



Self-Driving Cars: What Can We Realistically Expect?

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Self-Driving Cars: What Can We Realistically Expect?

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Abstract

Popular media have made many predictions about the dramatic changes self-driving cars (SDCs) will eventually bring about in society. Some prominent people working in the field worry that these predictions grossly overstate what can reasonably be expected of SDCs and may discredit the entire field when SDCs fail to meet expectations. Despite this concern, these researchers believe that SDCs will eventually prove their worth but probably not in the form and certainly not as soon as the media say. This paper draws on the comments and writings of these researchers to identify over a dozen problems in SDC development that have not yet been solved. The problems include not just technical issues such as the adequacy of machine learning, software validation, hardware reliability, cybersecurity, and the lack of adequate testing, but also matters non-technical as public fears about SDCs' lack of safety and questions of insurance and liability. The paper concludes by suggesting a future consisting of slow, incremental improvements in SDCs over many years. The radical changes in society that have been predicted in the media may never be achieved, but SDCs may result in the saving of the lives of many people who would have otherwise perished in automobile accidents.

Acronyms

ADAS	Advanced Driver Assistance System
ADS	Automated Driving System
AI	Artificial Intelligence
GMO	Genetically Modified Organism
GPS	Global Positioning System
ML	Machine Learning
NASA	National Aeronautics and Space Administration
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
ODD	Operational Design Domain
SAE	Society of Automotive Engineers
SDC	Self-Driving



Figure 1. A self-driving car on the road in Mountain View, California

1. Introduction

We're still very much in the early days of making self-driving cars a reality. Those who think fully self-driving vehicles will be ubiquitous on city streets months from now or even in a few years are not well connected to state of the art or committed to the safe deployment of the technology. For those of us who have been working on the technology for a long time, we're going to tell you the issue is still really hard, as the systems are as complex as ever. – Bryan Salesky, CEO of artificial intelligence startup Argo AI [1]

Figure 1 shows an iconic image of a “self-driving car” (SDC). The notion of an SDC has caught the public’s fancy, and popular media are full of articles describing how our lives will be dramatically changed by the widespread use of SDCs. However, many of the more thoughtful people working in SDC development have been bothered by the excessive media attention and the accompanying gross exaggerations of future SDC capabilities. These researchers fear that the entire field may be discredited when the public realizes SDCs cannot live up to the extreme claims that have been made. Gill Pratt, Executive Technical Advisor and CEO of the Toyota Research Institute, expressed this concern succinctly:

I think there's a general desire from the technical people in this field to have both the press and particularly the public better educated about what's going on. It's straightforward to get misunderstandings based on words or phrases like "full autonomy." What does full mean? This matters a lot: The idea that only the chauffeur mode of autonomy, where the car drives for you, is the only way to make the car safer and to save lives, that's just false [2].

The purpose of the present paper is to acquaint readers with what prominent researchers in the field think about the prospects of SDCs. Almost all of these researchers believe that SDCs will eventually prove their worth but probably not in the form—and indeed, not in the timeframe—the media have predicted.

2. The Promise of Self-Driving Cars

However, and this may sound a little complacent, I almost view [a self-driving car] as a solved problem. We know correctly what to do, and we'll solve it in a few years. – Elon Musk, founder of Tesla, Inc. [3]

Mechanical engineering professor and artificial intelligence researcher John Leonard told an audience ... at Harvard University that Tesla Motors founder Elon Musk's declaration of self-driving cars as "a solved problem" was more than a little optimistic. "Just very respectfully, I disagree," Leonard said. [4]

In recent years, various companies have made substantial investment bets on the potential for SDCs. For example, several years ago in a court filing, Google inadvertently revealed that it had spent \$1.1 billion on SDC research and development between 2009 and 2015 [5]. In March 2016, General Motors paid a billion dollars to buy a company involved in developing SDC technology, and in February 2017, Ford announced plans to spend a billion dollars on setting up a joint venture with Argo AI, a startup run by two prominent engineers having extensive experience in artificial intelligence and robotics [6]. An even more substantial acquisition was Intel's \$15.3-billion purchase of Mobileye, an Israeli company developing camera-based guidance for SDC navigation. In early 2015 the ride-sharing company Uber hired forty researchers away from Carnegie Mellon's National Robotics Engineering Center—which had somewhat more than one hundred technical personnel before the raid—by offering them hundreds of thousands of dollars in bonuses and a doubling of salaries to work on SDC technology [7]. These companies have concluded that SDCs will play a significant part in the future of transportation. However, they are not alone. Other large SDC projects are underway at Daimler-Bosch, Volkswagen, BMW-Intel-FCA, Aptiv, Renault-Nissan Alliance, Volvo-Autoliv-Ericsson-Zenuity, PSA, and dozens of other firms both large and small.

Just what is it about the future of SDCs that causes companies to invest billions of dollars in research and development? One apparent reason is the fear of being left behind. Ride-sharing companies that use robotaxis would have no drivers to pay and thus could charge much lower prices than companies with drivers. Long-distance trucking companies could cut costs dramatically if self-driving trucks were developed. Automakers producing SDCs might dominate the market for personal cars if SDCs turn out to be as popular as many people forecast.

Thus many companies see SDCs as a potential threat to their survival. These companies—and many other observers—also see much promise in improved safety. In 2016, about 37,000 people in the US died in traffic accidents, and the most recent data about accident fatalities worldwide indicates that in 2013 approximately 1.2 million people perished. The harm to US society from the loss of life and injury in traffic accidents is over half a trillion dollars annually. Ninety-four percent of US crashes involve human error, and about two out of three people will be required at some time in their life in an accident in which a driver had been drinking alcohol. By reducing human error and the effect of alcohol on driving, SDCs have the potential to save thousands of lives and reduce the economic loss from traffic accidents [8].

People have pointed out other potential advantages of SDCs. For example, time that people used to consume in operating their cars could instead be devoted to other pursuits such as reading, writing, or watching videos. Mobility would significantly improve or become available to groups in society who had previously lacked it—for example, persons with disabilities or illness, children, the elderly, the poor, and persons who for various reasons never were able to obtain a driver's license. Because accidents would decrease, insurance costs would drop. Automating long-distance trucking would lower costs significantly not only because drivers would not have to be paid but also because trucks could be operated around the clock. The cost of delivering everything from pizzas to packages would drop dramatically, and these lower costs could stimulate the development of new businesses that were previously limited by the loss of getting their products to the consumer. Cars would be designed to accelerate and brake efficiently, and thus fuel would be saved. Speed limits could be raised because self-driving vehicles could be operated safely at higher speeds. Thus travel times would be decreased.

Some commentators have looked far into the future to imagine a world in which *all vehicles were driverless* and driven by human beings would be made illegal (because human drivers would be too dangerous compared to SDCs). Transportation by automobile would be treated as a service provided by a transportation utility company, and people would have no more need to have their car than people today need their electricity generator.

