemented methods for extracting lane marker geolocations from LiDAR scans and camera images.

### Map-based Lane Detection & Lane Departure Warning System

2013 - 2014

Sponsor: Volvo Trucks

Fused monocular vision and a lane marker map to provide audible lane departure warnings to a tractor-trailer driver.

- Determined the lateral position of a Volvo tractor-trailer within a lane using a forward-facing camera, GPS/INS, and lane marker map at the Larson Transportation Institute test track.
- Provided an audible warning to the driver based on lane-level lateral position measurements.

### Inspection Robot For Spent Nuclear Fuel Dry-Storage Casks

2015 - 2016

Sponsor: Department of Energy

Worked with a team to develop a robotic system to inspect dry-storage casks containing nuclear spent fuel.

- Collaborated with three universities, industry partners, and representatives from the Department of Energy.
- Designed robot to adhere to tight geometry, high temperature, and radiation constraints.
- Fabricated closed-loop controlled winch to control the position and velocity of the robot.

# Supervision Roles

### Undergraduate & Graduate Student Research Mentor

2013 - 2019

Sponsor: The Pennsylvania State University

Supervised and mentored over ten undergraduate and graduate researchers, two of which resulted in completed honors theses, as well as two additional publications.

- Trained over 20 undergraduate and graduate students to operate and contribute to over 10 research projects within the Intelligent Vehicles and Systems Group.
- Held weekly meetings to coordinate and direct students with their research projects.
- Contributed algorithm development and thesis editing to over five Master's and PhD thesis projects.

# Technical Skills

Advanced to expert proficiency in all listed areas

- Robot Operating System (7 yrs)
- Linux (7 yrs)
- Python (7 yrs) / C++ (5 yrs) / Matlab (9 yrs)
- OpenCV (7 yrs)

- Database: MySQL, PostgreSQL, MongoDB (15 yrs)
- Server-side: Node.js, Go, PHP (8 yrs)
- Web: HTML, Javascript, CSS (17 yrs)
- Test Driven Development (5 yrs)

- Blender / Unity (5 yrs)
- API Development (8 yrs)
- Git (7 yrs)
- Swift (3 yrs)

# Related Hobbies

- Developed a bus transit iOS application to provide real-time transit information for 50 cities across the United States. Created Node.js API for communicating with MongoDB database backend.
- Developed photo-realistic driving simulator software. In the process of submitting a patent application.

# Educational Outreach

### Penn State Exploration-U (2017 - 2018)
Designed easy-to-understand hands-on activities to promote STEM education in local schools.

### Penn State Artificial Intelligence vs. Science-U Summer Camp (2012 / 2015)
Assisted in teaching programming and ground robot control algorithms to high school students and developed a website for an open-source robotics project geared towards beginners (bobbyleary.com/r3).

### Volunteer at Shaver's Creek Environmental Center (2014 - 2018)
Volunteer for the annual Fall Harvest Festivals, Maple Harvest Festivals, and general trail maintenance.

# Awards

- 2018 Global Programs Graduate Student Travel Grant
- 2013 Schreyer Honors College
- 2013 Outstanding Mechanical Engineering Senior
- 2011 Boscov Academic Excellence Award
- 2010-2011 Berks Campus Honors Program Award

# Publications

K. Varadarajan, **R. Leary,** E. Pelletier, M. Wahba, S. Brennan (2019) **"Analyzing the Effects of Geometric Lane Constraints on RADAR-based Sensing of Available Vehicle Headway using Mapped Lane Geometry and Camera Registration of Lane Position"** Proceedings of the ASME 2019 Dynamic Systems and Control Conference.

K. Wolkowicz, **R. Leary,** J. Moore, S. Brennan (2019) **"Real-time Path-based Fusion of Spatial Databases with Temporal Control Inputs for Assistive Operation of Wheelchairs"** Proceedings of the ASME 2019 Dynamic Systems and Control Conference.

K. Wolkowicz, **R. Leary,** J. Moore, S. Brennan (2019) **"Statistical Determination of Decision-Making Regions for Branching Paths: An Algorithm With A Wheelchair Assistance Application"** Proceedings of the ASME 2019 Dynamic Systems and Control Conference.

**R. Leary,** S. Brennan (2018) **"Region of Attraction of a Real-time Vehicle Pose Estimator Using Monocular Vision Lane Marker Maps"** Proceedings of the 14th International Symposium on Advanced Vehicle Control Conference.

**R. Leary,** S. Brennan (2018) **"Extracting Geometric Road Centerline and Lane Edges From Single-scan LiDAR Intensity Using Optimally Filtered Extrema Features"** Proceedings of the IEEE 2018 Conference on Control Technology and Applications.

K. Wolkowicz, **R. Leary,** J. Moore, S. Brennan (2018) **"Discriminating Spatial Intent from Noisy Joystick Signals for Wheelchair Path Planning and Guidance"** Proceedings of the ASME 2018 Dynamic Systems and Control Conference.

**R. Leary,** S. Brennan (2016) **"Region of Attraction for a Vehicle Pose Estimator Utilizing Monocular Vision and Lane Marker Maps"** Proceedings of the ASME 2016 Dynamic Systems and Control Conference.

M. Wahba, **R. Leary,** N. Ochoa-Lleras, J. Safi, S. Brennan (2016) **"A ROS-Simulink Real-Time Communication Bridge using UDP with a Driver-in-the-Loop Application"** Proceedings of the ASME 2016 Dynamic Systems and Control Conference.

B. McNelly, **R. Leary,** K. Reichard, S. Brennan (2016) **"Characterizing Successful Robotic Insertion and Removal from a Dry Storage Cask: Using Peg-like Jamming and Wedging Analysis"** Proceedings of the ASME 2016 Pressure Vessels and Piping Conference.

C.J. Lissenden, S. Choi, H. Cho, A. Motta, K. Hartig, X. Xiao, S. Le Berre, S. Brennan, K. Reichard, **R. Leary,** B. McNelly **"Toward Robotic Inspection Of Dry Storage Casks For Spent Nuclear Fuel"** Proceedings of the ASME 2016 Pressure Vessels and Piping Conference.

C.J. Lissenden, S. Choi, H. Cho, A. Motta, K. Hartig, X. Xiao, S. Le Berre, S. Brennan, K. Reichard, **R. Leary,** B. McNelly **"Toward Robotic Inspection Of Dry Storage Casks For Spent Nuclear Fuel"** Proceedings of the ASME 2016 Pressure Vessels Technology.

P. Stankiewicz, N. Ochoa-Lleras, **R. Leary,** S. Brennan (2015) **"Vehicle Rollover Prevention Using the Zero-Moment Point in an LQR Output Regulator"** Proceedings of the ASME 2015 Dynamic Systems and Control Conference.