Google Self-Driving Car Project
Monthly Report

November 2015

Activity Summary (all metrics are as of November 30, 2015)

Vehicles

- 23 Lexus RX450h SUVs – currently self-driving on public streets; 18 in Mountain View, CA, 5 in Austin, TX
- 30 prototypes – currently self-driving on public streets; 23 in Mountain View, CA & 7 in Austin, TX

Miles driven since start of project in 2009

"Autonomous mode" means the software is driving the vehicle, and test drivers are not touching the manual controls. "Manual mode" means the test drivers are driving the car.

- Autonomous mode: 1,320,755 miles
- Manual mode: 955,771 miles
- We're currently averaging 10,000-15,000 autonomous miles per week on public streets

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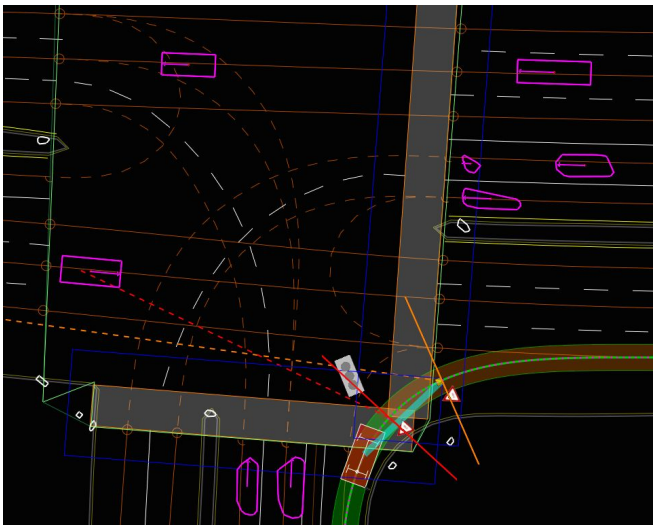
A better view on how our vehicles make a right on turn on red.

Most of us feel impatient and disappointed when we see a "No Right Turn on Red" sign, yet it's a maneuver that can make even experienced drivers nervous.

At busy intersections, a right on red requires a human driver to simultaneously track multiple moving objects in different directions, from fast-moving cars on your left who have the green light, to pedestrians crossing in front. There are also rules specific to each state; cars in California are required to enter the bike lane prior to and during a right turn, but in Texas, cars must leave the bike lane clear.



The orange line indicates our software allowing the vehicle to nudge forward for a better view so it can calculate when it's safe to make a right turn on red.

Our vehicles can identify situations where making a right turn on red is permissible and the position of our sensors gives us good visibility of left-hand traffic. After coming to a complete stop, we nudge forward if we need to get a better view (for example, if there's a truck or bus blocking our line of sight). Our software and sensors are good at tracking multiple objects and calculating the speed of oncoming vehicles, enabling us to judge when there's a big enough gap to safely make the turn. And because our sensors are designed to see 360 degrees around the car, we're on the lookout for pedestrians stepping off curbs or cyclists approaching from behind.

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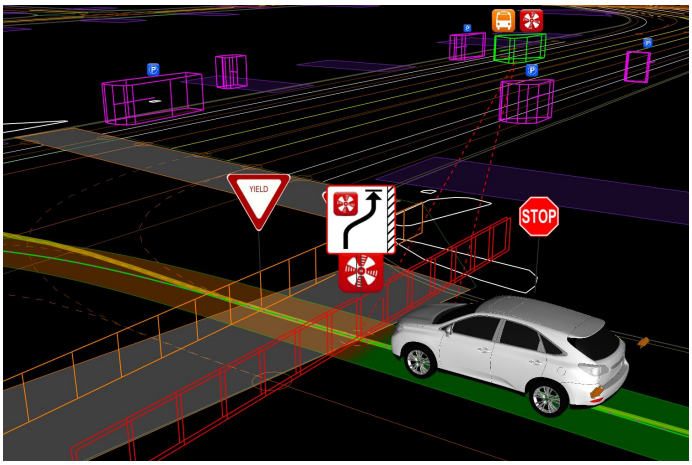
A need for the right speed: finding a pace for learning.



Our vehicle detects the sirens of an ambulance and yields at the intersection, allowing the emergency vehicle to pass through safely.

This month, one of our cars received some attention after being stopped by a Mountain View police officer who queried us for travelling 24mph in a 35mph zone. Here are answers to the most common questions we heard.

The Mountain View Police wrote that your prototype vehicles are considered "neighborhood electric vehicles" -- why did you choose to build one of these rather than a full speed automobile?

From the very beginning we designed our prototypes for learning; we wanted to see what it would really take to design, build, and operate a fully self-driving vehicle -- something that had never existed in the world before. This informed our early thinking in a couple of ways. First, slower speeds were easier for our development process. A simpler vehicle enabled us to focus on the things we really wanted to study, like the placement of our sensors and the performance of our self-driving software. Secondly, we cared a lot about the approachability of the vehicle; slow speeds are generally safer (the kinetic energy of a vehicle moving at 35mph is twice that of one moving at 25mph) and help the vehicles feel at home on neighborhood streets.

Doesn't this mean your prototypes can't travel on a lot of roads?

In California our prototypes are allowed to travel on roads with speed limits up to 35mph. Most roads in Mountain View are 25mph because they're quiet residential streets, so our prototype fits right in. On the larger boulevards where the speed limit is 35mph, there are usually 2 or 3 lanes so other cars can go around us -- and during rush hour, no one is moving anywhere close to 25mph! (Our Lexus vehicles are capable of travelling faster). We appreciate other drivers sharing the road with us and we welcome feedback from Mountain View and Austin residents.

What happens when an emergency vehicle comes along?

A siren is often the first sign of a fire truck, police car or ambulance nearby. We've built up a library of various sirens (such as the long wail of a fire truck and the short shrills of an ambulance) and taught our software to identify them. As soon as we're alerted, our cars drive more conservatively (e.g., slowing down a bit or avoiding entering an intersection) until we have a better sense of where the sirens are coming from. Even if sirens aren't sounding, our cameras are on the lookout for emergency vehicles and are designed to detect flashing lights. So if a fire truck is coming through an intersection, we'll stop and let it through. Or if an emergency vehicle is approaching from behind, we'll slow down and pull over until we know it's safe to resume the journey.

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Traffic Accidents Reported to CA DMV

Given the time we're spending on busy streets, we'll inevitably be involved in collisions; sometimes it's impossible to overcome the realities of speed and distance. Thousands of minor accidents happen every day on typical American streets, 94% of them involving human error, and as many as 55% of them go unreported. (And we think this number is low; for more, see here.) In the six years of our project, we've been involved in 17 minor accidents during more than 2 million miles of autonomous and manual driving combined. Not once was the self-driving car the cause of the accident.

(CA regulations require us to submit CA DMV form OL316 Report of Traffic Accident Involving an Autonomous Vehicle for all collisions involving our cars. The following summary is what we submitted in the "Accident Details" section of that form.)

November 2, 2015: A Google Lexus model autonomous vehicle ("Google AV") in autonomous mode travelling northbound on Clark Ave. in Mountain View was involved in an accident. As the Google AV approached the intersection of Clark St. and El Camino Real, it activated its turn signal to indicate its intention to make a right turn on El Camino Real. The Google AV came to a complete stop at a red light at the intersection and then began to slowly advance in order to get a better view of cross traffic on El Camino Real approaching from the left to determine whether it was clear to make the right turn on red. A vehicle approaching from behind came to a stop and then rolled forward and collided with the rear bumper of the Google AV. The approximate speed of the other vehicle at the time of impact was 4 MPH. The speed of the Google AV at the time of impact was below 1 MPH.

There were no injuries reported at the scene by either party. The Google AV sustained minor damage to the rear bumper. The other vehicle sustained minor damage to the passenger side headlight, vehicle hood, and front bumper.

What we've been reading

- **TechCrunch,** "The Myth Of Autonomous Vehicles' New Craze: Ethical Algorithms" (November 2015)
- **Autoweek,** "Jay Leno on autonomous cars: They might save lives" (November 2015)
- **USA Today,** "City of the future is closer, calmer than you think" (November 2015)
- **New York Times,** "The Dream Life of Driverless Cars" (November 2015)
- **Associated Press,** "How can people safely take control from a self-driving car?" (November 2015)