Incorporating AI into current autonomous vehicle design

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Abstract

Many hundreds of thousands of decisions are made by a driver during their regular commute to work. Determining the speed of the vehicle, merging with traffic, watching for road signs and traffic lights, etc, are just a few. Autonomous aspects are starting to be implemented into the present-day market, but enhancing the level of automation comes along with considerable challenges. One is dealing with different environmental conditions, such as rain, snow, fog, etc, each having distinct characteristics that make it tricky for sensors to do their proper job. Another is dealing with radar interference due to the size of precipitation that can completely scatter signals and discombobulate a vehicle. The last is upgrading the capabilities of autonomous vehicles presently being sold in the market by changing their perceptions and motion planning. Incorporating the many methods of artificial intelligence, such as machine learning, deep learning, and reinforcement learning, can make achieving these challenges a lot more efficient.

Introduction

In the current world, human errors cause 90% of automotive crashes [4]. However, almost all of these could be eliminated if we replace our current navigation systems with AI. Not only can it reduce the number of car accidents, but AI can also improve traffic flow and decrease the fuel used. AI can accomplish this through neural networks that it uses while on the road to detect obstacles. Cars that can self-drive use multiple features such as ultrasonic sensors, cameras, and radar. The data is given to AI algorithms to process and output proper procedures. People can do work while AI drives them to their office. Tesla and other companies are already using Level 2 automation, in which cars automatically center on car lanes and are aware of traffic, as seen in Figure 1. However, there are a couple aspects of it that if improved will greatly enhance the experience of automotive driving. These are adjusting to environmental conditions, radar interference, and enlarging the operational design domain. (Figure 1 - Levels of automation, reprinted from [2].)

Environmental Conditions

One way in which current autonomous vehicle (AV) capabilities can be improved through the usage of AI is in understanding different environmental conditions. This includes not only weather conditions but also road quality and traffic density. Currently, Lidar sensors are being used in AV. They bounce a laser off surrounding objects and measure the time it takes to come back to the receiver [1]. However, this can be improved by

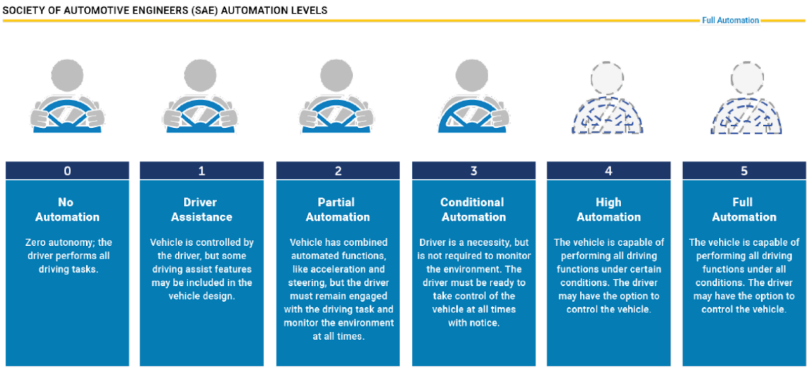

Figure 1 - Levels of automation, reprinted from [2].

implementing multiple sensors, which would require more complex machine learning algorithms to combine the data being obtained. Another option would be to use a different type of sensor called Millimeter wave radar (MWR). Its advantage over Lidar is that it uses radio waves, allowing it to be less attenuated by rain, snow, etc. Lidar sensors look at environmental conditions, but MWR sees through obstacles on the road. The only potential downside is that it can't view its surroundings in 3-D like Lidar [1]. However, using advanced Machine Learning Algorithms that train the model to combine data from Lidar and MWR, as seen in Figure 2, can help find the best and safest route, even through dangerous environmental conditions such as heavy rain and snow.

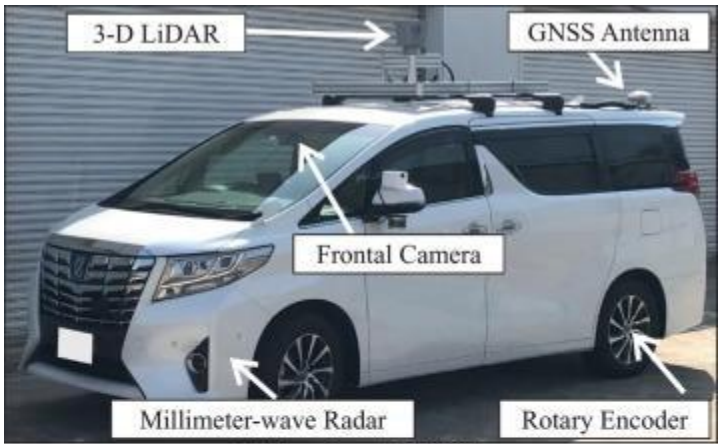

Figure 2 - Autonomous vehicle equipped with different receivers, reprinted from [1].

Radar Interference

Another way in which AV capabilities can be improved through the usage of AI is eliminating radar interference. During precipitation, any transmission made by the vehicle that is similar or smaller than the diameter of a water droplet (6mm) can be affected by Mie scattering. This can absorb the EM energy by water droplets and vapor which can cause deterioration in performance. It can also generate false alarms and mask actual targets in front of the sensor. However, local weather conditions do not affect the Global Navigation Satellite System (GNSS). The only problem with using GNSS is that windshield wipers can occasionally block the signals. This can be fixed by implementing AI algorithms that recognize the timing of windshield wipers and how to adjust when to send signals based on the frequency of

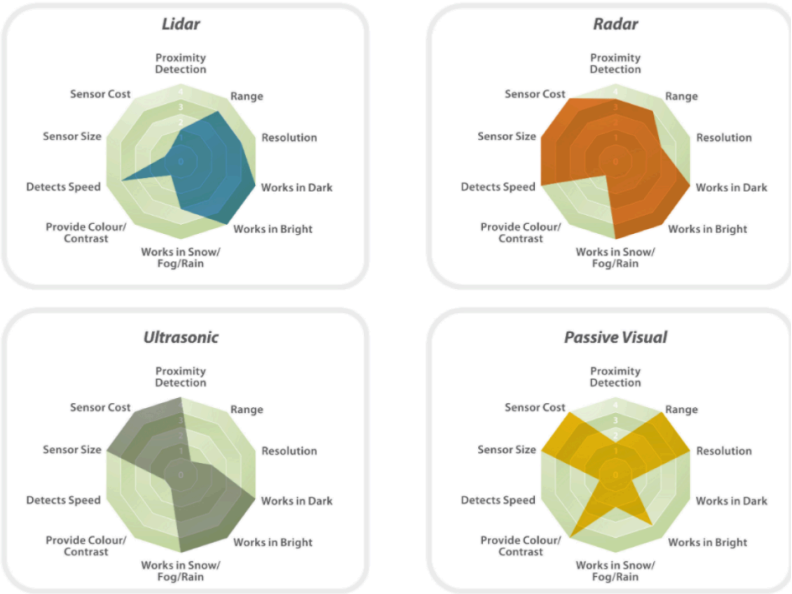

Figure 3 - Pros/Cons of different data receiving structures, reprinted from [2].

windshield wiping. Each type of sensor has its own pros and cons, as shown in Figure 3. If GNSS can be incorporated alongside Lidar and MWR as discussed in the previous paragraph it can diminish the effects of radar interference [2].

Operational Design Domain

The final way in which AI can be used to enhance AV capabilities is in enlarging the current Operational Design Domain (ODD). Currently, cars that have Level 2 automation are only adjusted to certain scenarios in driving, such as highways and parking. However, a self-driving Level 3 automation car has to achieve a lot of difficult tasks. These include perception of surroundings, motion planning, detection of pedestrians and road signs, and many more. In perception, deep learning algorithms can be used to distinguish drivable regions and obstacles. In motion planning, reinforcement learning can be used to determine velocity control based on current surroundings. In detection of pedestrians, complex machine learning algorithms can be used for identifying people in the way of AV and to respond appropriately. Lastly, in the detection of traffic signs, an AI model can be trained on different images of signs and put to the test in the real world to check if the AV responds properly to each situation [3].

Discussion

Research in autonomous vehicles can prove to be beneficial for everyone. The main reason is for improvement in safety. A higher level of automation, for example level 3 automation, can greatly reduce human error and end the chain reaction that begins when one human has a fatal mistake on the road [4]. The Insurance Institute for Highway Safety found that current self-driving capabilities can reduce accidents by 34%, and this will definitely improve in the future [12]. AV can also greatly improve traffic conditions and travel time because of its ability to optimize paths based on communication with cars around itself. This leads to environmental benefits as well because of lower emissions due to better traffic conditions. Lastly, AV is guaranteed to create massive economic wealth in the future due to its high potential as a staple in human lifestyle. The current market is worth $54 billion, and it grows annually by 16% [7].

Limitations

Nothing in the world exists without restrictions, and that includes autonomous vehicles. For AV to be able to communicate with each other and coordinate the best possible routes, they would have to be on the same network, leaving them susceptible to possible hacking, which could lead to collisions and traffic, as shown in Figure 4. Another potential problem is the loss in labor. Jobs such as taxi drivers, fast food delivery, etc. could become obsolete because AV could just do it without the need of humans [5]. Lastly, autonomous vehicles have slow mapping software. Although it can predict the fastest route for the long term, when faced with construction, detours, or accidents, these systems may not be up to date quick enough to prevent the self-driving car from going into traffic [6].

Figure 4 - Potential limitations of AV, reprinted from [3].

Current market

Many companies are leading the race for autonomous vehicle advancement, such as Tesla, Waymo, and Cruise. Using its latest Model 3, Tesla is shown to have 360° of visibility as well as being able to see 250 meters in all directions. It can also automatically change lanes on highways, autopark and summon, and guide the user on navigation [8]. Another company, Waymo, has gone far deeper into the field of Level 3 automation. It has mapped out entire cities and uses these custom maps rather than GPS to mark its exact location at all times. It is one of the few companies that has achieved almost complete automation because of its usage of many different sensors, as discussed in the paper [9]. Another company, Cruise, is similar to Tesla in that it uses multiple sensors to have a complete 360° visibility, but it is also shown to have 65% fewer collisions in a study [10]. The company also has support from many others, such as Walmart, Honda, and Microsoft. [11] Also, many car companies, such as BMW, GM, and Hyundai are starting to incorporate AI into safety measures such as an emergency braking system, warning lights for nearby cars, and cruise control.

Conclusion

In this research paper, different methods were discussed as to how AI can be incorporated into current Autonomous Vehicle technology. Understanding the different environmental conditions and combining data from multiple sensors can help AV work in any situation. This can also be improved upon by adding GNSS along with other sensors to deal with rain and radar interference. Lastly, to truly make the jump from a Level 2 to Level 3 and beyond in automation, AV has to utilize Machine Learning to recognize signs. Pedestrians, plan its velocity, etc. This paper can help in formulating ideas for how the growing field and potentials of AI can be harnessed to benefit all cars on the road.
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