Why Partial Self-Driving Now?

Self-driving cars have started to come into reality and many cities in U.S. have prepared to embrace self-driving, because of the benefits of introduction of autonomous vehicles. Controlled by programmatic computers with wireless communications, self-driving cars could improve safety and efficiency of traffic transportations. Also, self-driving cars could lower the driving barriers for the disabled and the elderly. However, currently, the sensor and software still cannot handle all the driving circumstances, and there lack sufficient supporting infrastructures for wireless communications. Thus, currently, partial self-driving with human-supervision could be launched as a compromise approach to enjoy the benefits. At the same time, more real self-driving data could be collected to advance autonomous vehicles, and the wireless communication infrastructures could be updated to prepare for full self-driving.

Self-driving technologies could be divided into five levels, starting from driver assistance system, like cruise control service, and ending with full driving automations (Society of Automotive Engineers, 2021, pp. 21-23). So far, the car-embedded assistant system has become mature to help avoid human-caused errors. Equipped with the technologies of lidar, radar, and camera, the system provides a great deal of services to guarantee the safety of driving, such as blind spot detection, automatic emergency braking, and so many other functions (Galvani, 2019, pp. 11-12). Also, today increasingly more companies funded the research and development of Level 4 cars which could run without human supervision and intervention in front of the wheel under most conditions (Ornes, 2019, p. 4). In addition, some cities have prepared for the driverless cars. For example, both ride-sharing companies Lyft and Uber have put several self-driving cars with a safety driver in Pittsburgh and Las Vegas, respectively (Ornes, 2019, p. 5).

With the rapid development of self-driving cars, the introduction of self-driving cars in a large scale becomes possible.

There are many reasons to introduce self-driving. Most importantly, through digital enablement and wireless connection, self-driving cars could avoid human-caused errors and lower the traffic incident risk. Currently, the traffic accident is still one leading reason of injuries and fatalities. Only in 2019, roughly five million vehicle crashes happened in U.S., with around 1.9 million injuries and 36,096 deaths (U.S. Department of Transportation, 2021, p. 33). Also, most of these traffic accidents are caused by human-related factors. Even the average proportion among the past ten years could be up to 94% (Rojas-Rueda, 2020, p. 331). Thus, regarding the level of safety, the traffic system needs self-driving technologies.

With self-driving technologies, many human-related errors could be avoided by gaining 360° vision. Usually, such nearby obstacle detection technologies comprise advanced driver-assistance system (ADAS) (Blanco, 2020, p. 2). Through ADAS, the car could detect the surrounding environments in the real time, which is almost impossible for a human driver. Equipped with lidar, radar, sensor, and camera, the car could detect obstacles in the different distances and set up accurate 3D map by calibration with multiple information sources (Ondruš et al., 2020, p. 229). With the aid of all-around information, the car could make better decision to guarantee the safety. Through this, the intelligent services could be provided, like automatic problem alert, autonomous obstacle avoidance, and automatic car brake (Galvani, 2019, p. 12). With these environmentally adaptive designs, the traffic accident risks could be lowered.

Besides, with wireless connections, self-driving cars could use the environmental information obtained by other vehicles to further lower the traffic accident risks. Through digital communications, the information exchange of “vehicle to vehicle” could be achieved, allowing the car to predict the following path. For example, if an accident happens, the vehicle could send timely alert message to later cars to avoid further collisions on the road (Yang et al., 2017, p. 205). Thus, the likelihood of secondary accident could be lowered. In addition, the interaction framework of “vehicle to everything” could be organized. With more participants involved, the mechanism could further prevent the vehicle accidents with pedestrians, cyclists, and motorcyclists (Ahangar et al., 2021, p. 13). As a result, the road safety could be leveraged into a very high level.

In fact, the wireless communications by self-driving not only improve traffic safety but also increase traffic capacity and efficiency. With wireless communications, autonomous cars could be managed to flow steadily on a macro level, decreasing traffic congestions. The field experiment by Stern et al. (2018) demonstrated that the traffic congestion waves of “stop and go” could be dampened by only a small proportion of connected autonomous cars (p. 206). Thus, only with some connections, the operation algorithm could closely platoon and steadily put forward the cars. Consequently, by avoiding brake events in the traffic congestions, the throughput increased by around 15% while the fuel consumption decreased by around 40% (Stern et al, 2018, p. 207). The results indicate the large potential of connected self-driving cars to upgrade the capacity and efficiency of current traffic system. Also, another empirical study illustrated the higher efficiency of autonomous vehicles by comparing fuel consumptions. The study by Shi et al. (2022) found that self-driving vehicles always consume less fuel than human-driving vehicles for all settings (p. 2). That is also because with connections, self-driving cars could be effectively stabilized with optimal operation strategies.

In addition to straight-line traffic flow, the wireless connections make the efficient road intersection management possible. According to some researchers, the road intersections could cause great traffic delays and are the major source of traffic collisions (Rahmati & Talebpour, 2017, pp. 1316, 1321). Thus, the operation optimization for the road intersections has a great significance regarding safety and efficiency. Compared with traditional traffic light controlling, the intelligent transportation system could communicate real-time information between autonomous vehicles and the central control unit. With the aid of information, the self-driving cars could make dynamic planning and decision (Li et al., 2021, p. 3). Then the response time for traffic coordination could be significantly reduced. At the same time, the central control unit could optimize the group of cars together. In this way, the optimal crossing strategy could be chosen to carry on at the intersections (Li et al., 2021, p. 2). Then, by the time and space reservations, traffic congestions at the intersection could be dampened.

Apart from car safety and road efficiency, self-driving cars could make driving more accessible for some certain groups, including the disabled and the elderly. In fact, being disable is one of leading factors to driving inequality. It is estimated 25.5 million people with disabilities in the U.S. have difficulties in travelling (Brumbaugh, 2018, p. 2). However, the self-driving technologies could make travelling relatively easy for them. Then the disabled could become more independent in work and life. For example, the self-driving technologies could help Down syndrome community to find jobs as transportation is one huge barrier regarding employment for them (Halsey, 2017, p. 1). This indicates that the self-driving could also indirectly promote the equality in other aspects by guaranteeing driving equality. This is also true for the elderly. With the aid of self-driving, the elderly could regain the mobility and freedom. For example, the self-driving technologies could function as an assistance system to provide necessary aids to the elderly (Faber & Dea, 2020, p. 354). So, the self-driving could reenable the elderly's driving capacity and make the elderly more self-reliant regarding travelling.

From above merits, self-driving cars display a large potential to greatly improve the traffic system. However, at the current state, many technological limitations exist, restricting these benefits. First and foremost, autonomous cars are still unable to handle all circumstances. So far, most of self-driving cars are only trained on the ideal conditions (Ornes, 2019, p. 9). Thus, there are still some gaps between the lab and the reality. Also, there are many hard technical difficulties to solve on special cases. For example, on severe weathers, the inaccuracy of environmental perception prevents the safe road operation. Like, on the frequent rainy conditions, the raindrops on the lens could degrade the quality of image, affecting object recognition (Zhang et al., 2021, p. 10). With false recognition, traffic accidents are more likely to happen, decreasing the road safety. Further, on rainy days, the 3D mapping of lidar could become problematic with disordered sensing information. In the case, the splash of rainwater just messes up with the crossing car by no distinguishment (Yoneda et al., 2019, p. 258). This effect could directly disable the self-driving system. Thus, at least currently, self-driving cars could not run on all cases with full automations.

In addition, there lack sufficient infrastructures to support wireless communications. As described above, for the safe and efficient operation, self-driving cars need to communicate with others. To establish such cooperative environment, the robust and powerful wireless communication system is needed, which should be able to transmit huge data in a high speed without intervention (Martínez-Díaz & Soriguera, 2018, p. 277). However, at least for now, the requirement of bandwidth and speed could not be satisfied. Equipped with an array of sensors, one self-driving car produces a large amount of data to transmit. According to some statistics, one self-driving car would produce around 4,000 GB data each day, equivalent to 2,700 people's use (Ghansiyal et al., 2021, p. 66). Yet, such amount of data is only produced by one car. In a large scale, the current framework of wireless communications would be considerably overloaded. Further, the safe operation of self-driving cars requires low latency for wireless communications to minimize the error caused by information delay. Usually, the criterion is extremely strict with less than 1 ms while the prevailing 4G connection could lead to 50 ms time delay, creating 50 cm error (Tanwar et al., 2019, p. 67). Such large error is unacceptable for self-driving, which significantly increases the risk of traffic accidents. Therefore, the update of wireless communication infrastructures should be done before the launch of self-driving cars.

Therefore, partial self-driving with human supervision could come into a compromise to enjoy the benefits under the premise of safety. In this way, the backup driver could take over the control of car when the car cannot deal with the case by itself. So far, many companies have successfully launched the kind of self-driving cars in different cities with a backup driver for special circumstances, such as Aptiv, Cruise, and Zoox (Ornes, 2019, p. 5). These successful examples illustrate the feasibility of partial self-driving at the current stage. In the setting, the backup driver could be the bottom line to guarantee the safety on extreme conditions. Further, on the other side, the self-driving system could provide real-time accurate information for the driver in most cases. As described at the beginning, with a set of sensors, the self-driving car could provide exhaustive surrounding information for the human driver (Ondruš et al., 2020, p. 229). Based on the information, the human driver could make better decision, which decreases the risk of traffic crashes. Even under the restriction of current state, some simple wireless connections could make up effective safety mechanism. For example, with the short-range transmission which could be directly applied, such as Bluetooth and BLE, the self-driving cars could share the traffic information among the proximal cars to prevent collisions (Ahangar et al., 2021, p. 16).

Then the road safety could be further improved. Therefore, at the current stage, partial self-driving could maximize the net benefits in the process of car automatization.

In addition, with the launch of partial self-driving, more training and testing data for self-driving could be collected from the real operation environments. In fact, the self-driving technologies are powered by data. That is because the self-driving system learn obstacle-recognizing and decision-making from a very large amount of data (Christianson, 2020, p. 2). Thus, without the adequate data, the improvement of self-driving technologies could be stuck, and this problem has become increasingly more prominent. By a comprehensive survey, there are only 27 available datasets for self-driving training and testing (Grigorescu, 2019, p. 377). This indicates that there lack sufficient datasets specifically for autonomous vehicles. However, the launch of partial self-driving could improve the current situation. With a set of sensors and cameras, when driving, the partial self-driving car could also perform the work of data discovery and collection (Gupta et al., 2021, p. 6). Later, the collected data could be processed and then used to train and test self-driving car to further advance the technologies, like for the severe weather cases.

Also, at the same time, the wireless communication infrastructures could be updated and experimented with partial self-driving to prepare for the next stage full self-driving. For the problem of transmission latency, Tactile Internet (TI) emerged as a promising solution with high performance. According to Ghansiyal et al. (2021) and Tanwar et al. (2019), TI could provide the high robust network connection with ultra-low latency less than 1ms (p. 65; p. 67). So, TI could meet the safety criteria of wireless communication for self-driving, and next stage is to integrate TI with self-driving cars in practice. Also, multiple types of networks and signals could be involved in the next step. The exhaustive comparison analysis based on the transmission range by Ahangar et al. (2021) has shown different types of vehicular communication technologies have different advantages and disadvantages (p. 21). Combined these technologies together step by step at first with partial self-driving, the performance of wireless communications could be maximized at the end. Finally, with these improvements, the launch of full self-driving could become possible.

In conclusion, self-driving could bring about benefits to the urban traffic systems, improving traffic safety and efficiency and increasing driving equality. However, self-driving cars still need to be advanced to handle some special road conditions and the supporting communication infrastructures need to be updated. Therefore, partial self-driving could be launched as a transitional phase to enjoy the benefits and further advance related technologies under current restrictions. In this way, more data could be collected to train self-driving cars to be more familiar with complex real environments. Also, the update of wireless communication infrastructures could be done for the next stage of full self-driving. With the reasonable plan step by step, in the nearby future, it could become possible to launch full self-driving cars on a large scale to enjoy all the benefits of self-driving.

References

Ahangar, M. N., Ahmed, Q. Z., Khan, F. A., & Hafeez, M. (2021). A survey of autonomous vehicles: Enabling Communication Technologies and challenges. *Sensors*, *21*(3), 1–33. https://doi.org/10.3390/s21030706

Blanco, S. (2020, May 26). *Advanced driver-assistance systems. What the heck are they anyway?* Forbes. Retrieved May 1, 2022, from https://www.forbes.com/wheels/advice/advanced-driver-assistance-systems-what-are-they/

Brumbaugh, S. (2018). *Travel patterns of American adults with disabilities*. U.S. Department of Transportation. https://www.bts.gov/travel-patterns-with-disabilities

Christianson, P. (2020, September 30). *Billions of miles of data: The autonomous vehicle training conundrum*. CloudFactory Blog. Retrieved May 3, 2022, from https://blog.cloudfactory.com/autonomous-vehicle-training-conundrum

Faber, K., & Lierop, D. v. (2020). How will older adults use automated vehicles? Assessing the role of AVs in overcoming perceived mobility barriers. *Transportation Research Part A: Policy and Practice*, *133*, 353–363. https://doi.org/10.1016/j.tra.2020.01.022

Galvani, M. (2019). History and future of Driver Assistance. *IEEE Instrumentation & Measurement Magazine*, *22*(1), 11–16. https://doi.org/10.1109/mim.2019.8633345

Ghansiyal, A., Mittal, M., & Kar, A. K. (2021). Information management challenges in Autonomous Vehicles: A systematic literature review. *Journal of Cases on Information Technology*, *23*(3), 58–77. https://doi.org/10.4018/jcit.20210701.oa5

Grigorescu, S., Trasnea, B., Cocias, T., & Macesanu, G. (2020). A survey of Deep Learning techniques for autonomous driving. *Journal of Field Robotics*, *37*(3), 362–386. https://doi.org/10.1002/rob.21918

Gupta, A., Anpalagan, A., Guan, L., & Khwaja, A. S. (2021). Deep learning for object detection and scene perception in self-driving cars: Survey, challenges, and open issues. *Array*, *10*, 1–20. https://doi.org/10.1016/j.array.2021.100057

Halsey, A. (2017, November 23). *Driverless cars promise far greater mobility for the elderly and people with disabilities*. The Washington Post. Retrieved May 1, 2022, from https://www.washingtonpost.com/local/trafficandcommuting/driverless-cars-promise-far-greater-mobility-for-the-elderly-and-people-with-disabilities/2017/11/23/6994469c-c4a3-11e7-84bc-5e285c7f4512_story.html

Li, S., Shu, K., Chen, C., & Cao, D. (2021). Planning and decision-making for connected autonomous vehicles at road intersections: A Review. *Chinese Journal of Mechanical Engineering*, *34*(1), 1–18. https://doi.org/10.1186/s10033-021-00639-3

Martínez-Díaz, M., & Soriguera, F. (2018). Autonomous vehicles: Theoretical and practical challenges. *Transportation Research Procedia*, *33*, 275–282. https://doi.org/10.1016/j.trpro.2018.10.103

Ondruš, J., Kolla, E., Vertaľ, P., & Šarić, Ž. (2020). How do autonomous cars work? *Transportation Research Procedia*, *44*, 226–233. https://doi.org/10.1016/j.trpro.2020.02.049

Ornes, S. (2019, February 1). Self-Driving Cars. *CQ Researcher, 29*, 1-27. Retrieved from http://library.cqpress.com/cqresearcher/cqresrre2019020100

Rahmati, Y. & Talebpour, A. (2017). Towards a Collaborative Connected, Automated Driving Environment: A Game Theory Based Decision Framework for Unprotected Left Turn Maneuvers. *Proceedings of IEEE Intelligent Vehicles Symposium (IV)*, 1316-1321. https://doi.org/10.1109/ivs.2017.7995894

Rojas-Rueda, D., Nieuwenhuijsen, M. J., Khreis, H., & Frumkin, H. (2020). Autonomous vehicles and public health. *Annual Review of Public Health*, *41*(1), 329–345. https://doi.org/10.1146/annurev-publhealth-040119-094035

Shi, X., Yao, H., Liang, Z., & Li, X. (2022). An empirical study on fuel consumption of commercial automated vehicles. *Transportation Research Part D: Transport and Environment*, *106*, 1–11. https://doi.org/10.1016/j.trd.2022.103253

Society of Automotive Engineers. (2018). *Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles*. https://www.sae.org/standards/content/j3016_201806/

Stern, R. E., Cui, S., Monache, M. L. D., Bhadani, R., Bunting, M., Churchill, M., Hamilton, N., Haulcy, R., Pohlmann, H., Wu, F., Piccoli, B., Seibold, B., Sprinkle, J., & Work, D. B. (2018). Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. *Transportation Research Part C: Emerging Technologies*, *89*, 205–221. https://doi.org/10.1016/j.trc.2018.02.005

Tanwar, S., Tyagi, S., Budhiraja, I., & Kumar, N. (2019). Tactile internet for autonomous vehicles: Latency and reliability analysis. *IEEE Wireless Communications*, *26*(4), 66–72. https://doi.org/10.1109/mwc.2019.1800553

U.S. Department of Transportation. (2021). *Transportation statistics annual report 2021*. https://doi.org/10.21949/1524191

Yang, H., Wang, Z., & Xie, K. (2017). Impact of connected vehicles on mitigating secondary crash risk. *International Journal of Transportation Science and Technology*, *6*(3), 196–207. https://doi.org/10.1016/j.ijtst.2017.07.007

Yoneda, K., Suganuma, N., Yanase, R., & Aldibaja, M. (2019). Automated Driving Recognition Technologies for adverse weather conditions. *IATSS Research*, *43*(4), 253–262. https://doi.org/10.1016/j.iatssr.2019.11.005

Zhang, Y., Carballo, A, Yang, H., & Takeda K. (2018). *Autonomous driving in adverse weather conditions: A survey*. Unpublished manuscript. https://doi.org/10.48550/arXiv.2112.08936