Google Self-Driving Car Project
Monthly Report

August 2015

This month we spent a lot of time in Austin, both on the roads and hosting community meetings to help people learn more about our project. Last weekend we hosted an open house at Austin's Thinkery, a museum of science for kids; it's in an area where we've been self-driving our Lexus vehicles. We had both a Lexus and a prototype on display, and Mayor of Austin Steve Adler announced that a few more of our prototype vehicles will be arriving in early September so we can start testing them (with test drivers aboard) in the coming weeks. Our favorite part of the weekend: hearing kids shout out their ideas for what our prototype looks like...an owl, an egg, a turtle, and "the future!"

Activity Summary (all metrics are as of August 31, 2015)

Vehicles

- 23 Lexus RX450h SUVs – currently self-driving on public streets in Mountain View, CA, & Austin, TX
- 25 prototypes – 5 are currently self-driving on public streets in Mountain View, CA

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: 1,158,818 miles
- Manual mode: 877,477 miles
- We're currently averaging ~10,000 autonomous miles per week on public streets

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Updates from Austin

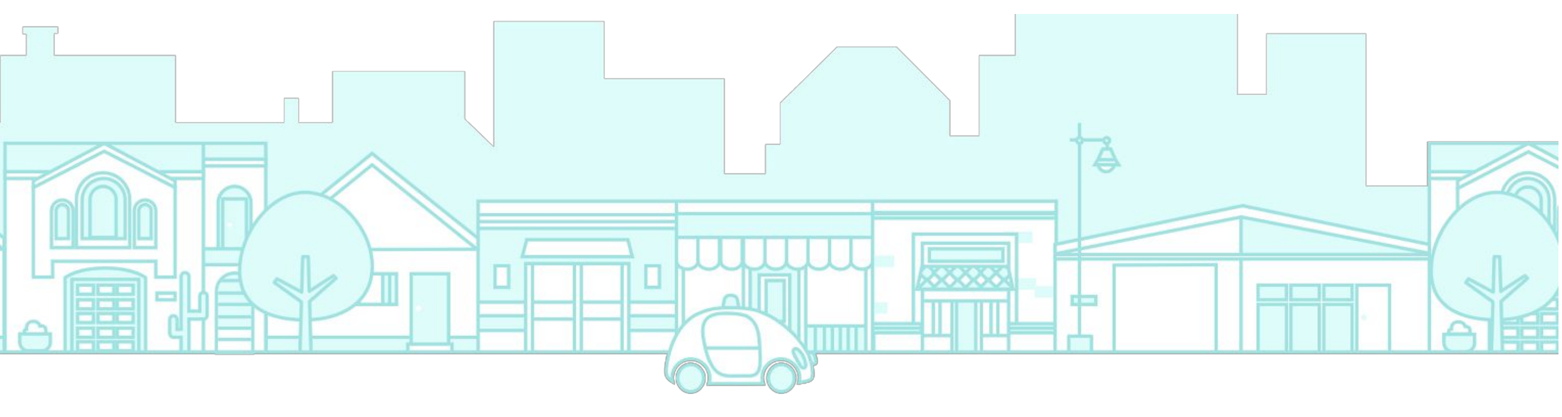
We've now been driving in Austin for about two months, and as we've visited various groups in the community, here are the top 5 questions we've been getting.

#1. How do you handle deer?

Apparently Austin has a lot of deer, and we're ready for them! Even at night, the sensors on our vehicle can detect animals like deer, even when they're on the side of the road. We can detect that they're different from an inanimate object (like a mailbox) and if the animal appears to be moving into the road, the car will slow down or come to a stop.

#2. How is your experience in Austin different from Mountain View?

We're already learning a lot from being in a community far from Silicon Valley. It's been helpful to get out and talk to people who aren't used to seeing self-driving cars every day. We're also learning what's necessary to operate and maintain a fleet of vehicles far away from our home garage. And on the streets, we've had to learn how to handle new types of street infrastructure, like horizontal traffic signals. But on the whole, in terms of how the cars operate, there's far more that's similar than different.



#3. How does the car know where to go when you get in?
We're working on different ideas but it's still very early—this is a great example of the kind of thing we'll be researching and testing in the coming months. People are already carrying their phones so it would make sense for us to take advantage of that. Our prototype vehicles also have a screen built into the dashboard; it'll be interesting to experiment with various interfaces for that over time.

#4. What if...[insert hypothetical situation that could be tricky]?
People love asking us how we'd handle situations that are rare but possible -- an object falling off a truck, a cyclist suddenly darting into our path from between parked cars, a woman in an electric wheelchair chasing a duck around the middle of the road. (That last one really happened!) Rather than teaching the car to handle very specific things, we give the car fundamental capabilities for detecting unfamiliar objects or other road users, and then we give it lots of practice in a wide range of situations. Most often the best approach -- for our software or for a human driver -- is to slow down or come to a stop until more information about the situation is available. And because the car has 360 degree visibility out nearly 200 yards in all directions at all times and is always paying attention, it should be able to detect and respond to tricky situations before they get really sticky.

In addition to driving many thousands of miles every week to accumulate lots of real-world experience, we also have a special team that creates challenging situations for our vehicles on our test track. Sometimes they're difficult variations on what we've seen out on the roads (e.g., a car suddenly pulling out from a parking spot right into our path), and sometimes they're diabolical creations of the team's imagination. We've done everything from throwing piles of loose paper in the road to purchasing giant stuffed birds from a Halloween store.

#5. When will they launch / be available / be ubiquitous?
We're just starting to test our prototype vehicles; we have a few on the streets of Mountain View now, and they'll be arriving in Austin in early September. In the current phase of the project, we're studying how these communities perceive and interact with us, and we're continuing to smooth out the vehicles' behavior to make them feel more natural to people inside and around them. We also want to uncover challenges that are unique to a fully self-driving vehicle—e.g., where it should stop if it can't stop at its exact destination due to construction or congestion. The next step for us will be running pilot programs with our prototypes to learn more about what people would like to do with vehicles like this, though we don't have any specific timelines to share right now. Our project lead Chris Urmson's goal is to make sure his 11 year old son doesn't need to get a driver's license.

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Scenes from the Street - *each month we'll give examples of everyday situations we encounter*
On Mountain View's Shoreline Boulevard, a delicate dance happens many times daily between drivers and pedestrians (and, of course, self-driving cars). Shoreline is one of the city's main arteries, with 3 lanes traveling 35mph in each direction, divided by a median with trees and bushes. At many of the smaller intersections, there are big crosswalks marked by neon yellow signs, but they're not protected by stoplights or stop signs. Pedestrians can press a button to make yellow lights flash when they want to cross, though not all do. These crosswalks can create nerve-wracking situations for drivers and pedestrians alike.

One of the biggest challenges is that a pedestrian stepping off a curb often isn't visible to the drivers in all the lanes; they can easily be obscured by other cars or trucks. So pedestrians often start walking across, only to see vehicles continuing to zoom through. This is also stressful for drivers -- they have to brake when the pedestrian comes into view, or when the cars in front of them suddenly stop for a pedestrian that they themselves might not see. Unfortunately, our self-driving car and test drivers found themselves in this kind of situation on August 20, when our Lexus AV was rear-ended.

Upon detecting a pedestrian entering the crosswalk, our car began braking autonomously and started to slow down. Our test driver, in the abundance of caution that they're trained for, took manual control of the AV and applied the brakes, and our AV stopped safely outside the crosswalk. Our driver's braking was firm but ordinary for this road environment. The vehicle behind us had been changing lanes to merge between our AV and another vehicle, and it crashed into our rear end. We're guessing they'd glanced to the side or rear as they merged, and then didn't see what was going on straight ahead of them until it was too late to stop. It was a classic road situation that's difficult for human drivers. (You can read the details below in the report we submitted to the CA DMV.)

One of the most useful features of our system is that we can go back and replay a version of the incident as if our test drivers hadn't intervened -- in other words, we can see what the car would have done if we'd left things entirely up to the software. In this case, if the car had been left to operate autonomously, it would have stopped safely in front of the crosswalk -- great. Intriguingly, though, it would have braked slightly less hard and traveled a bit closer to the crosswalk before stopping.

In other words, our software might have created some extra margin in a situation where fractions of inches and seconds mattered. To be clear, there's no way to know this would have protected us from a collision; if someone's driving too close, they're still very likely to hit us. Our driver was 100% correct in hitting the brakes. But this situation highlights what computers are good at. Our software could do the math on many complicated factors all at once -- pedestrian speed and trajectory, our speed and trajectory, the other vehicle's speed and trajectory. And then it could make an extremely nuanced braking calculation *and* implement a very controlled response, all very quickly. We're putting this down as an officially interesting moment in self-driving car history.

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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 16 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.)

August 20, 2015: A Google Lexus autonomous vehicle ("Google AV") operating in autonomous mode and traveling northbound on Shoreline Blvd. in Mountain View in lane two (the second of three lanes) was involved in an accident. As the Google AV approached the intersection of Shoreline Blvd. and High School way, a pedestrian began to cross the northbound lanes of Shoreline Blvd. in the crosswalk traveling westbound. The Google AV slowed to yield as it approached the crosswalk, and out of an abundance of caution the Google AV test driver disengaged the autonomous technology and took control of the vehicle. A vehicle in lane three to the immediate right of, and traveling in the same direction as, the Google AV was already stopped and yielding the right of way to the pedestrian. A vehicle in the process of changing lanes from lane one into lane two and approaching from the rear struck the Google AV. The Google AV was travelling 5 mph at the time of impact, and braking to stop for the crosswalk. The other vehicle was travelling approximately 10 mph at the time of impact.

The Google AV test driver reported minor back pain and was taken to a local hospital by Google employees, where he was evaluated and released by medical staff. The Google AV co-test driver did not report any injuries. The Google AV sustained minor damage to its rear left bumper. The other vehicle sustained moderate damage to its front end and was towed from the scene. The driver of the other vehicle did not report any injuries at the scene.

What we've been reading

- Crain's Detroit Business, "Autonomous cars will crash and be hacked...and that's ok," August 2015
- Vox, "Why Google's Self-Driving Cars Will Be Great for Cyclists and Pedestrians," August 2015
- Fast Company: This Cute Simulation Proves Why We Need Driverless Cars, August 2015
- AP, "High Tech Cars Bring Detroit, Silicon Valley Face to Face," August 2015
- Washington Post, "As Self-Driving Cars Come to More States, Regulators Take a Back Seat," August 2015