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SHOULD WE REQUIRE LICENSING TESTS AND GRADUATED LICENSING FOR SELF-DRIVING VEHICLES?

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16. Abstract

This white paper examines whether self-driving vehicles should be subjected to a licensing test as people are, and if so, whether the licensing process should be analogous to the current graduated driver licensing (GDL) systems for novice young drivers.

There are several arguments in support of the need for self-driving vehicles to pass a licensing test that would allow them to operate in all driving situations:

(1) Sensing hardware, spatial maps, and software algorithms will vary among manufacturers of self-driving vehicles, resulting in variability of on-road performance—as is the case with humans.
(2) Visual and sensing performance of self-driving vehicles in inclement weather is not yet sufficient.
(3) Visual-pattern recognition is a potential problem for current sensing systems in self-driving vehicles.
(4) Current self-driving vehicles have not yet been tested thoroughly under a variety of demanding conditions (e.g., in snow).
(5) On-road performance of some current self-driving vehicles is not yet perfect, even in good weather.
(6) Self-driving vehicles will face, on rare occasions, ethical dilemmas in their decision-making.

For self-driving vehicles, in contrast to novice human drivers, experience under one set of conditions that requires certain hardware or software capabilities does not improve performance under a different set of conditions that requires different hardware or software capabilities. Thus, the underlying logic for the use of GDL systems with novice young drivers does not apply to self-driving vehicles: A self-driving vehicle either has the hardware and software to deal with a particular situation, or it does not. If it does not, experience in other situations will not be of benefit.

On the other hand, the GDL approach would be applicable should a manufacturer explicitly decide to limit the operation of its vehicles to certain conditions, until improved hardware or software become available. For example, a manufacturer might feel confident that its vehicles could handle all situations except nighttime and snow. In such a situation, after passing a licensing test related to the limited conditions, the vehicle would be given a provisional license that would exclude nighttime driving and driving in snow. A full license could then be obtained once future updates to hardware or software are developed and made available, and the updated vehicle passes an unrestricted licensing test.

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Introduction

In the United States, a person cannot legally drive unless he or she has passed a driver-licensing test. Furthermore, in all U.S. jurisdictions (i.e., states), full driving privileges for a young person can be obtained only through a so-called graduated driver licensing system, in which the person must pass, without a major failure, through progressively more demanding driving conditions. In this white paper, we will examine whether self-driving vehicles should be any different, given that the sensing hardware, spatial maps, and software algorithms will likely vary among manufacturers.

Rationale for and implementations of current driver-licensing tests and graduated driver licensing

Driver-licensing tests

Most driver-licensing tests evaluate the following three aspects of driving readiness: visual performance, knowledge of rules and regulations related to driving and traffic in general, and driving-related psychomotor skills. The reasons for the need to test prospective drivers are that (1) vision is essential for driving (Sivak, 1996), (2) driving and traffic laws and regulations need to be learned and followed, (3) driving-related skills need to be acquired through practice, and (4) people differ in performance for all of the above aspects. The evaluation of visual performance and driving-related knowledge is made indoors under static conditions, while the evaluation of driving-related skills is performed in actual driving.

Graduated driver licensing (GDL) systems

GDLs are designed to provide gradual immersion into progressively more challenging driving situations. Typically, these systems include the following three phases: (1) driver's permit, which allows supervised driving only, (2) restricted license, and (3) full license. For example, most states do not allow any cell-phone use with a restricted license—only when the full license is achieved (Governors Highway Safety Association, 2015). The logic here is that the distraction from using cell phones is easier to handle once psychomotor performance requires less conscious attention. Similarly, driving alone at night—under more challenging visual conditions—is also generally restricted to those with a full license, after successfully negotiating daytime driving for some duration.

Visual performance[1]

The following sections related to visual performance for self-driving vehicles assume that all necessary sensors are kept clean and in good working order.

Vision in good weather

Most current driver-licensing tests include an evaluation of visual acuity in good ambient conditions. Computer vision systems aboard self-driving vehicles should have no problems passing even a strict visual-acuity test.

Vision in inclement weather

Visual performance of self-driving vehicles in inclement weather is currently a problem. For example, a Google spokesperson was quoted recently as saying that Google "doesn't intend to offer a self-driving car to areas where it snows in the near term" (Trudell, 2015). Furthermore, even rain can be a problem for some current prototype systems (Sutherland, 2015).

Visual-pattern recognition

Computer vision has difficulty with pattern recognition—a skill that humans excel at but current computers do not. That is why many websites use CAPTCHAs (Completely Automated Public Turing tests to tell Computers and Humans Apart) to prevent computers from automatically accessing websites (CAPTCHA, 2015).

The existence of CAPTCHAs is evidence for the need to test visual pattern recognition of computer systems designed to guide self-driving vehicles. Two examples of potentially difficult conditions for a computer are shown in Figure 1 (downed power line) and Figure 2 (flooded roadway).

Pattern recognition is currently not being tested in any U.S. jurisdictions, presumably because all humans are skilled in that area. However, given that computer-vision systems have difficulties with pattern recognition, and pattern recognition is important in driving, self-driving vehicles need to perform as well as humans in this respect.

[1] The discussion in this section applies not only to camera-based vision systems, but also to other types of sensing and object-detection systems (e.g., LIDAR).

Figure 1. An example of a difficult pattern-recognition task for a computer: Downed power line. (Photo: U.S. Air Force/Tech. Sgt. Brian Ferguson.)

Figure 2. An example of a difficult pattern-recognition task for a computer: Flooded roadway. (Photo: © Chris Talbot.)

Driving and traffic laws and regulations

Programming all driving and traffic laws and regulations into an onboard computer should be relatively easy. In principle, all that needs to be done is to program the complete set of laws and regulations that are contained in any state's booklet for prospective drivers (e.g., Michigan Department of State, 2014). (To the extent that state laws and regulations are not identical, all 50 sets of laws and regulations would have to be programmed. The vehicle would presumably know, through GPS, which state it is in.)

Indeed, the problem here might not be disobeying appropriate laws and regulations. Instead, the problem might be just the opposite: Self-driving vehicles may follow the letter of the law too strictly, compared to what people typically do (Richtel and Dougherty, 2015). Let us consider two examples. The first example comes from Visnic (2015). He points out that "merging at the speed limit onto a highway of cars zipping past at well over the speed limit is just plain dangerous." The second example is from Knight (2015): "Another clip…showed the first time one of Google's cars encountered a traffic roundabout, when it decided the safest thing to do was to keep going around," presumably because of the aggressive behavior of other traffic participants. Other examples of traffic-law violations by human drivers include going over the speed limit by a few miles per hour, performing rolling stops at stop signs, and leaving less-than-recommended spacing between vehicles.

Consequently, the newest versions of self-driving software attempt to make vehicles "drive more like humans" (Barr and Ramsey, 2015). This is achieved, for example, "by cutting corners, edging into intersections and crossing double-yellow lines" (Barr and Ramsey, 2015).

The fact that human drivers are relatively lax about many relevant laws and regulations creates a real quandary: Should manufacturers be allowed to program a vehicle to willfully break applicable laws? If so, which laws and to what extent? A related question—one which is connected to the main issue of this paper—is as follows: If, eventually, there would be testing procedures for self-driving vehicles, would one pass by obeying the laws or by disobeying the laws?

Evaluating driving-related skills

Current prototypes of self-driving vehicles are not perfect. For example, some of them occasionally cross the centerline on curves even in good weather conditions, and do so not by design (e.g., Visnic, 2015).

Furthermore, it is unclear under what conditions self-driving vehicles have been tested thus far by their manufacturers. For example, the route for the only coast-to-coast trip to date using a self-driving vehicle avoided mountainous driving. This trip required about 1% of the distance (34 miles out of 3,400 miles) to be driven by a human driver (Durbin, 2015). It would be instructive to know what the conditions were that required a switch from an autonomous mode to human driving.

In the same vein, how much of the 1.2 million miles accumulated by Google vehicles was during nighttime and on limited-access roadways? Furthermore, all of the publicly disclosed mileage of the Google cars was accumulated in and near Mountain View, California, and Austin, Texas—two areas for which Google has developed detailed maps. Consequently, using Google's approach of relying extensively on detailed maps raises the issue of performance on roads that might never be mapped in detail, such as private roads, private parking structures, off-road areas, etc.

On rare occasions, self-driving vehicles will face ethical dilemmas of having to choose the lesser of two evils (e.g., Newcomb, 2015). (An example is being forced to decide between two inevitable crashes that involve different participants.) It would be desirable if the resolutions of such ethical dilemmas were consistent with societal norms, as is hopefully the case with human drivers.

Graduated driver licensing

As pointed out above, GDL systems are designed to expose novice drivers to progressively more challenging driving situations. The reasoning is that, for human drivers, driving experience under relatively easy conditions improves the readiness for challenging conditions. Let us consider three examples of challenging situations to see whether the logic behind GDLs would be applicable to self-driving vehicles as well: speaking on a cell phone while driving, nighttime driving, and driving in inclement weather.

Cell-phone prohibition for novice young drivers is intended to assure that, during the early phases of mastering basic psychomotor skills, the entire attentional capacity is available for driving. As one accumulates driving experience, good psychomotor performance becomes more automatic. However, for self-driving vehicles, attentional limitation is not an issue, even during the first mile of travel.

For self-driving vehicles, experience with daytime driving does not improve nighttime performance. Instead, good nighttime performance requires everything that good daytime performance does, plus sensors that provide the necessary information even at low levels of illumination. Thus, the GDL approach would not be appropriate here either.

Analogously, experience in good weather will not, by itself, improve the performance of a self-driving vehicle in inclement weather. Therefore, the GDL approach would not be applicable here either.

These three examples indicate that the logic behind GDL systems does not fit self-driving vehicles. This is the case because a given self-driving vehicle implementation either has the capability to deal with a given situation (e.g., nighttime driving) or it does not. Exposure to a nominally similar but easier situation—but one that depends on, for example, different sensor capabilities (such as those involved in daytime driving)—would not be of benefit to nighttime driving. In other words, a self-driving vehicle either has the hardware and software to deal with a particular situation, or it does not. If it does not, experience in other situations will not be of benefit if the other situations demand different hardware or software capabilities. (These arguments are not inconsistent with the fact that machine learning is essential in the development of successful self-driving vehicles [Madrigal, 2014].)

Conclusions

This white paper examined whether self-driving vehicles should be subjected to a licensing test as people are, and if so, whether the licensing process should be analogous to the current graduated driver licensing systems for novice young drivers.

Licensing test: unrestricted license

There are several arguments in support of the need for self-driving vehicles to pass a licensing test that would allow them *to operate in all driving situations*:

- Sensing hardware, spatial maps, and software algorithms will vary among manufacturers of self-driving vehicles, resulting in variability of on-road performance—as is the case with humans.
- Visual and sensing performance of self-driving vehicles in inclement weather is not yet sufficient.
- Visual-pattern recognition is a potential problem for current sensing systems in self-driving vehicles.
- Current self-driving vehicles have not yet been tested thoroughly under a variety of demanding conditions (e.g., in snow).
- On-road performance of some current self-driving vehicles is not yet perfect, even in good weather.
- Self-driving vehicles will face, on rare occasions, ethical dilemmas in their decision-making.

Graduated-licensing approach: restricted license

For self-driving vehicles, in contrast to novice human drivers, experience under one set of conditions that requires certain hardware or software capabilities does not improve performance under a different set of conditions that requires different hardware or software capabilities. Thus, the underlying logic for the use of GDL systems with novice young drivers does not apply to self-driving vehicles: A self-driving vehicle either has the hardware and software to deal with a particular situation, or it does not. If it does not, experience in other situations will not be of benefit.

On the other hand, the GDL approach would be applicable should a manufacturer explicitly decide to limit the operation of its vehicles to certain conditions, until improved hardware or software become available. For example, a manufacturer might feel confident that its vehicles could handle all situations except nighttime and snow. In such a situation, after passing a licensing test related to the limited conditions, the vehicle would be given a provisional license that would exclude nighttime driving and driving in snow. A full license could then be obtained once future updates to hardware or software are developed and made available, and the updated vehicle passes an unrestricted licensing test. (An example of such a software update for certain autonomous functions on a conventional vehicle is the recent Autopilot software update for Tesla vehicles [Kessler, 2015].)

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