Autonomous Cars

Jason Danker

Overview

Automation in cars is nothing new, automatic transmissions and cruise control have been around since 1939[1] and 1958[2] respectively, but these systems serve to aid, rather than replace, human drivers. What is new, is a near future potential for fully autonomous cars, cars that are capable of full operation without an attending human driver.

While other vehicles, such as people movers, have been capable of fully automatic operation since 1967[3], these vehicles have the luxury of operating in closed environments and only need to be able to respond to a defined set of inputs. Autonomous cars do not have this luxury. In operating 'in the wild,' the systems guiding these cars may be forced to respond to any number of unanticipated situations. As the automation system cannot enumerate all possible situations, it must instead rely on continuous organization of its operating environment.

This is clearly a technical challenge, but it also raises ethical and legal issues. As autonomous cars act based on the organization of sensory inputs, the organizing systems are necessarily imbued with ethical considerations. At the most basic level, the organizing system will direct the autonomous car in making decisions analogous to those posited in the trolley problem.[4] Beyond ethics, autonomous cars also raise legal questions: if an autonomous car crashes, who is liable for the damages?

What is being organized?

An autonomous car will organize information about the car itself, the objects in its vicinity, and environmental conditions. The car must keep track of its movements, those of other objects, and the relative positions between itself and the other objects. It must organize this information within the environmental framework of lane markings, speed limits, road signs, traffic signals, weather and traffic conditions, and numerous other constraints. As autonomous cars become common, the cars will likely communicate with one another and this information will also need to be brought into the organizing system. The car will also need to organize, and likely prioritize, inputs from a human 'driver.' Regardless of the exact implementation, the organizing system will necessarily limit what is worthy of organization: it is likely not possible, or desirable, to keep track of every insect in the vicinity of the car.

Why is it being organized?

The car organizes its surroundings in order to safely navigate to a destination. While this is the primary interaction enabled by the organization, countless other interactions support this primary interaction. The supporting interactions fall into the two categories of prediction and reaction. The systems being developed by Google use the information that has been organized to predict what is most likely to happen next: 'It predicts that the cyclist will ride by and the pedestrian will cross the street.'[5] The systems that have been launched by Tesla tend to be more reactionary: 'Side Collision Warning further enhances Model S's active safety capabilities by sensing range and alerting drivers to objects, such as cars, that are too close to the side of Model S.'[6]

How much is it being organized?

The extent of organization varies based on the implementation. While Google[7] uses on-board sensors and extremely detailed street maps to implement self-driving functionality, Tesla's Autopilot[8] relies on-board sensors and standard GPS data. While the exact extent of the organization is not publicly available information, Google has publicly stated 'the system is engineered to work hardest to avoid vulnerable road users (think pedestrians and cyclists), then other vehicles on the road, and lastly avoid things that don't move.'[9] Given this, Google's categories, and their hierarchy, appear to be defined by their vulnerability.

When is it being organized?

For information gathered by on-board sensors, organization takes place as objects enter and leave the vicinity of the autonomous car. The organization is ongoing as the car's surrounding and environment are constantly changing. In addition to the sensor data, autonomous cars also rely on map data which is organized in advance. Google's cars rely on specialized, highly detailed maps that are being developed as part of the self-driving car project and, as such, are unable to drive on roads that have not yet been mapped to the necessary level of detail. While Tesla's Autopilot also relies on maps, uses standard GPS maps and is not similarly restricted.

How, or by whom, or by what computational process, is it being organized?

The car's computational processes are responsible for the organization. That said, the car is restricted to organizing within the organizing system implemented by the manufacturer. While Google and Tesla are

two of the main companies in this space, many traditional automotive companies are also developing autonomous systems.

Where is it being organized?

Except for map data, the organization takes place within the car's onboard systems. The organization must take place in the car itself due to the potential catastrophic consequences of a lag in information flow. Additionally, ensuring all organization takes place within the car provides greater security: a self contained car is less susceptible to attack than a network dependent one.

Other Considerations

While it is likely that fully autonomous cars will be technologically feasible within a few years, the cars may still require human interactions for legal reasons. This is clearly seen in Tesla's press release for Autopilot: 'The driver is still responsible for, and ultimately in control of, the car.'[10] This human-in-the-loop design principle creates a legal buffer for autonomous car manufacturers by treating the 'driver' as a 'liability sponge' or 'moral crumple zone.' As articulated by Madeleine Elish and Tim Hwang, 'the human in an autonomous system may become simply a component—accidentally or intentionally—that is intended to bear the brunt of the moral and legal penalties when the overall system fails.'[11]

While these issues will ultimately play out in through a combination of court rulings and policy decisions, it is interesting to note that there is legal precedent that could either blame, or exonerate, the 'driver' of an autonomous car. Drawing parallels to aviation automation, precedent suggests that the human 'driver' will be held responsible for liability claims arising from the operation of the car.[12] On the other hand, product liability law offers recourse for consumers when a company's product fail. Many people has argued that this existing legal framework is sufficient to handle the liability issues brought up by autonomous vehicles.[13]

Regardless of the legal complexities that will arise from specific incidents, autonomous cars have great potential to reduce car crashes and improve overall road safety.[14] The promise of the autonomous technology, even for partially autonomous systems, is so great that the National Highway Traffic Safety Administration is proposing updates to its safety ratings that will penalize manufacturers that don't include autonomous technologies in their vehicles.[15]

[1] "Automatic transmission." *Wikipedia*. Wikimedia Foundation, Inc., 29 Nov. 2015. Web. 11 Dec. 2015.
[2] "Cruise control." *Wikipedia*. Wikimedia Foundation, Inc., 8 Dec. 2015. Web. 11 Dec. 2015.
[3] "People mover." *Wikipedia*. Wikimedia Foundation, Inc., 6 Dec. 2015. Web. 11 Dec. 2015.
[4] For background, see: "Trolley problem." *Wikipedia*. Wikimedia Foundation, Inc., 9 Dec. 2015. Web. 11 Dec. 2015.
[5] "Google Self-Driving Car Project: How it Works." *Google*. Google, n.d. Web. 11 Dec. 2015. <https://www.google.com/selfdrivingcar/how/>.
[6] "Model S Software Version 7.0." *Tesla Motors*. Tesla Motors, n.d. Web. 11 Dec. 2015. <https://www.teslamotors.com/presskit/autopilot>.
[7] Madrigal, Alexis C. "The Trick That Makes Google's Self-Driving Cars Work." *The Atlantic*. Atlantic Media Co., 15 May 2015. Web. 11 Dec. 2015. <http://www.theatlantic.com/technology/archive/2014/05/all-the-world-a-track-the-trick-that-makes-googles-self-driving-cars work/370871/>.
[8] "Your Autopilot has arrived." *Tesla Motors Blog*. Tesla Motors, 14 Oct. 2015. Web. 11 Dec. 2015. <http://www.teslamotors.com/blog/your autopilot-has-arrived>.
[9] "Google chief of self-driving cars downplays 'trolley problem.'" *San Francisco Chronicle*. Hearst Corporation, 2 Dec. 2015. Web. 11 Dec. 2015. <http://www.sfchronicle.com/business/article/Google-chief-of-self-driving-cars-downplays-6671052.php?t=4cc32ef640>.
[10] "Your Autopilot has arrived." *Tesla Motors Blog*. Tesla Motors, 14 Oct. 2015. Web. 11 Dec. 2015. <http://www.teslamotors.com/blog/your autopilot-has-arrived>.
[11] Elish, Madeleine Clare and Tim Hwang. "When your self-driving car crashes, you could still be the one who gets sued." *Quartz*. Atlantic Media Co., 25 July 2015. Web. 11 Dec. 2015. <http://qz.com/461905/when-your-self-driving-car-crashes-you-could-still-be-the-one-who-gets sued/>.
[12] Elish, Madeleine Clare and Tim Hwang. "Praise the Machine! Punish the Human! The Contradictory History of Accountability in Automated Aviation." *Data & Society Research Institute* (24 Feb. 2015): n. pag. Web. 11 Dec. 2015. <http://www.datasociety.net/pubs/ia/Elish Hwang_AccountabilityAutomatedAviation.pdf>.
[13] For additional information, see:

Autonomous Vehicles Team. "Autonomous Vehicle Law Report and Recommendations to the ULC." *Technology Policy and Law Clinic*. University of Washington (n.d.): n. pag. Web. 11 Dec. 2015. <https://www.law.washington.edu/Clinics/Technology/Reports/AutonomousVehicle.pdf>.

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[14] Stemwedel, Janet D. "Are Self-Driving Cars An Ethical Imperative?" *Forbes*. Forbes, Inc., 7 Aug. 2015. Web. 11 Dec. 2015. <http://www.forbes.com/sites/janetstemwedel/2015/08/07/are-self-driving-cars-an-ethical-imperative/>.
[15] Spector, Mike. "U.S. Proposes Overhaul of Car-Safety Ratings." *The Wall Street Journal*. News Corp, 8 Dec. 2015. Web. 11 Dec. 2015. <http://www.wsj.com/articles/u-s-proposes-overhaul-of-car-safety-ratings-1449603983>.

Autonomous Cars and the Human-in-the-Loop

Jason Danker

While many automotive manufacturers are developing autonomous vehicle technologies, two of the projects furthest along are the Google Self-Driving Car Project and Tesla Autopilot. Though the two firms likely rely on similar underlying technologies and sensory inputs, there is a fundamental difference in the originating intent behind these projects. This difference, which is even apparent in the respective names of the projects, necessarily results in differing organizational and design principles which leads to differing ethical imperatives and legal liabilities.

Starting with the names, it is clear that Google is striving to build a car capable of fully autonomous operation—this is the essence of a self-driving car—a car that does not require any further human inputs once a destination has been specified. Tesla, on the other hand, in naming their product Autopilot, makes clear their system is a tool to assist, as opposed to replace, human drivers.[1] This is not to say that Tesla's ultimate vision is any less ambitious than Google's, but rather that the company is taking a different approach to full automation.

Regardless, the differing approaches of the two projects results in a fundamental difference in the design of the organizing system, namely, the human-in-the-loop principle. This principle 'require[s] that an automated action always include some sort of human input, even if that input is just clicking "OK"…it's meant to theoretically ensure that human judgment can trump automation.'[2] While this principle may primarily be intended as a safeguard, it has significant ethical and legal ramifications.

Whether or not there is a human-in-the-loop determines the extent to which the system must be capable of making sense of its operating environment; that is to say, how much of its environment must the system be capable of organizing and reacting to? The major burden here is on fully autonomous systems such as that being developed by Google. Their autonomous cars, having little to no manual controls, must be capable of reacting to any situation, even if the situation falls outside the scope of the car's organizing system. Due to the complexity of this problem, the team at Google has proposed a simple, if potentially inconvenient to the user, solution: the car will stop moving and wait for the situation to resolve itself.[3] Tesla, on the other hand, has a fallback: the human-in-the-loop. When the system encounters a novel situation, it can pass control back to the human driver.

Given this design difference, what are both the ethical and legal implications? From an ethical standpoint, Tesla is able to bypass the issue altogether: when an ethically ambiguous situation arises, Autopilot will pass control to the driver. In doing so, the ethical implications resulting from the response to the situation are placed on the driver rather than the system or company. In this way, Autopilot may need to be able to identify 'ethical' dilemmas in the environment, but it does not need to determine how to respond to them. Whether or not the driver will actually be in a position to respond will vary based on circumstance, but shifting the burden of control still provides an 'out' for Autopilot.

This is not the case for Google. Without a driver to fallback on, Google's self-driving car will be forced to react to the situation at hand. While the current solution to stop the vehicle works at the low speeds[4] the vehicles are being tested at, it is far from clear that this solution will scale. While I won't enter the debate regarding the utilitarian ethics of fully autonomous cars here, what is clear is that the system must have some way of responding and this response, regardless of its genesis, will have ethical thinking embedded in it.

Legally, there are major differences depending on the whether the implementation as a human-in-the-loop. When there is a human-in-the-loop, such as with Tesla Autopilot, the human is not only a 'moral crumple zone' but also a 'liability sponge' in the event of a car crash or other incident.[5] By reverting control to the driver, the driver is then legally responsible for the ensuing consequences. While there may be some room for the application of product liability law to Autopilot car crashes, legal precedent from the failure of aviation autopilot system overwhelmingly blames pilot-error for the resulting tragedies.[6]

Google will not have this luxury. In removing standard automotive controls from their vehicles, it will be hard, if not impossible, to argue that the human occupants are somehow responsible.[7] As such, is it very likely that Google will be accountable for the actions of its systems. Given this, it is likely that existing product liability law will provide recourse for those adversely impacted by their autonomous cars.

While the end goal of both companies is the same, it is clear that the organizational and design decisions made in the development of autonomous cars have significant ethical and legal ramifications. Yet, in spite of these complications, autonomous cars have great potential to improve overall road safety.[8] Given the promise of greater overall safety, the difference of having, or not having, a human-in-the-loop is

incidental: autonomous technology, regardless of the implementation details, will lead to safer roads than having human drivers be fully in control.

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[1] The difference in approach is likely a reflection of the respective business models of the two companies. A rolling launch of autonomous technologies will help drive car sales for Tesla while Google's revenue streams are, for all practical purposes, wholly independent of their self-driving car project.

[2] Elish, Madeleine Clare and Tim Hwang. "When your self-driving car crashes, you could still be the one who gets sued." *Quartz*. Atlantic Media Co., 25 July 2015. Web. 11 Dec. 2015. <http://qz.com/461905/when-your-self-driving-car-crashes-you-could-still-be-the-one-who-gets sued/>.

[3] Knight, Will. "Google's Self-Driving-Car Chief Defends Safety Record." *MIT Technology Review*. Massachusetts Institute of Technology, 22 July 2015. Web. 11 Dec. 2015. <http://www.technologyreview.com/news/539611/googles-self-driving-car-chief-defends-safety-record/>.

[4] Harris, Mark. "When a robot car makes a mistake, a human always gets the ticket." *The Guardian US Edition*. Guardian Media Group, 14 Nov. 2015. Wed. 11 Dec. 2015. <http://www.theguardian.com/technology/2015/nov/14/when-a-robot-car-makes-a-mistake-a-human-always gets-the-ticket>.

[5] Elish, Madeleine Clare and Tim Hwang. "When your self-driving car crashes, you could still be the one who gets sued." *Quartz*. Atlantic Media Co., 25 July 2015. Web. 11 December 2015. <http://qz.com/461905/when-your-self-driving-car-crashes-you-could-still-be-the-one-who-gets sued/>.

[6] Elish, Madeleine Clare and Tim Hwang. "Praise the Machine! Punish the Human! The Contradictory History of Accountability in Automated Aviation." *Data & Society Research Institute* (24 Feb. 2015): n. pag. Web. 11 Dec. 2015. <http://www.datasociety.net/pubs/ia/Elish Hwang_AccountabilityAutomatedAviation.pdf>.

[7] While purely speculation, it may be determined that the owner of a vehicle is liable for any eventualities arising from the use of the vehicle. However, this may be complicated by separate issues regarding licensing, versus ownership, of the car's operating software.

[8] Stemwedel, Janet D. "Are Self-Driving Cars An Ethical Imperative?" *Forbes*. Forbes, Inc., 7 Aug. 2015. Web. 11 Dec. 2015. <http://www.forbes.com/sites/janetstemwedel/2015/08/07/are-self-driving-cars-an-ethical-imperative/>.