M@uto: Autonomous Vehicle Design Group at the University of Michigan-Dearborn

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M@uto

The M@uto is the autonomous vehicle design group at the University of Michigan-Dearborn. The team has strong faculty leadership in Robotics and Power Electronics areas. The team is a relatively new team since Dr. Jaercok Kwon joined the University of Michigan-Dearborn in January 2020. Yet, Dr. Kwon has been actively involved in autonomous vehicle development as well as Indy Autonomous Challenge Design.

Team IndyAuto

Faculty Leadership

Jaerock Kwon, Ph.D., Assistant Professor, Robotics Engineering

College of Engineering and Computer Science
Electrical and Computer Engineering
University of Michigan-Dearborn

Research Areas: Artificial Intelligence, Machine Learning, Optimization, Intelligent Systems, Neuroscience, Robotics

Alireza Mohammadi, Ph.D., Assistant Professor, Robotics Engineering

College of Engineering and Computer Science
Electrical and Computer Engineering
University of Michigan-Dearborn

Research Areas: Robotics

Samir Rawashdeh, Ph.D., Assistant Professor, Robotics Engineering

College of Engineering and Computer Science
Electrical and Computer Engineering
University of Michigan-Dearborn

Research Areas: Computing and Networks, Power Electronics and Energy Systems, Robotics

Ph.D., Assistant Professor, Electrical Engineering

College of Engineering and Computer Science
Electrical and Computer Engineering
University of Michigan-Dearborn

Research Areas: Artificial Intelligence, Cybersecurity, Power Electronics and Energy Systems

Ph.D., Associate Professor, Electrical Engineering

Division of Electrical Engineering
Hanyang University ERICA

Research Areas: Wireless communications, Embedded software systems

Students

Graduate Students

- Sewoong Min, Ph.D. student, Hanyang University-ERICA, Korea
- Donghyun Kim, Ph.D. student, Hanyang University-ERICA, Korea

Undergraduate Students

- Filip Buda, Robotics Engineering, University of Michigan-Dearborn
- Khallad Jobah, Robotics Engineering, University of Michigan-Dearborn
- Jean Louis Masongsong, Robotics Engineering, University of Michigan-Dearborn
- Joshua Vanden Berg, Robotics Engineering, University of Michigan-Dearborn
- Steven Phan, Computer Engineering, University of Michigan, Ann Arbor
- John Brooks, President of Smart Vehicle Club, Electrical & Computer Engineering, Oakland University

Engineers

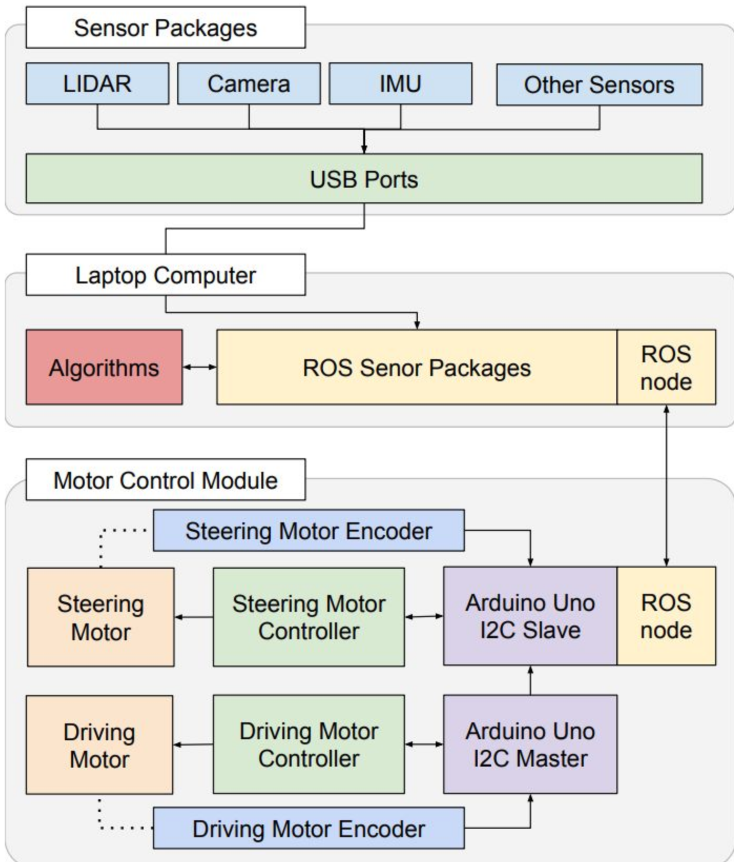
- Alex Mattia, Founder of Pool, Inc and Engineer at GHD.

History of Automation

The leadership of M@uto has been working on the design of autonomous vehicle platforms, the study of sensor fusion, X-By-Wire (Drive, Brake, Steering-By-Wire), and Deep Learning-based lateral control along with traffic sign recognition.

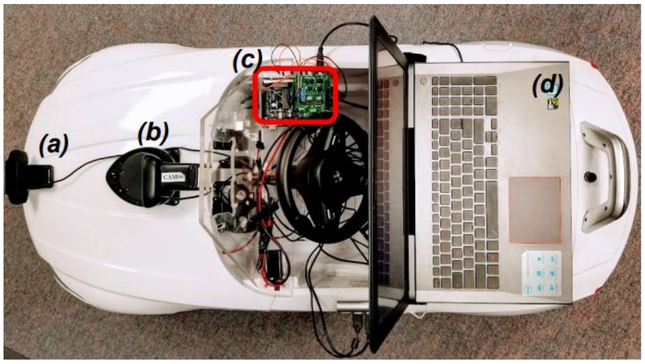
Vehicle Platform Design

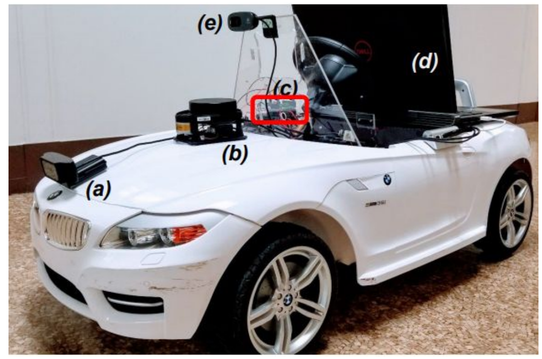
We built a ROS-based vehicle platform with a ride-on-electric car. The block diagram of the platform is shown below.



The block diagram of the vehicle platform. The laptop computer hosts device drivers of the sensor packages and runs a ROS node that communicates with the microcontrollers through the ROS serial communication. The motor control module's only concern is the low-level motor control and it is independent of the main unit where higher-level perception and control algorithms are executed. The components in one module are easily replaceable without affecting other modules.

The following are the actual platform that was built.





A Small Scale Vehicle Platform: MIR-Vehicle. Top: The top view of the MIR Vehicle. Bottom: The profile view. (a) is a camera and (b) is a LIDAR for data acquisition. (c) is the motor control module. (d) is a laptop computer. (e) is a camera to take first-person-view videos for the platform.

Sensor Fusion Study

We conducted sensor fusion study using the aforementioned vehicle to show the feasibility of our approach. Three different combinations were used here: camera only, LIDAR only, camera and LIDAR combined, the ensemble with camera and LIDAR in weighted input.

Rviz screen with multiple ROS nodes to use sensor packages. The remote control is shown here to provide the ability of the system for data collection. https://youtu.be/A2z2HRd1rhg

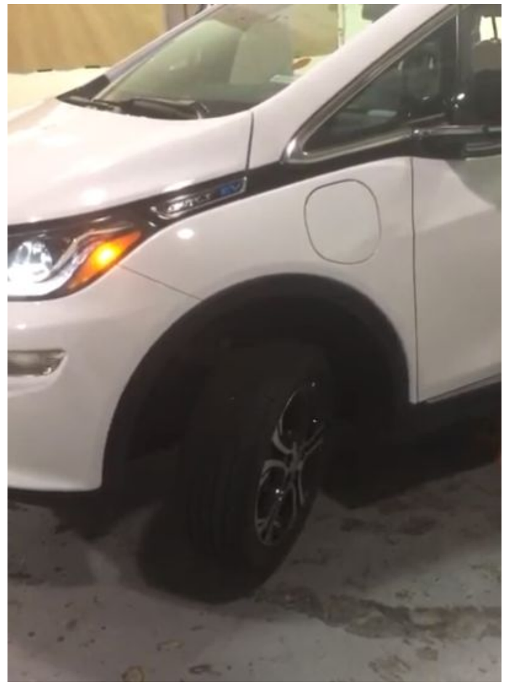
Autonomous driving after End-to-End training. https://youtu.be/LoJGX4yfP-A

X-By-Wire

Dr. Kwon was part of the AutoDrive Challenge, which is a collegiate design series sponsored by SAE International and General Motors. He was an active member in developing lateral control system using Deep Learning in Year 1 competition where his team won 2nd place in the lateral control challenge and was the only team that used the Deep Learning approach.

Drive-By-Wire example.

https://youtu.be/TehA2a42g-Y

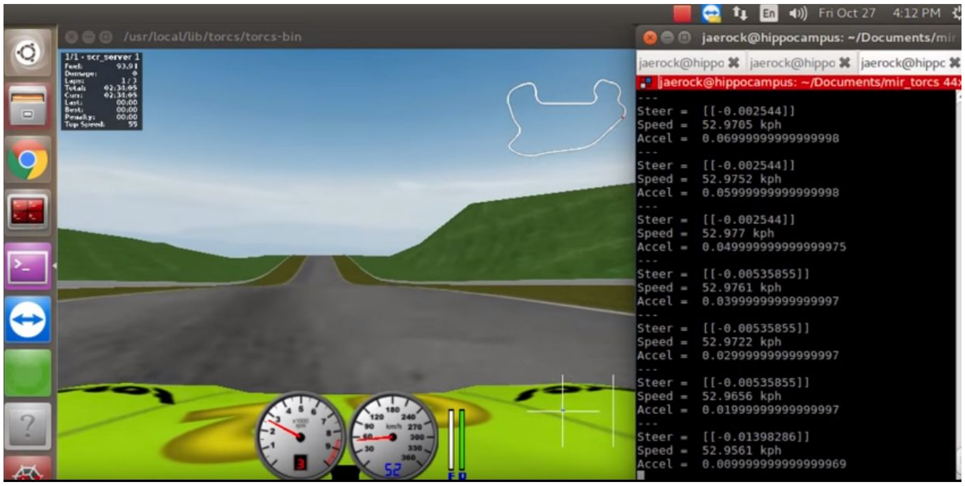


Steer-By-Wire example.

https://youtu.be/BJGt0dIr-PY

End-to-End Learning by Cloning Driver Behavior

We also conducted a series of studies to build an End-to-End learning system by cloning a human driver's behavior. We used TORCS, a racecar simulator. We collected about four-hour long driving data from a human driver. Then, the steering angle values corresponding camera view input were fed to a Deep Neural Network. After training, the system was able to successfully complete the racing track. The longitudinal control was implemented with a PID controller.

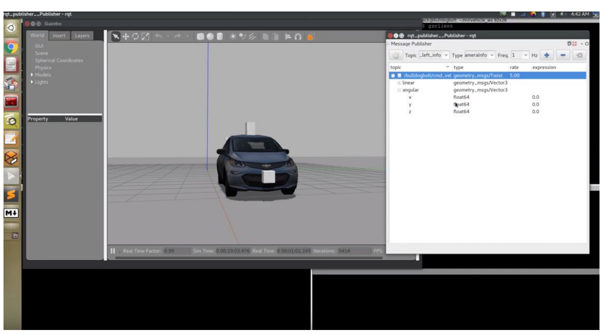


The left window shows the driver's view of the racecar simulator. The right window displays the predicted steering angle values along with the current velocity and acceleration values.

https://youtu.be/SliR1yEUotI

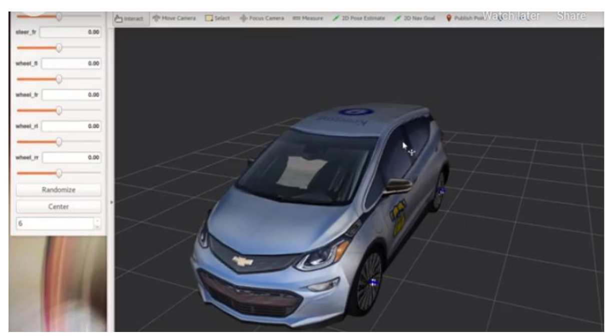
Simulation

Having a simulation environment with a car model is beneficial. We were able to test algorithms before deploying the real car.



Chevy Bolt Simulation. The model car is controlled by ROS topics.

https://youtu.be/OYdKNySltuQ

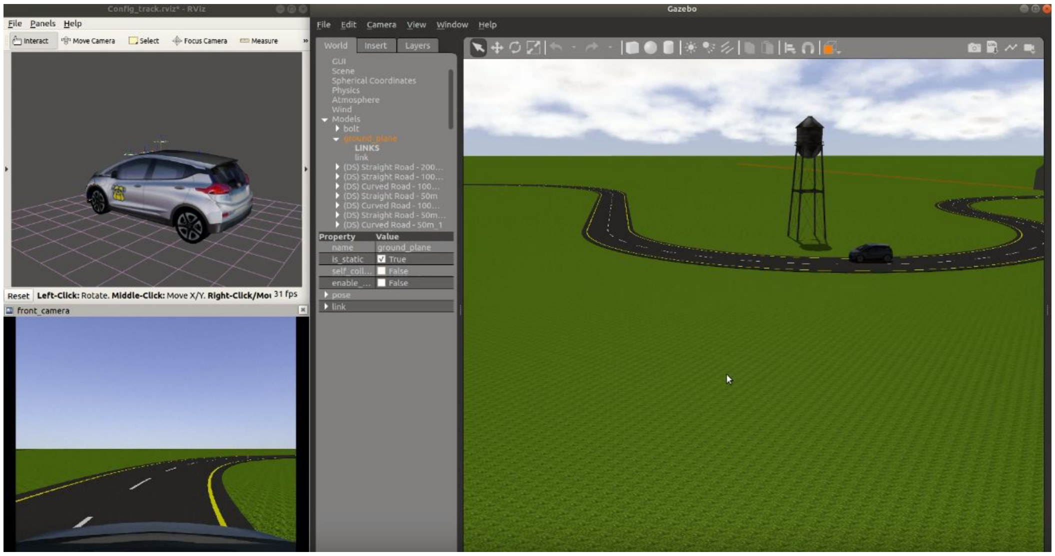


Chevy Bolt Model built for Gazebo simulation and ROS Visualization (Rviz).

https://youtu.be/nGS5SAC5JaA

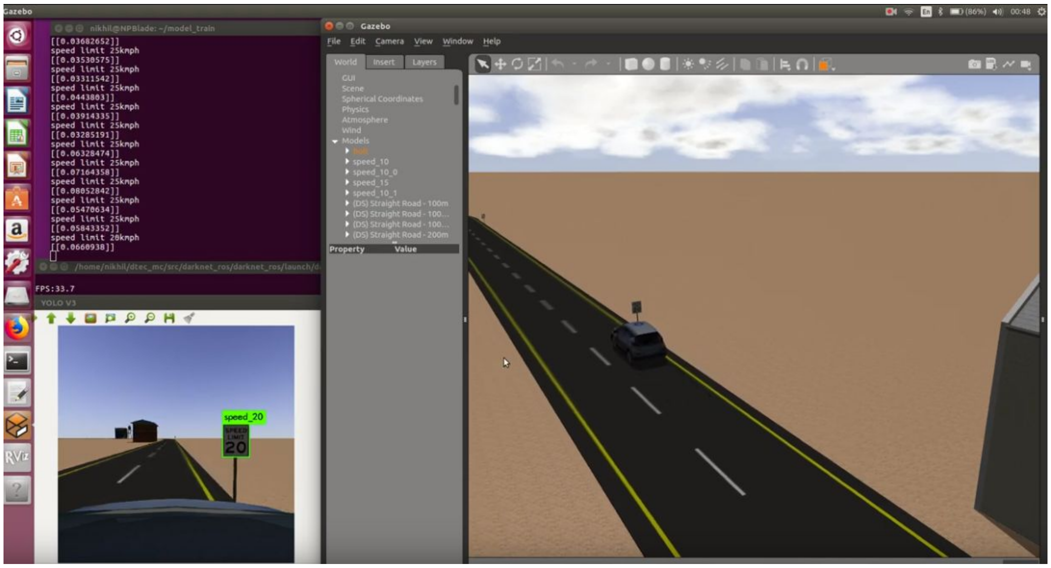
Traffic Sign Recognition

We trained a Deep Neural Network and deployed it to a car controller as a lateral control.



Train and test a lateral controller. https://youtu.be/fnTmeEBM0n0

With the trained network for the lateral control, we were able to make the car drive as it detects traffic signs and behaves accordingly. We used YOLOv3 for object detection and recognition with ten different traffic signs. A transfer learning technique was used to replace the original object detection and recognition capability with our traffic sign detection and recognition.



A car is being able to be driven by the trained controller while it detects traffic signs. The longitudinal controller was also activated to change the behaviors of the car.

https://youtu.be/TXlIM6zF6Jg

Plans

Simultaneous Localization and Mapping and Controls

In addition to the conventional PID-based control schemes, we plan to implement MPC-based control laws, with guarantees of performance and stability of both lateral/longitudinal autonomous vehicle dynamics, for the steering motor and the driving motor controllers. One of the fundamental issues for implementing efficient control algorithms for autonomous racing cars is that of the complicated coupling between the lateral and the longitudinal dynamics. During aggressive maneuvers, where the coupling effects between the lateral-longitudinal dynamics cannot be ignored, more complicated control schemes in contrast to simple PID controllers will be needed. Furthermore, we plan to use adaptive numerical algorithms, which will be run in real-time, for updating the dynamic model of the autonomous vehicle. Such real-time adaptive algorithms ensure that varying road conditions, gradual changes in vehicle mass, and varying interaction forces between the vehicle tire and the road surface are incorporated into the steering motor and driving motor controllers.

To further improve the quality of our neural networks, which are trained using human driver data, we will also use a game theoretic approach to model various human operator behaviors such as lane-changing behavior. Training our neural networks using such analytical models will further improve the stability and performance of our autonomous vehicle. Furthermore, we plan to investigate shared steering control between the driver and autonomous vehicle in the presence of uncertainties.

Testing

In addition to University of Michigan - Dearborn property, the team has identified multiple potential testing locations throughout Michigan that have been designed for testing autonomous vehicles. These locations include the American Center for Mobility in Ypsilanti Michigan, Mcity in Ann arbor Michigan, and the Mobility Research Center in Flint Michigan.

Project Management

The team plans to hold weekly all-hands status meetings for all project team members in addition to weekly status meetings for each of the team’s subgroups. Subgroups will consist of the following disciplines: Mechanical, Electrical, Software, and Simulation.

There will be a team Project Manager that will provide an overlap between members in each of these meetings to ensure the big picture progress of the team is meeting internal schedules to align with competition deadlines.

Fundraising

The Institute of Advanced Vehicle Systems (IAVS) at the University of Michigan-Dearborn provides seed funding of up to $20,000 for supporting the faculty research in the area of autonomous vehicles.

Depending on the outcome of collaborations with industry partners, the team may also seek fundraising opportunities from the industry partners.

Collaboration

The team plans to work with multiple collaborators throughout the duration of the competition based on mutual interests in the autonomous vehicle space. Potential unofficial collaborators recognized so far may include partners from other universities (Oakland University, University of Michigan, Hanyang University in South Korea, and MIT Driverless, Technical University of Munich, Germany) and industry partners (Zenuity, GM, FCA), among others.