What Is the Future of Self-Driving Cars?

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The Future of TECHNOLOGY

Contents

Important Events in the Development of Self-Driving Cars

1939
At the World's Fair in New York, General Motors presents a model of a futuristic 1960 city, complete with self-driving cars.

1977
Japanese engineer Sadayuki Tsugawa builds an intelligent car with a computer that allows it to ride along a rail without a driver.

1979
Hans Moravec at the Stanford University Artificial Intelligence Laboratory uses a computer to make a cart (the Stanford Cart) travel across a room on its own.

1995
A self-driving Pontiac minivan created by Carnegie Mellon researchers travels from Washington, DC, to San Diego, California.

1940 1950 1960 1970 1980 1990

1956
A General Motors promotional film portrays a family speeding along a track highway in a self-driving car.

1986
German engineer Ernst Dickmanns tests a self-driving van guided by cameras and sensors.

1991
Dean Pomerleau, a roboticist at Carnegie Mellon University, modifies a Chevy van with a video camera and laser range finder; using a computer, Pomerleau "teaches" the van to drive.

1995
A Mercedes-Benz that Dickmanns equips with cameras, sensors, and microprocessors drives nearly 1,000 miles (1,609 km) from Munich, Germany, to Copenhagen, Denmark, without a human steering or operating the gas.

Introduction

The Driverless Car

From Theory to Application

Self-driving cars, also known as autonomous cars, driverless cars, or robot cars, are vehicles that can steer, brake, and carry passengers from one place to another—all without human intervention. To drive themselves, cars must use a combination of technologies. Sensors such as video cameras, light detection and ranging, and radar capture information about the car's position relative to objects around it. They help the car stay within its lane, detect traffic lights and stop signs, and avoid other vehicles and pedestrians. Global positioning system (GPS) software provides a map that helps the car travel along its route and reach its destination. A computer in the car's trunk gathers all the information from these sensors and sends directions to operate the steering wheel, gas, and brakes. A set of instructions or rules, called algorithms, help the car make decisions in much the same way a human driver would.

In Las Vegas, Nevada, a gray Audi A7 pulls into the entrance of the Mandarin Oriental hotel parking garage, stops, and turns off. A woman steps out of the car. She pulls out her smartphone and touches a box on the screen marked *Park*. Inside the car, the dashboard controls light up. A monitor pops up from the dash. As the woman turns to leave the garage, the car's ignition turns back on. The Audi drives into the garage with no one in the driver's

seat, its steering wheel turning as if by some unseen force. The car navigates its way to an open spot in the garage and backs in perfectly. Then the car turns itself off. When the woman returns to the parking garage a short time later, she presses *Pickup* on her cell phone. The car's lights pop on, and the engine roars back to life. The Audi pulls out of the spot and drives itself back to where the woman is waiting at the garage entrance.

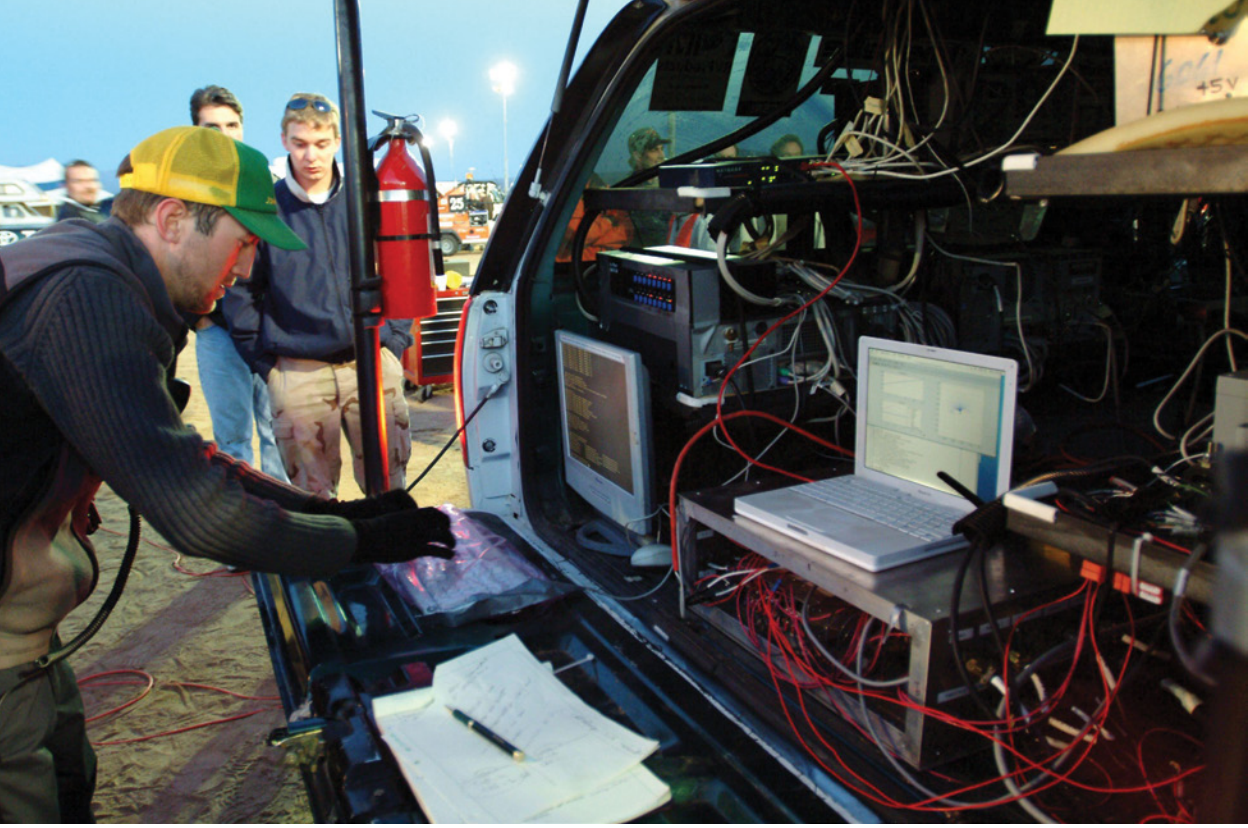
What appeared to be a magic trick—a car parking itself in a garage—was actually the display of a very real technology. Audi was showcasing its new autonomous parking system, called Piloted Parking, for visitors to the 2013 Consumer Electronics Show. The so-called magic behind this self-parking marvel were sensors Audi had placed around the car. These sensors helped the car find its way around the garage and find an open space. Wi-Fi and lasers in the garage helped the car navigate. A computer in the car gathered the information its sensors received and quickly analyzed them to make driving decisions like a human driver. The computer gave directions to operate the steering wheel, gas pedal, brakes, and shifting and get the car where it needed to go—no human needed. After seeing Audi's self-parking feature in action, a *Car and Driver* magazine reporter called it "nothing short of astounding."[1]

WORDS IN CONTEXT

algorithm
A set of rules a computer follows to perform a task or series of tasks.

The Future of Today

Cars that drive themselves might seem like an idea straight out of a science fiction movie. Yet the technology needed for cars to steer through traffic, avoid other vehicles and pedestrians, and carry passengers safely to their destinations is here, and it has been developing for decades. The first ideas for self-driving cars were hatched in the early part of the twentieth century. These visions of autonomous cars relied more on the road they drove on than on the cars themselves. Imaginative engineers of the 1930s proposed cars that could ride driverless down a track-like road, guided to their destination by radio signals from a control tower.



A member of the Caltech team updates his computer and GPS systems on the morning of the DARPA Grand Challenge. The 2004 race across the Mojave Desert involved fifteen teams competing to see if their driverless vehicles could navigate the terrain and other obstacles.

waypoints, along the route. GPS is a satellite-based navigation system run by the US military that tracks a vehicle's exact location by measuring the time it takes a satellite signal to travel to and from that vehicle. Today's car navigation systems use GPS to help drivers get to their destinations. The DARPA teams used the GPS waypoints to program their vehicles to navigate the route.

On March 13, 2004, the fifteen autonomous vehicles drove off across the desert, trailed by chase vehicles in case they went off course. What started with big fanfare ended in big disappointment. None of the entrants got very far. Seven of the vehicles broke down within a mile of the starting line. Some of the computers couldn't properly analyze the information coming in from the sensors and got confused by the terrain. The team from the California Institute of Technology barely passed the mile mark before its Chevy Tahoe careened through a fence. The Golem Group, a team of engineers

from Southern California, made it 5.2 miles (8.3 km) before getting stuck trying to ascend a steep hill. Carnegie Mellon University's Humvee drove the farthest—7.4 miles (12 km)—before its front wheels slipped off the side of a mountainous curve and burst into flames.

Each entrant in the race had its own design drawbacks that kept it from reaching the finish line. "Some of the vehicles were able to follow the GPS waypoints very accurately; but were not able to sense obstacles ahead," comments Tom Strat, deputy program manager for the DARPA Grand Challenge. "Other vehicles were very good at sensing obstacles, but had difficulty following waypoints or were scared of their own shadow, hallucinating obstacles when they weren't there."[7]

WORDS IN CONTEXT

global positioning system (GPS) A satellite-based navigation system that determines a vehicle's position by measuring the time it takes a signal to bounce from the satellite to the vehicle and back.

Though the first challenge seemed like a failure, DARPA considered it a success. "We are an agency that takes risks, to push technology beyond what anybody thinks is possible," said Strat. "Even though nobody got more than about 5 percent of the way through the course, this has made these engineers even more determined."[8] Those engineers had a chance to learn from their mistakes and refine their vehicles for the next DARPA Grand Challenge, which would come just one year later.

DARPA Challenge—Take Two

Undeterred by the failure of any self-driving vehicle to reach the finish line in its first challenge, DARPA issued a second challenge in 2005. This time the agency doubled the prize to $2 million. This race ran a 132-mile (212 km) loop that started and ended in Primm, Nevada. The course was even harder than the previous year, with more twists and turns and narrower roads.

Almost two hundred teams signed up for the second DARPA challenge. Through a series of qualifying trials, DARPA narrowed the field down to around forty teams. Twenty-three of them made it into the final race.

Chapter 3

Developing the First Self-Driving Car

Google—the search engine more than 2.5 billion people now use each day—started from a meeting of minds. Computer science students Larry Page and Sergey Brin met in 1995 at Stanford University in Palo Alto, California. Two years later they registered the domain name *Google*. The name plays off the word *googol*—a math term that represents the number one followed by one hundred zeros. The name reflected their goal—to create a search engine that could retrieve a virtually limitless supply of information across the web.

Over the years Google expanded its capabilities beyond basic search and retrieval. It began to offer images and videos, an e-mail service called Gmail, and the translation of text into many languages. In 2003 Page became interested in capturing images of the country at street level. He strapped a camera onto his car and took pictures around the San Francisco area. Then he sent those images to computer graphics expert Marc Levoy, who wrote a program that assembled the pictures into a simulated street view.

In 2005 Google vans equipped with panoramic cameras began capturing images from around the country to create a virtual map. The technology, called Street View, allowed people sitting at home on their computers to see 360-degree images of streets, homes, and businesses in other cities and eventually in other countries. The company added Street View to its Google Maps service, which also included detailed maps and driving directions. By 2007 Street View was available in five cities—New York, San Francisco, Las Vegas, Miami, and Denver. Today Street View lets people virtually drive down streets in more than fifty countries

An Audi Climbs Pikes Peak

Pikes Peak soars above central Colorado at an elevation of 14,114 feet (4,301 m). A steep and twisting 12.4-mile (20 km) mountain road takes visitors nearly all the way to the summit. In November 2010 an Audi TTS made the drive to the top of Pikes Peak in twenty-seven minutes. The time wasn't particularly fast. What made the trip special was that the car reached the mountaintop without a driver behind the wheel.

The Pikes Peak run was a test of self-driving technology—a partnership between Audi, scientists at Stanford University (designers of Stanley, winner of the 2005 DARPA challenge), and Volkswagen's Electronics Research Laboratory in Palo Alto, California. "We are not trying to replace the driver," Stanford professor Chris Gerdes said of the test. "Instead, we want to learn how the best drivers control the car so we can develop systems that assist our robotic driver and, eventually, you and me." After reaching the top of Pikes Peak, the engineers planned to do more tests of self-driving technology at ground level. "The goal is to improve driver safety and save lives by creating extremely robust electronics," said Burkhard Huhnke, director of the Electronics Research Laboratory.

Quoted in Chuck Squatriglia, "Audi's Robotic Car Climbs Pikes Peak," *Wired*, November 19, 2010. www.wired.com.

around the world. It also served as the foundation for Google's next ambitious project.

How to Solve a Big Problem

When Page and Brin founded Google, their goal was to use technology to solve big problems, which they called *moon shots*. The term refers to the *Apollo 11* mission, which in July 1969 was the first spaceflight to land humans on the moon. To develop these moon shot technologies, Google's founders created a semisecret project called Google X.

One of the biggest problems that concerned Page and Brin was car safety and efficiency. In 2008 alone, 5.8 million vehicle accidents killed more than thirty-four thousand people in the United States. They were also worried about the amount of polluting

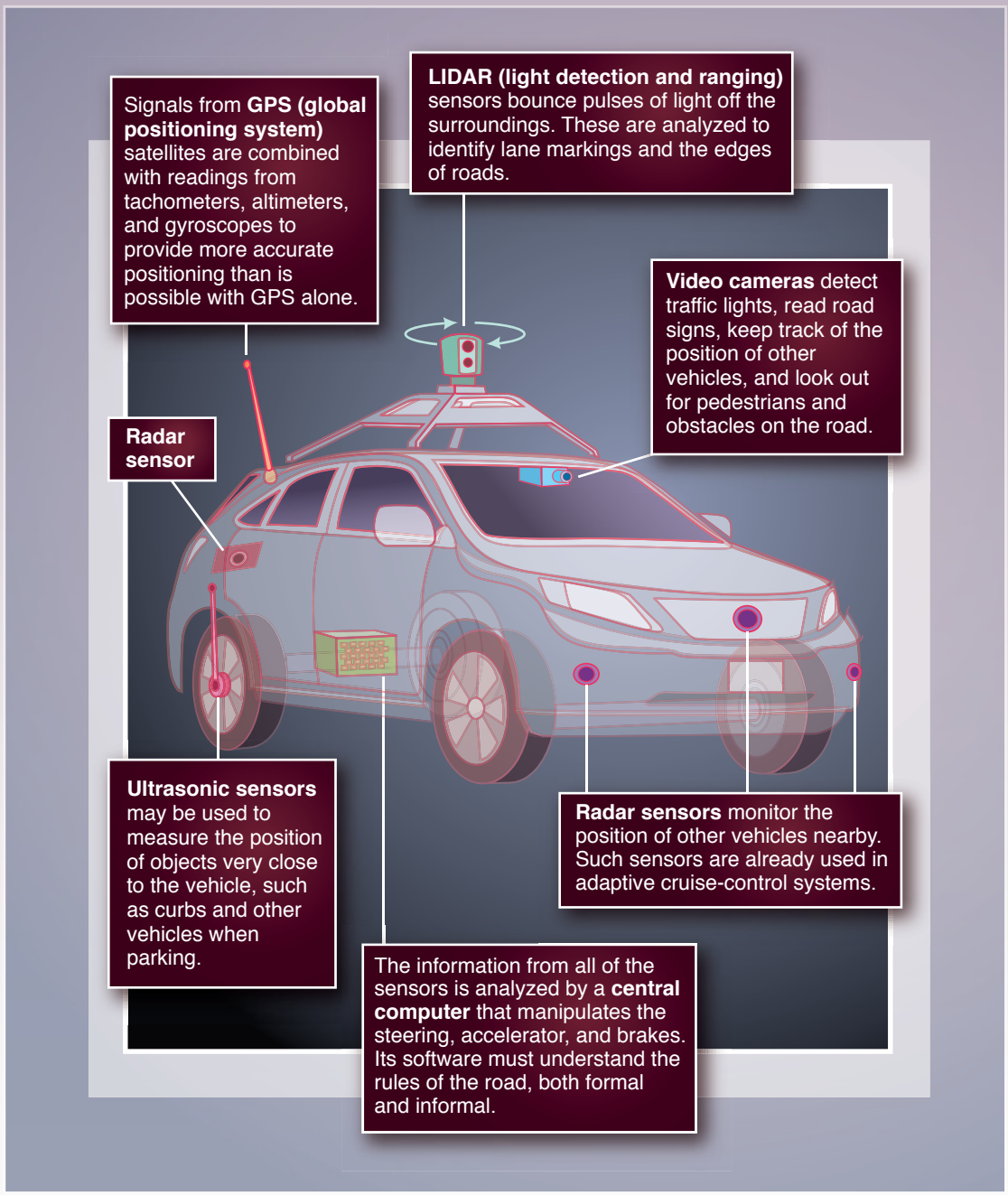
lasers, and a 3-D map of the San Francisco waterfront. They called their car a Pribot.

On September 7, 2008, as Levandowski and the show's producers watched from a chase truck, the Pribot drove through San Francisco's streets and crossed the Bay Bridge, its steering wheel turning on its own. The event went off without a mishap until the Pribot tried to make the sharp off-ramp turn onto Treasure Island and a navigation misjudgment wedged it against a concrete wall. Though the drive wasn't a complete success, it proved to the Google team that a self-driving car could pilot itself through a city. The next step would be to take the technology used in the Pribot and DARPA challenges, add them to Google's existing Street View and mapping navigational capabilities, and develop a practical self-driving vehicle for consumers.

The First Two Hundred Thousand Miles

Google started by modifying existing vehicles. Its hardware and software engineers outfitted a few Toyota Priuses with cameras, lasers, and radar, in configurations based on what they had learned during the DARPA challenges. (Google chose Priuses for their light weight and fuel efficiency.) LIDAR mounted on the roof created a highly detailed 3-D map of the area around each car. Radar devices mounted on the front and rear bumpers kept the cars at a safe distance from other vehicles in front of and behind them. GPS on the roof helped the cars pinpoint their exact locations. A computer in the trunk combined all of the views collected and analyzed the data. Software categorized objects around the car by their size and movement—a person or squirrel, a pothole or skateboarding child. It quickly analyzed and responded to that information to pilot the car in the right direction at a safe speed. "We're analyzing and predicting the world 20 times a second,"[16] Levandowski said. A reporter who took a test-drive in one of Google's early self-driving vehicles remarked, "It is absolutely fascinating, almost illicitly thrilling, to watch as the car not only plots and calculates the myriad movements of neighboring vehicles in the moment but also predicts where they will be in the future, like high-speed, mobile chess."[17]

How a Self-Driving Car Works



Source: Economist, "How Does a Self-Driving Car Work?," April 29, 2013. www.economist.com.

Source Notes

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