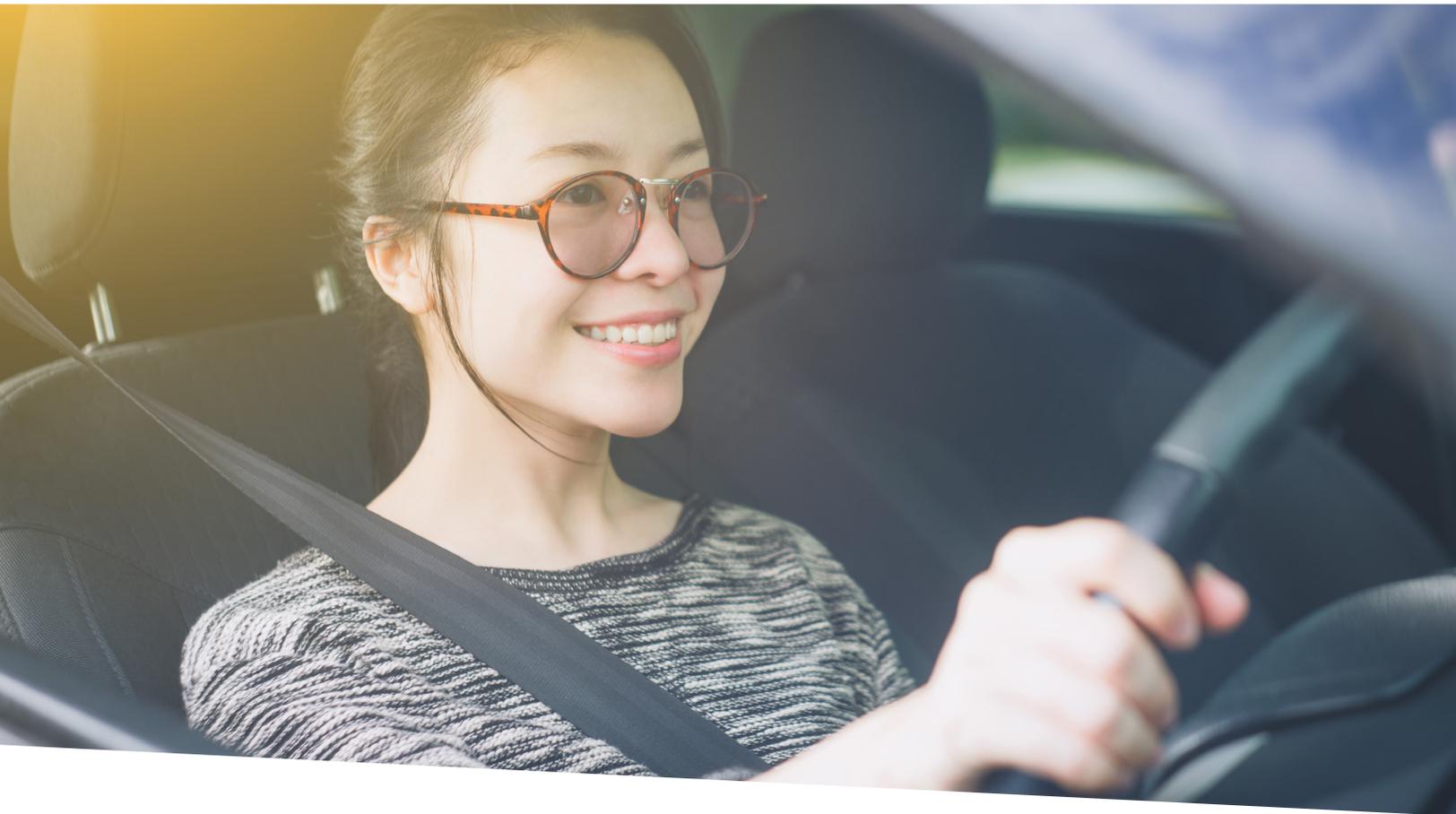


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A SAFETY-FIRST APPROACH TO DEVELOPING AND MARKETING DRIVER ASSISTANCE TECHNOLOGY

White Paper

December 2018

A SAFETY-FIRST APPROACH TO DEVELOPING AND MARKETING DRIVER ASSISTANCE TECHNOLOGY¹

According to the World Health Organization, car crashes kill 1.3 million people worldwide annually.² Therefore, improving roadway safety is an urgent task. Because 93% of these accidents are caused by human error,³ companies are striving to develop technological systems that automate driving tasks. In the aftermath of DARPA's Autonomous Vehicle Grand Challenge,⁴ in which multiple teams developed vehicles capable of fully-autonomous operation, there has been great progress in this domain. Indeed, fully-autonomous (robotic) shuttles, buses and taxis are already being deployed on public streets, offering a glimpse of a future that promises universal and safe transportation.

As a guide for the burgeoning automated vehicle industry, in 2014 the Society of Automotive Engineers (SAE) released a document describing different levels of vehicle automation.⁵ Since publication, these classifications have been adopted as the standard for understanding and marketing developments in this field. SAE has also been actively revising and clarifying this standard.⁶ However, some confusion remains with regards to how these classifications should be understood and, most importantly, conveyed to consumers for safe implementation.⁷ Specifically, there is debate within the industry about whether the definition of Level 3 encourages honest marketing and safe implementation, and, if not, whether it should exist as a category of automation.^{8,9} We also currently lack an industry-wide standard for when it is appropriate to describe and market a vehicle as being "autonomous" or "self-driving" as opposed to simply having driver assistance features, or Advanced Driver Assistance Systems (ADAS). Finally, the reasons why LiDAR technology is required to enable complete automation, or "self-driving," as well as LiDAR's ability to significantly extend the capabilities of today's driver assistance systems, are not commonly understood. In this paper, we address these topics – first by discussing the levels of vehicular automation, then the advantages of LiDAR sensors and finally, how LiDARs enable significant advances in driver assistance.

REFRAMING SAE'S LEVELS 2 AND 3

For decades, auto-OEMs have endeavored to increase driving safety and comfort. Many recent advancements have resulted from OEMs developing and releasing as driver assistance features a few of the many capabilities required for fully-autonomous driving. This incremental approach has resulted in vehicle control systems currently marketed as falling under Levels 2 and 3 of SAE's taxonomy. In Level 2 vehicles, features such as Lane Keep Assist and Adaptive Cruise Control are advertised as allowing drivers to, under certain conditions, safely take their hands off the steering

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 2. "10 facts on global road safety," World Health Organization. July 2017.
 3. National Highway Traffic Safety Administration, "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey," National Center for Statistics and Analysis. February 2015.
 4. "DARPA Grand Challenge," Wikipedia. Accessed October 2018.
 5. "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems," SAE International. October 1, 2014.
 6. "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems," SAE International. June, 2018.
 7. Steve Hanley, "Consumer Groups Say Tesla's "Autopilot" Is Deceptive Marketing," Clean Technica. May 25, 2018.
 8. Joseph Capparella. "Toyota Is Uneasy about the Handoff between Automated Systems and Drivers," Car and Driver. November 3, 2017.
 9. Bruce Gain. "Waymo Was Right: Why Every Car Maker Should Skip Level 3," Wonder How To. June 30, 2017.

wheel and their feet off the pedals. However, at this level, drivers are still required to maintain their attention on the surrounding environment in case the need to manually intervene arises.

Similar to Level 2, Level 3 vehicles include features described as allowing drivers to remove their hands and feet from controlling the vehicle's speed and direction. However, unlike Level 2, Level 3 places the responsibility of monitoring the surrounding environment on the vehicle's sensor system, and instead makes the driver responsible primarily for any fallback actions that should be taken in case the automation fails. Therefore, Level 3 in theory does not require drivers to monitor the driving environment even though the vehicle does not have complete self-driving capability. Vehicles operating at Level 3 might include audio, tactile, and visual warning mechanisms that alert a driver to pay attention and take back control of the vehicle in dangerous situations created by potential limitations or failures of automation. However, there are legitimate concerns about the ability to create a smooth handoff between the vehicle system and the human driver, especially given the time it takes for a distracted driver to fully become aware of her surroundings, take control of the vehicle and make the right driving decisions that prevent an accident due to the sudden non-availability of the automated system. As a result, the risk of creating a situation that goes against the safety goal of Level 3 might be significant.

Consequently, given the automotive industry's continued focus on improving roadway and vehicle safety, there are prominent views questioning the efficacy of Level 3. For example, following some experiments conducted in 2013 that demonstrated the tendency for drivers of Level 3 vehicles to become substantially distracted, Google/Waymo ceased development of systems that require sudden driver intervention. "What we found was pretty scary," explained company CEO John Krafcik, "It's hard [for drivers] to take over because they have lost contextual awareness."¹⁰ Jim McBride, Ford's Senior Technical Leader for autonomous vehicles, has also spoken out against Level 3 implementation, stating, "We're not going to ask the driver to instantaneously intervene—that's not a fair proposition."¹¹ More recently, Jake Fisher, Director of Auto Testing at Consumer Reports, stated, "The best systems balance capability with safeguards—making driving easier and less stressful in the right situations. Without proper safeguards, overreliance on the system is too easy, which puts drivers at risk."¹²

Moreover, a future in which people increasingly utilize Level 4 and 5 vehicles could compound this problem, when they are simultaneously exposed to Level 3 vehicles which require rapid driver intervention. In other words, as people increasingly use vehicles as passengers rather than as drivers, opportunities to gain experience and learn driving strategies in unsafe scenarios will decrease. In situations that place a high cognitive load on the driver, it has been shown that a lack of prior experience slows response time and general driving performance.¹³

Requiring human intervention is fundamentally in conflict with the approach to automated driving that teams adopted during the DARPA Grand Challenge, where there was an understanding that "partial-autonomy" carried significant risks. The shared focus of the Grand Challenge was not to create a system that would allow drivers to briefly shift attention from their driving responsibilities but that would allow vehicles to safely arrive at their destination even when there was not a driver available to intervene.

10. James Ayre. "Google/Waymo Stopped Testing Level 3 Self-Driving Tech After Testers Literally Fell Asleep While Using It, Switched To Full Autonomy," Clean Technica. November 1, 2017.

11. Hope Reese. "Updated: Autonomous driving levels 0 to 5: Understanding the differences," Tech Republic. January 20, 2016.

12. Olsen, Patrick. "Cadillac Tops Tesla in Consumer Reports' First Ranking of Automated Driving Systems," Consumer Reports. October 4, 2018.

13. Bruno, Jennifer L., et al. "Mind over Motor Mapping: Driver Response to Changing Vehicle Dynamics." Human Brain Mapping (2018).

In support of a safety-first perspective, we therefore propose that any vehicle rated below Level 4 should not be marketed as being “autonomous” or “self-driving.” Vehicles below Level 4 might have excellent driver assistance features that contribute to the comfort and safety of vehicle occupants, but they do not drive themselves except in narrowly constrained conditions that often require human intervention. To ensure safe and responsible operation of those vehicles, there must always be an attentive driver at the wheel. The usefulness of Level 3 as a category is therefore debatable. In response, this paper proposes that any vehicle that can control speed and steering but that requires an attentive driver should be marked “Level 2+.” These vehicles can be marketed as having advanced driver assistance features, but they should also be transparently labeled as being “not self-driving.”¹⁴

In an environment where driver assistance systems’ true capabilities and required conditions for performance are not always clear to consumers, eliminating Level 3 would have the beneficial effect of creating a clear boundary between the levels of automation that require an attentive driver (Level 2+) and those that do not (Level 4+). This distinction should be the primary bifurcation of any automated vehicle classification system. The implications would then be clear: In Level 2+, if the driver falls asleep, is distracted, or otherwise incapacitated, there is an increased chance of accident, injury, and death. This is not the case in Levels 4 and 5. Vehicles with less than Level 4 capabilities that are marketed as “autonomous” or “self-driving,” but require drivers to respond within a moment’s notice to emergency alerts or driving system disengagements, should therefore be treated with extreme caution.

| SAE Levels Included | L2+ | L4+ |
|-----------------------------------|--|--|
| Appropriate Marketing Descriptors | Driver Assistance, Advanced Driver-Assistance Systems (ADAS) NOT autonomous, NOT self-driving | Autonomous, Self-driving |
| Occupant Responsibilities | Attentive driver required | No driver required All occupants are passengers |

Segmenting vehicles as Level 2+ (ADAS) and Level 4+ (autonomous vehicles) would also help significantly reduce confusion about the meaning of “self-driving” as evident from a review of articles in the press. For instance, articles covering Tesla accidents frequently apply the term “self-driving” to Tesla vehicles, particularly ones with the Autopilot feature.^{15,16,17,18} However, Tesla’s Autopilot feature achieves only Level 2+ automation because it requires the driver to remain attentive to the driving environment for safe operation. This is clear from Tesla’s public comments after an accident involving Autopilot:¹⁹

The Palo Alto-based automaker, led by Elon Musk, has said it repeatedly warns drivers to stay alert, keep their hands on the wheel, and maintain control of their vehicle at all times while using the Autopilot system.

14. A comprehensive overview of vehicles falling in the category of 2+ ADAS can be found at <https://www.consumerreports.org/car-safety/cars-with-advanced-safety-systems/>

15. Nathan Bomey. “Driver killed in Tesla self-driving car crash ignored warnings, NTSB reports,” USA Today. June 20, 2017.

16. Douglas Rushkoff. “Tesla crash highlights real problem behind self-driving cars,” CNN. July 2, 2016.

17. Neal E. Boudette. “Tesla’s Self-Driving System Cleared in Deadly Crash,” The New York Times. January 19, 2017.

18. Jessica Castro. “Tesla self-driving car fails to detect truck in fatal crash,” KGO-TV San Francisco. July 1, 2016.

19. Brittny Mejia. “Tesla in Autopilot mode crashes into parked Laguna Beach police cruiser,” The Los Angeles Times. May 29, 2018.

"Tesla has always been clear that Autopilot doesn't make the car impervious to all accidents, and before a driver can use Autopilot, they must accept a dialogue box which states that 'Autopilot is designed for use on highways that have a center divider and clear lane markings,'" a Tesla spokesperson said in an emailed statement.

After a Tesla using Autopilot crashed into a fire truck parked on the freeway, another article pointed out the following:²⁰

The Tesla's owners manual states:

"Warning: Traffic-Aware Cruise Control can not detect all objects and may not brake/decelerate for stationary vehicles, especially in situations when you are driving over 50 mph (80 km/h) and a vehicle you are following moves out of your driving path and a stationary vehicle or object, bicycle, or pedestrian is in front of you instead."

Finally, Tesla's public statement after a 2018 crash was quite direct:²¹

The crash happened on a clear day with several hundred feet of visibility ahead, which means that the only way for this accident to have occurred is if Mr. Huang was not paying attention to the road, despite the car providing multiple warnings to do so.

The fundamental premise of both moral and legal liability is a broken promise, and there was none here. Tesla is extremely clear that Autopilot requires the driver to be alert and have hands on the wheel. This reminder is made every single time Autopilot is engaged. If the system detects that hands are not on, it provides visual and auditory alerts. This happened several times on Mr. Huang's drive that day.

By requiring these disclaimers, it is clear that Tesla's Autopilot feature cannot be described, promoted, or represented as being "autonomous" or "self-driving."

OPTIMIZING LEVEL 2+ FOR SAFETY

Although vehicles with Level 2+ driver assistance features are not self-driving, they are still capable of improving driving experiences and increasing roadway and vehicle safety if implemented responsibly. Therefore, a review of the general capabilities of different sensor technologies that companies use to build these systems is valuable not only for OEMs deciding which of these to include in their vehicles, but for consumers who are trying to develop a better understanding of this industry. This discussion is likewise helpful in the context of tragic accidents involving Tesla vehicles using cameras and radars to implement advanced driver assistance (L2+) features.^{22,23}

Most current Level 2+ systems, which have contributed to improved vehicle and occupant safety,

20. Junko Yoshida, "Did Tesla Flunk 'Interpretation' Test?" EE Times. January 25, 2018.

21. Dan Noyes. "EXCLUSIVE: Wife of man who died in Tesla crash gives emotional interview to I-Team," KGO-TV San Francisco. April 10, 2018.

22. Mark Green and Matt McDonald. "Utah woman who crashed into fire truck sues Tesla, says Autopilot feature failed to function," KSTU Salt Lake City. September 5, 2018.

23. Neal E. Boudette. "Autopilot Cited in Death of Chinese Tesla Driver," The New York Times. September 14, 2016.

employ camera-centric sensor suites for monitoring the environment and enabling some of the driving automation. However, images produced by cameras – even stereo cams – do not always provide the level of accurate depth perception necessary for full autonomy. Technological advances to work around limitations in camera technology are still not fully adequate to achieve complete autonomy or “self-driving” capability in the real world. Also, many vehicles that employ camera-centric systems base driving decisions on their ability to identify and follow the vehicle in front of them. This strategy of having a vehicle’s movements overly rely on following the path of a lead car can result in serious driving errors.^{24,25} Further, a single camera cannot provide a full 360-degree view of the surroundings. Instead, to see all around a car, multiple cameras must be mounted at different sites on the vehicle and their images must be “stitched” together by the car’s computer system, which introduces more complexity.

Because camera-centric systems typically base their perceptions on analyses of 2-D images rather than precise distance calculations, cameras are susceptible to optical illusions. For example, tree shadows stretched across the road have been shown to cause camera systems to produce an unacceptably large number of false positive readings, resulting in vehicles’ driver assist systems dangerously applying the brakes in inappropriate situations.²⁶ Furthermore, camera systems operate in ways similar to the human eye in that their performance depends on particular ambient light conditions. That is, cameras do not perform well in conditions of high (“blinding”) or low light. Optimal sensor suites would include technologies that combine their relative strengths to ensure safe performance in all lighting conditions.

Radar systems complement cameras very well. They typically offer better range and horizontal field of view. Radars are not hampered by inclement weather or lack of light. Additionally, radars provide accurate information on speeds of other vehicles. That said, radar has poor resolution (>10+ cm), so a radar’s 3D image is unacceptably fuzzy. Radars also have difficulty detecting stationary objects. Consequently, radars cannot be used for accurate object detection and classification without combining them with cameras.

The combination of cameras and radars offers an impressive set of capabilities that are available in today’s L2+ vehicles. However, even with that combination, significant limitations remain. The addition of LiDAR sensors to the mix significantly enhances the level of possible automation and safety. To understand why, we will provide a high-level comparison of camera, radar, and LiDAR technologies and illustrate how LiDARs enable full autonomy and substantially enhanced safety in the context of autonomy. We then discuss how LiDAR provides enhanced capabilities in the context of advanced driver assistance features such as Automatic Emergency Braking (AEB), Adaptive Cruise Control (ACC), and Lane Keep Assist (LKA).²⁷

The key advantages of LiDAR technology can be summarized as follows. Unlike radar, LiDAR provides much higher resolution, enabling accurate object detection. Unlike cameras, LiDAR provides accurate depth perception, with distance accuracy of a few cm, making it possible to precisely localize the position of the vehicle on the road and detect available free-space for the vehicle to navigate. LiDARs also offer 360 degrees horizontal field of view and up to 40 degrees

24. Kim Reynolds. “Testing (Semi) Autonomous Cars with Tesla, Cadillac, Hyundai, and Mercedes: Getting Ready for Self-Driving Cars,” Motor Trend. July 6, 2016.

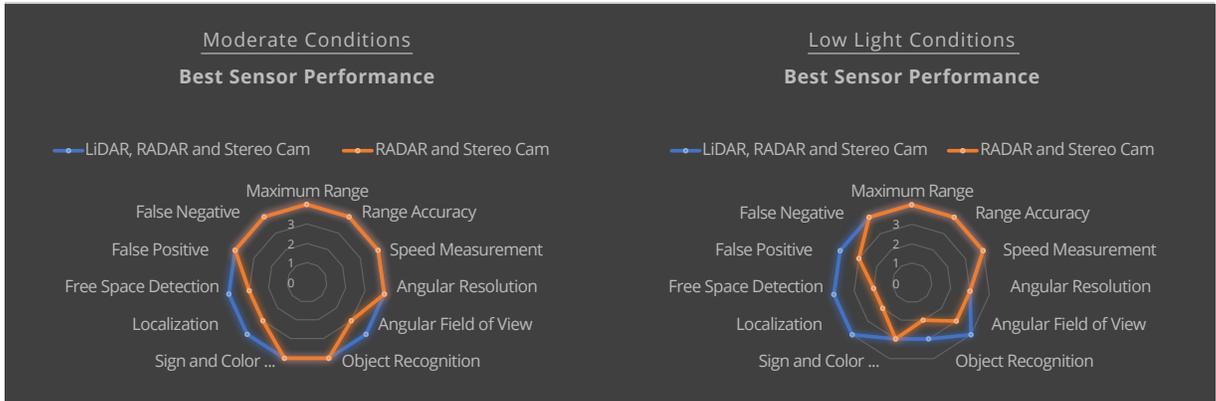
25. Insurance Institute for Highway Safety. “Evaluating Autonomy: IIHS examines driver assistance features in road, track tests,” Status Report, 53, No. 4. August 7, 2018.

26. Insurance Institute for Highway Safety. “Evaluating Autonomy: IIHS examines driver assistance features in road, track tests,” Status Report, 53, No. 4. August 7, 2018.

27. Insurance Institute for Highway Safety. “Evaluating Autonomy: IIHS examines driver assistance features in road, track tests,” Status Report, 53, No. 4. August 7, 2018.

vertical field of view, providing the vehicle the ability to generate dense, high-resolution 3D maps of the environment up to 10-20 times per second, another essential capability for accurately locating the vehicle within its environment and planning its driving path. Moreover, LiDARs can operate in poor lighting conditions unlike cameras, since LiDARs are their own light source.

The key advantages of LiDAR become evident when comparing the capabilities of vehicle systems with radars and stereo cameras with those that have all three sensors. As the first chart below indicates, even under perfect conditions for cameras and radars, the addition of LiDAR allows better field of view and makes more accurate localization and free space detection possible. Under low light conditions, LiDARs significantly fill in the gaps created by the limitations of the other sensors.



[Original Image Credit: Brad Kruse, Veoneer – Modified with permission]

Equally important is the scenario when one of the sensors in the vehicle malfunctions or fails. In a situation like this, a focus on safety requires the use of a sensor suite that includes LiDAR – as shown in the images below - such that even if the most capable sensor associated with a certain capability fails, an alternative sensor is available to provide enough information to keep the vehicle operating safely for a sufficient period of time. In short, LiDAR technology is the key technology to enable both full autonomy as well as safe driver assistance.



[Original Image Credit: Brad Kruse, Veoneer – Modified with permission]

In the remaining part of this paper, we briefly discuss how LiDAR allows significant advancements to key ADAS features.

Automatic Emergency Braking (AEB): Automatic Emergency Braking or Autonomous Emergency Braking (AEB) is a system that helps prevent vehicle collisions by braking the vehicle before it makes contact with an object in its path. The braking system not only helps prevent collisions, it can also help drastically reduce the impact of an unavoidable collision.

Implementing and improving AEB is of great importance for vehicle and traffic safety since AEB could prevent 38% of front-to-rear collisions.²⁸ The European Union has mandated AEB on all new vehicles by 2021. In addition, The National Highway Traffic Safety Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS) recently announced that 20 automakers in the U.S. committed to making AEB standard equipment on their vehicles by 2022. The voluntary commitment covers 99% of all new vehicles in the US.

At present, vehicles with AEB systems employ radar and camera technologies. Some of these systems have shown excellent results in road tests and in real-life situations. However, camera and radar centric systems still have significant limitations,²⁹ including false positives³⁰ and false negatives.³¹ As a result, customers complain that some AEB systems apply braking vigorously when it is not necessary, and in other cases don't apply the brake when they should potentially causing driver confusion and in the worst case, accidents. IIHS has expressed concerns that this has prompted users to disengage the AEB function on their vehicles, causing them to lose out on the added safety it would otherwise offer.³²

LiDAR has the potential to provide higher fidelity object detection at high resolution compared to systems using only cameras and radar. With more accurate object detection, the risk of false positives and false negatives should drop dramatically. Since LiDAR is able to provide much more accurate range measurements of even small objects at a distance, it allows for more effective obstacle detection and braking schemes. A vehicle with a LiDAR sensor is not dependent on a lead vehicle in front of it, in order to determine its own position on the road. The high-density 3D mapping and accurate localization enabled by the LiDAR sensor places the vehicle more precisely within its environment, allowing for safer navigation around any potentially hazardous object on the road. LiDAR also fares much better than cameras in low light conditions. Finally, while current implementations of AEB apply to forward-facing vehicle scenarios, the technology can also be expanded to include situations in which objects coming from the side are in a collision path with the vehicle. This would require a wider horizontal field of view, which is most efficiently provided by a LiDAR with a 360-degree view of the surroundings.

Adaptive Cruise Control (ACC): ACC is a system that automatically adjusts the speed of the vehicle to maintain a safe distance from the vehicle in front of it. ACC thereby combines the benefits of traditional cruise control systems with a collision avoidance system. With ACC, the vehicle system attempts to keep a safe following distance between the vehicle and the vehicle ahead of it with a set maximum speed to maintain that distance. Typical implementations of ACC today involve radars or a combination of radar and camera.

As sophisticated as ACC is, with significant safety benefits, the technology has some significant limitations today. Problems could arise with ACC when roads are curved, leading to the vehicle

28. "Study Confirms High Effectiveness of Low Speed Autonomous Emergency Braking (AEB)," Euro NCAP. May 13, 2015.

29. Rachel Burgess. "Some automatic braking systems have proven to be 'ineffective,'" Autocar. June 29, 2018.

30. For example: Aaron Adelson. "Reality Check: Automatic Emergency Braking malfunction causes terrifying moment," WLOS Asheville. August 22, 2018.

31. Jack Stewart. "Why Tesla's Autopilot Can't See a Stopped Firetruck," Wired. August 27, 2018.

32. Insurance Institute for Highway Safety. "Evaluating Autonomy: IIHS examines driver assistance features in road, track tests," Status Report, 53, No. 4. August 7, 2018.

not properly detecting the car in front of it.³³ This could lead to the vehicle wrongly speeding up in curved roads.³⁴ ACC implementations may not include AEB (which has its own limitations, as discussed earlier) and might therefore be unable to avoid some collisions, especially with stationary objects.³⁵ When other vehicles enter the lane in front of the ACC-enabled vehicle, it could lead to abnormal or unsafe behaviors.³⁶ Unnecessary braking with ACC has also been observed in real-world driving conditions, especially due to tree shadows on the road or other vehicles far ahead in the road.³⁷ ACC may also not work at low speeds. The addition of LiDAR to an ACC implementation could eliminate many of the challenges associated with current ACC systems, given the significantly improved object detection, object tracking, free space detection, localization, and range accuracy, as well as the wider field of view.

Lane Keep Assist (LKA): LKA systems have similar functionality to Lane Departure Warning (LDW) systems with the added function of automating corrective action by steering the car away from the lane marker to re-center the vehicle in the driving lane. LKA systems are increasingly coupled with ACC systems to offer features like “Highway Pilot.”³⁸

With average driver reaction times being of the order of a few seconds, and time to collision in inadvertent or unwanted lane change accidents often being less than one second, LKA systems could save up to 8,000 lives per year.³⁹ However, for these systems to work properly, the lane markings on a road must be clearly visible to the cameras used for lane detection. Camera-based systems do not work well in poor lighting or environmental conditions and when lane markings are worn-out or non-existent.⁴⁰

The LKA use case presents particular issues for range and field of view. At close range, the system needs to keep the vehicle in the lane. At long range, it must detect lane splitting and merging either to maintain proper lane position or to alert the human driver to take control in complex situations. Given the constant activity of other vehicles merging in and out of lanes in front of the vehicle, the system cannot always depend on a leading vehicle, nor can it depend on vehicles around it to remain within their lanes. While cameras have excellent capability to detect lane markings under good road and environmental conditions (unlike radar), cameras cannot detect lane markings at all times, and may have difficulty with lane-splitting and merging. Hills and curves impact the performance of most LKA systems because lane markings are not always visible where cameras might expect them to be.⁴¹ This could lead to dangerous situations with the car veering wrongly into another lane. The addition of LiDAR allows an independent set of data to be made available to the vehicle’s system precisely locating the vehicle on the road in relation to static elements such as barriers, highway exits, lane merges and splits, hills, curves, and road boundaries as well as dynamic objects like vehicles and pedestrians. Thus, a LiDAR-centric system is able to provide high quality navigation references even in the absence of reliable lane information. This is readily evident from LiDAR-centric Level 4 autonomous vehicles deployed in urban streets without lanes. Moreover,

33. Erik Shilling. “Why Adaptive Cruise Control Should Be The Last Driving Aid Before Full Autonomy,” Jalopnik. April 26, 2018.

34. H.M Jagtman & E. Wiersma. “Driving with Adaptive Cruise Control in the Real World,” 16th ICTCT Workshop, Safety Science Group.

35. “Use of Advanced In-Vehicle Technology by Young and Older Early Adopters: Survey Results on Adaptive Cruise Control Systems,” AAA Foundation for Traffic Safety. February 2018.

36. H.M Jagtman & E. Wiersma. “Driving with Adaptive Cruise Control in the Real World,” 16th ICTCT Workshop, Safety Science Group.

37. Insurance Institute for Highway Safety. “Evaluating Autonomy: IIHS examines driver assistance features in road, track tests,” Status Report, 53, No. 4. August 7, 2018.

38. Erik Shilling. “Why Adaptive Cruise Control Should Be The Last Driving Aid Before Full Autonomy,” Jalopnik. April 26, 2018.

39. Insurance Institute for Highway Safety. “New estimates of benefits of crash avoidance features on passenger vehicles,” Status Report, 45, 5. May 20, 2010.

40. Erik Shilling. “Why Adaptive Cruise Control Should Be The Last Driving Aid Before Full Autonomy,” Jalopnik. April 26, 2018.

41. Insurance Institute for Highway Safety. “Evaluating Autonomy: IIHS examines driver assistance features in road, track tests,” Status Report, 53, No. 4. August 7, 2018.

some LKA systems have shown that their reliance on following a vehicle in front of them (when the distance of separation is small) could lead to the lane-keeping vehicle exiting the roadway with the vehicle in front of it, rather than continuing on its intended course.⁴² The addition of LiDAR to such a system would enable the vehicle to stay in its traveling lane and more effectively alert the driver to upcoming lane shifts, for example at highway interchanges or in construction zones.

CONCLUSION

Recognizing the problematic requirement inherent to current definitions of Level 3 automation - that drivers need to rapidly take control of the vehicle when automation fails - this paper proposes applying a rating of "Level 2+" to vehicles with driver assistance systems capable of controlling speed and direction but requiring an attentive driver. This distinction will encourage transparent marketing and safe deployment. Only vehicles rated at Level 4+ - ones that do not require an attentive driver - should be marketed as "autonomous" and "self-driving," and even then the speed, route and geographical constraints of such vehicles must be clearly conveyed. A comparison of camera, radar, and LiDAR technologies demonstrates that LiDAR has a critical role to play in maximizing safety in Level 2+ driver assistance features.

42. Insurance Institute for Highway Safety. "Evaluating Autonomy: IIHS examines driver assistance features in road, track tests," Status Report, 53, No. 4. August 7, 2018.

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