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BACKGROUNDER

Torc self-driving car technology

Introduction

Torc Robotics is an autonomous vehicle technology firm that has developed a complete self-driving system for consumer automobiles. Its self-driving car technology is based on commercially proven systems that Torc has developed over the past decade for safety-critical situations such as mining and defense.

The Torc team is passionate about robotics and is dedicated to making the world safer and more accessible through its autonomous systems, according to Michael Fleming, CEO and co-founder.

Torc first established itself as a leader in autonomous vehicles in 2007, when its vehicle placed third in the Defense Advanced Research Projects Agency (DARPA) Urban Challenge, a ~60 mile course which required vehicles to travel through on and off-road environments autonomously and navigate through situations like parking lots, road blocks, and merging while obeying traffic laws. While many members of the other winning teams joined Google's autonomous driving project, Torc retained 85 percent of its talent.

Since then, Torc has continuously improved upon its technology—successfully applying it to a variety of commercial ground vehicles, from large mining trucks to military vehicles. "We have been developing our autonomous systems and have resolved issues in hazardous environments with no or little pavement. Applying our technology to the safer, engineered paths of modern roads is a logical step," Fleming says.

"We have been waiting for the time when it would be feasible to apply to consumer cars," Fleming says. "That time is now." In July 2017, Torc unveiled its self-driving car project. The technology has been implemented on two Lexus RX vehicles, which have been operating on public roads, in a variety of weather conditions, since February 2017.

One of Torc's self-driving vehicles demonstrated a long-distance drive in April 2017, logging more than 1,000 autonomous miles during a round trip from company headquarters in Blacksburg, Virginia, to the Ford Piquette Avenue Plant in Detroit—birthplace of the Model T. The car drove autonomously on highways, freeways, winding mountain roads, and city streets.

More recently, Torc's self-driving car completed a round-trip journey from coast to coast. The car started from Washington, D.C., and arrived in Seattle as Washington State's first certified pilot test. The trip ended in Richmond, where the Torc team was welcomed home by Governor Terry McAuliffe and Secretary of Technology Karen Jackson at Virginia's Executive Mansion. The vehicle drove 4,300+ autonomous miles—successfully maneuvering heavy urban traffic, aggressive tailgating, heavy rains, and highway detours.

Torc continues to refine its technology with continual testing and offers the technology to carmakers and systems developers around the world.

Torc products and services

Torc offers the following technology and services to carmakers and systems developers:

Autonomous software

Torc offers an end-to-end self-driving software stack that integrates easily on third-party hardware such as sensors and actuators, as well as computing and communication systems.

Engineering partnership

While Torc offers commercial off-the-shelf solutions for customers to use independently, the firm also offers a seasoned team to help automakers implement autonomous technology on their unique vehicles.

> *"There is so much confusion about how to implement robotics on cars and how autonomous software can interface with different mass-produced car models. Our team helps carmakers and systems developers navigate the different options and jumpstart their programs for a fast-approaching transportation revolution"*
>
> —Michael Fleming

Hardware/software products

Torc offers complete systems for localization, safety and drive-by-wire control.

Technology

Similar to a human driver, Torc's system performs a See-Think-Act process while driving. It **perceives** the environment, **plans** how to react, then **controls** or implements the behavior.

Perception incorporates a balance between proven algorithms and emerging algorithms such as deep learning. The multi-sensor (vision, LiDAR, and radar) approach enables Torc's self-driving solutions to operate in non-ideal weather conditions.

Planning integrates route planning, behaviors, and motion planning.

Control provides the appropriate actuation of vehicle control and monitoring of vehicle feedback to obtain motion planning's desired path. Torc's product line has integrated with different automakers' vehicles to provide a highly responsive but smooth and natural driving profile.

Core Software

Torc also owns the **end-to-end self-driving software stack**. By controlling every decision made throughout the autonomous system, and by basing those decisions on raw sensor data, the company can ensure the intelligence, reliability, and trustworthiness of its technology.

Validation and Testing

Testing and validation are key elements of Torc's ability to rapidly deploy self-driving vehicles.

The self-driving automotive technology is currently implemented on two Lexus RX vehicles, which have been operating on public roads since February 2017. They have undergone extensive testing on closed courses at Chelsea Proving Grounds and the VTTI Smart Road, a testing road located only a few miles from Torc headquarters.

In April 2017, one of the vehicles demonstrated a long distance drive, logging over 1000 autonomous miles during a round trip from Torc's headquarters to the Ford Piquette Avenue Plant in Detroit—birthplace of the Model T.

Experience

Torc has more than 10 years of experience building and testing self-driving vehicles in real-world conditions. Its technology has allowed businesses in a wide range of industries to work safer, smarter and more efficiently.

Many of Torc's clients require off-road autonomous capabilities that are more complicated than on-road systems. Their vehicles must maneuver past small obstacles that are difficult to see, areas without marked pathways, and uneven terrain.

Torc engineers have a strong understanding of the tradeoffs in designing and deploying self-driving vehicles—from sensor selection and placement, distributed versus centralized computing, algorithm selection, and dynamics and safety. This includes system hardware and software design, vehicle integration, along with validation and testing.

The Team

Torc's headquarters in Blacksburg, Virginia, is strategically located to support self-driving vehicle development. The 20,000-square-foot facility contains garages, a 22-acre test site, and is adjacent to a 2.2-mile closed road course with weather generating capabilities.

Torc has one of the deepest and longest-tenured benches of engineering talent, having retained 85 percent of its employees who competed in the 2007 DARPA Urban Challenge.

The firm has one core value: winning teams, which supports a culture of collaboration, growth, and excellence.

History

Early beginnings

In 2005, a group of Virginia Tech students lead by Dr. Charlie Reinholtz designed and built three autonomous robots to compete in the AUVSI Intelligent Ground Vehicle Competition. The competition required robots to autonomously drive through obstacle courses at speeds up to 5 mph. After three rigorous days of competition with 27 other competitors, the team placed first, second and third in the autonomous and navigation challenges, and first and second in the design competition.

The team built two autonomous vehicles to compete in the DARPA Grand Challenge. After competing against an initial 195 applicants, the team placed eighth and ninth, completing nearly 100 combined miles of autonomous driving in the harsh rocky desert terrain.

These successes generated a wealth of interest across several markets including automotive, mining and defense. After receiving numerous requests for the commercial application of its technologies, the team created a spin-off company called Torc Robotics. Shortly thereafter, DARPA announced the next robotic challenge.

DARPA Urban Challenge

The 2007 DARPA Urban Challenge was a 60-mile race through urban and off-road terrain. Unlike previous challenges, other manned and autonomous vehicles would be present on the course at the same time. This required teams to obey California's driving laws and be able to merge with moving traffic, intersection progression, and execute U-turns.

Torc entered the competition in partnership with Virginia Tech, forming team VictorTango, and was awarded one of the $1 million DARPA grants. The team finished third out of 89 teams, completing the event in four hours and 36 minutes. This early success and funding positioned the company to further develop its self-driving technology.

Blind driver challenge

In 2010, Torc partnered with a robotics team at Virginia Tech to develop a vehicle for the National Federation of the Blind's (NFB) Blind Driver Challenge. The team received the National Instruments' 2010 Application of the Year for the project.

On January 29, 2011, a blind driver independently drove Torc's vehicle down the main straightaway, onto the road course at the Daytona Speedway. While the systems were specifically designed for the Challenge, they were later used for other autonomous driving solutions.