The Path to Commercial Autonomous Cars: The DARPA Urban Challenge and Beyond

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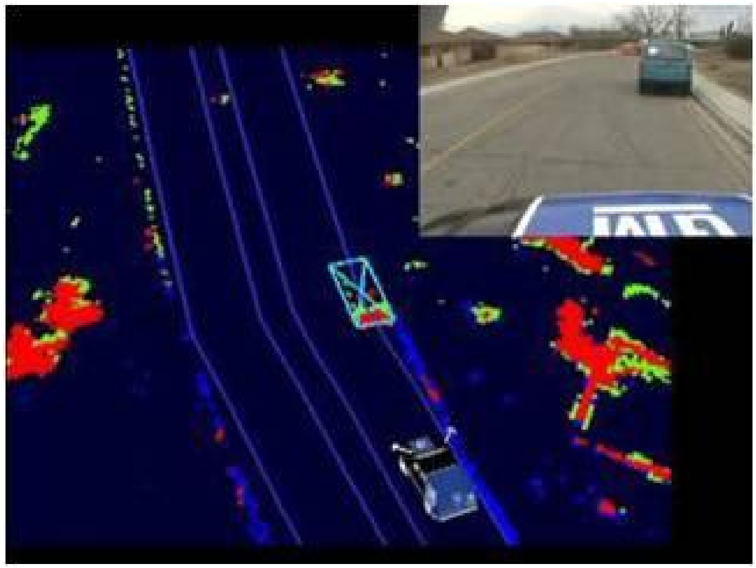
In recent years, the automotive industry has seen an increasing trend towards "smart" cars that are capable of automatically performing driving tasks for their occupants. Eventually, this technology will mature to the point that it allows cars to drive under complete machine control, but for now such automated cars are still many years away from commercialization. The sensing and control technologies that would make fully autonomous cars possible are starting to find their way into today's vehicles as features such as automated parallel parking where the car controls the steering and adaptive cruise control where the car controls the throttle. These vehicle automation capabilities show great promise in improving safety, fuel efficiency, and overall reliability of cars. Creating a fully autonomous car that can perceive and reason about its current position and intended path, detect and track other vehicles and pedestrians in real time, and safely navigate to its destination is a daunting and fascinating technical challenge but has the potential for great societal impact by revolutionizing automotive safety, fuel efficiency, and overall reliability.

Boss: Winner of the 2007 DARPA Urban Challenge

In 2007, the US Defense Advanced Research Program Agency (DARPA) organized and held its third and final contest for autonomous vehicles. While the first two races were off-road single-track challenges, this race, called the DARPA Urban Challenge, was a 60-mile road race through a simulated suburb where completely autonomous robotic cars, fielded by teams from both academia and industry, were required to follow a set of pre-defined routes while simultaneously obeying US traffic laws (speed limits, intersection precedence, no passing zones, etc.) Unlike the prior two races where the robot cars were kept far apart from each other, all of the robotic cars in the Urban Challenge drove through the course at the same time and had to contend with not only each other's presence but also the presence of many other vehicles driven by the race organizers. Of the dozens of teams who entered, only a handful ended up actually completing the full 60 miles of the race in the required time limit. Carnegie Mellon University's Tartan Racing team won that race with their robot "Boss," a heavily modified 2007 Chevy Tahoe. Boss made use of over a dozen different sensors to perceive its environment and the traffic with which it shared the road. The robot had to constantly use this sensor information to evaluate the state of its local surroundings, monitor its position in its representation of the road network, plan a path to reach its goals, estimate the future positions of vehicles around it, and be ready to perform defensive driving maneuvers in an emergency situation.

While the technical achievements demonstrated by the teams entering the 2007 DARPA Urban Challenge were quite significant, the complexity of that race course still pales when compared to the complexity of roadways in the real world. For instance, the road network was fully known in advance, the vehicles did not have to contend with roads that had more than two lanes, there were no pedestrians or other vulnerable road users (e.g. bicyclists) allowed in the race, the speed limits averaged at 15mph (max 30), and the vehicles did not have to "see" and interpret street signs or lane markings. These and many other challenges remain to be solved before the dream of roadways populated by fully autonomous cars can become reality.



A representation of the world generated by the sensors on Boss.

In the first part of this talk, I will provide a brief overview of the history and state of autonomous driving technology and describe why such technical goals are relevant and useful to the roadways of the future. I will describe the problems that had to be solved by the Urban Challenge teams and the robust and innovative solutions developed by the Tartan Racing team that ultimately allowed them to win the race. I will talk about issues such as why vehicle perception is very difficult even with modern LIDAR, RADAR, and camera sensors as well as on the complexities of planning and how to control the robot on the road. This background will lead into the second part of my talk where I will devote the remaining time to the open challenges that must still be solved before autonomous cars can safely drive on open roads. I will present current research being performed at Carnegie Mellon University's various autonomous driving programs that seek to address the technology gaps that must be filled before fully autonomous cars become a reality in society.