YSEA Grant Proposal Abstract:

A Formal, Model-based Approach to Enhancing the Safety of Autonomous and Connected Vehicles

Self-driving cars are the future of transportation. By sensing their environments, these autonomous cars can navigate the roads without any human direction. The advent of these autonomous modes of transportation have the potential to make the streets safer, reducing the number of accidents by 90% [9], by removing human-error caused accidents. While the technology rapidly progresses, there are unresolved problems regarding human trust in these systems as well as questions about how these vehicles should interact with each other. Much of current research focuses solely on the machine learning capabilities to detect objects and path plan for an individual car [4, 7]. These capabilities can be complemented with improved communication systems once all cars are autonomous, a more holistic perspective. A reliable communication protocol could resolve the need of having each car try to predict, often erroneously, the intended trajectories of other cars.

This project focuses on ensuring safety (i.e. collision freedom) of autonomous vehicles through *vehicle-to-vehicle communication*. Vehicle-to-Vehicle (V2V) [1], is the technology that allows cars to communicate with one another. Each car broadcasts and receives information from surrounding vehicles over a wireless communication called Dedicated Short Range Communication (DSRC) [2]. This research can be extended beyond applications in self-driving cars to many multi-agent systems that could benefit from coordinated planning. Schwartz et al.[8] proposed a set of mathematical models which capture the minimal requirements needed to guarantee safety assurance in self-driving cars. Building off of proposed distributed hybrid model-based methods by [3, 6], we intend to define a *formally-verifiable* planning algorithm and messaging protocol using V2V communication that would satisfy the minimal requirements of [8]. Each car will maintain their own model of the world around them and update it based on incoming messages from the DSRC. When the car is planning on changing its current behavior, such as changing lanes, it will send its *intents* back into the DSRC. Each DSRC message must contain sufficient information for the surrounding cars to make safe decisions, and keep personal information about each car private. We will also ensure that it fits into current and proposed regulations from the government. The difficulty of this problem arises from combining the continuous nature of car dynamics with a discrete set of decisions.

It is important to note that none of the previously referenced papers have been tested with real data or in a real-world setting, which makes it difficult to evaluate whether they are actually viable options for real-world safety-critical systems like self-driving cars. Our protocol will not only be formally verified, but will also be implemented as a proof-of-concept in small model cars (see Figure 1). The model self-driving cars are one-tenth the size of a real car and equipped with features commonly found on a self-driving car (e.g., a front facing camera, LIDAR, on-board computer, and WIFI connection that will facilitate as the DSRC channel). We will build a miniature city for these cars, similar to [5], to operate in, starting simply with two cars on a multi-lane highway and later extending to include traffic signals, multiple cars, and intelligent infrastructure. Specifically, a scenario we want to study in this proposal is the resolution of concurrent transitions into a lane by two cars, where both cars communicate the same intent. Having an implementation of the system also allows us to run experiments and iterate on the proposed protocol with feedback from a realistic setting. The deliverables for this project include: a proposed V2V communication infrastructure and associated mathematical tools as well as a validated hardware and software implementations for the model self-driving cars in our miniature town.

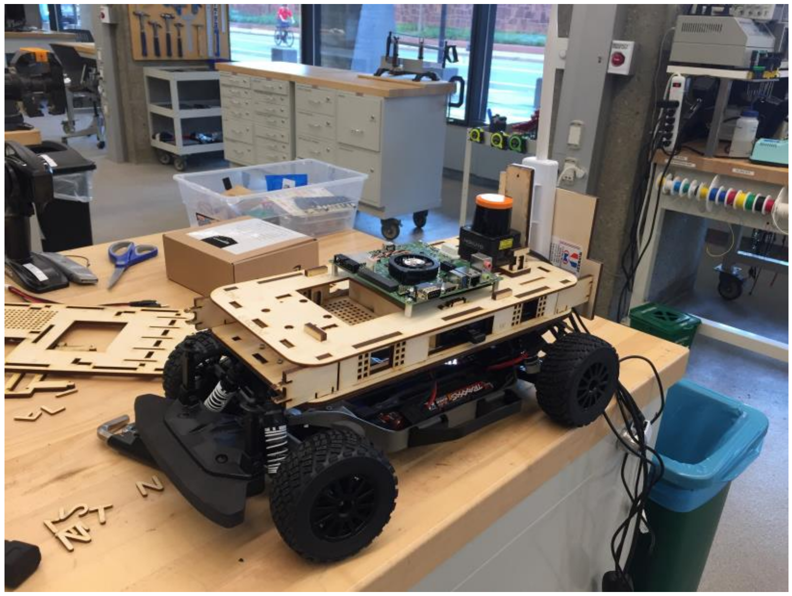

Figure 1: This is the model car, one-tenth the size of a real car, which we will use to test the V2V communication infrastructure.

References

[1] URL: https://www.its.dot.gov/research_areas/connected_vehicle.htm.

[2] URL: https://www.its.dot.gov/factsheets/dsrc_factsheet.htm.

[3] Gregor V Bochmann et al. “Synthesizing and verifying controllers for multi-lane traffic maneuvers”. In: *Formal Aspects of Computing* 29.4 (2017), pp. 583–600.

[4] Mariusz Bojarski et al. “End to end learning for self-driving cars”. In: *arXiv preprint arXiv:1604.07316* (2016).

[5] Adam Conner-Simons — CSAIL. *Self-driving cars, meet rubber duckies*. 2016. url: http://news.mit.edu/ 2016/self-driving-cars-meet-rubber-duckies-0420.

[6] Ehsan Moradi-Pari et al. “Utilizing model-based communication and control for cooperative automated vehicle applications”. In: *IEEE Transactions on Intelligent Vehicles* 2.1 (2017), pp. 38–51.

[7] Sebastian Ramos et al. “Detecting unexpected obstacles for self-driving cars: Fusing deep learning and geometric modeling”. In: *Intelligent Vehicles Symposium (IV), 2017 IEEE*. IEEE. 2017, pp. 1025–1032.

[8] Shai Shalev-Shwartz, Shaked Shammah, and Amnon Shashua. “On a Formal Model of Safe and Scalable Self-driving Cars”. In: *arXiv preprint arXiv:1708.06374* (2017).

[9] Michele Bertoncello Wee and Dominik. *Ten ways autonomous driving could redefine the automotive world*. URL: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-waysautonomous-driving-could-redefine-the-automotive-world.

Itemized Budget

Component	Quantity	Total Cost
Traxxas 1/10th Car platform	1	$289.95
Traxxas 7-Cell Flat NiMH Battery 3000	1	$39.99
Nvidia Jetson	1	$299.99
Teensy 3.2	1	$24.45
Battery Pack	1	$99.99
Picostation	1	$88.95
USB Hub	1	$31.49
SparkFun 9DoF Razor IMU M0	1	$49.95
Logitech C920 Webcam	1	$57.79
USB Wifi Adapter	1	$16.99
Xbox 360 wireless controller	1	$30.50
Xbox 360 wireless controller receiver	1	$10.89
LCD Module	1	$9.99
Other Miscellaneous Parts	1	$100
Road Marking Tape	1	$20.40
Foam Floor Mats	5	$53.97
Total		$1,225.29

Note: Currently we already have one model car but need to buy another one to be able to test the V2V protocol. The itemized budget is based on the model car that we previously built with some of the budget allocated to buying road markers for our miniature town.

Contact information for the department administrator to whom grant funds are to be sent:
[Edit from YSEA – contact information for department administrator omitted for purposes of anonymity]