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Irregular operation of autonomous vehicles

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Abstract

Today, with the spread of autonomous functions in vehicles, the role accountability for causing accidents is emphasized. Self-guided functions work in certain traffic situations, but accidents happen, and, therefore, the following article presents an analysis of the issue. Its purpose is to show that vehicles with self-drive functionality do not provide the driver's level of safety that vehicle manufacturers suggest. In this article, four recent events and an analysis whether these accidents could have been avoided a human driver or how they could have happened with appropriate self-drive function. In each of the investigated cases, vehicles equipped with self-drive function are involved. Based on the evaluation and assessment of accidents, conclusions are drawn whether current self-propelled vehicles provide the safety level that drivers and society expect from these vehicles. The reconstruction of the accident process is illustrated with the help of a vehicle simulation program, with the resultant parameters being given a special emphasis, in particular to the avoidance of the accident.

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1. Introduction

In the paper two accidents involving autonomous vehicles are presented, which have been interrupted in autonomous mode during their journey. In the first case (The Guardian, 2018), a situation which involves Volvo XC 90 operated by Uber and the pedestrian is presented , the second case concerns a Tesla Model S and a fire truck (Autoweek, 2018). The paper analyses the cases, determines the reaction points, examines the likelihood of avoiding accidents.

The examples illustrate that current autonomous systems in the real-world transport environment do not yet provide what manufacturers have promised and users have expected.

2. Experimental

In the first case a person pushing a bicycle was crossing a 4-lane road, partially illuminated road cross. The Volvo car was going along the outside lane around at the speed of approximately 40 mph*. There was a crew in the vehicle at the time of the crash, but the Advanced Driver Assistance System (ADAS) was on. The crash occurred in the 4th, outside, lane, the vehicle was caught at a point of ca. 40-50 meters away.

As far as the second accident is concerned, a fire truck was standing on the inside lane of the highway because of an earlier event. The Tesla car was travelling at 65 mph and then collided with the fire truck.

Note: 65 mph = 104 $^{km}/_{h}$

Note: 40 mph = 64 $^{km}/_{h}$

The sites of the accidents

The full reports of the sites of the accidents were not available when the following paper was being written. In the case of the first accident based on the data of the on-board camera presented in the media, the location of the collision could be determined in an appropriate way. The width of the roadway and other environmental conditions were determined on the basis of data available in the media and with the use of the Google Earth program. The trajectory of the accident site, the vehicle and the intended pedestrian pathway could be determined. The accident occurred in Arizona, in the city of Tempe on N Mill Avenue, at 33.436195, -111.942370 GPS coordinates.

The Figure 1 depicts the site of the accident process. The figure shows the direction of the Volvo and the pedestrian path.

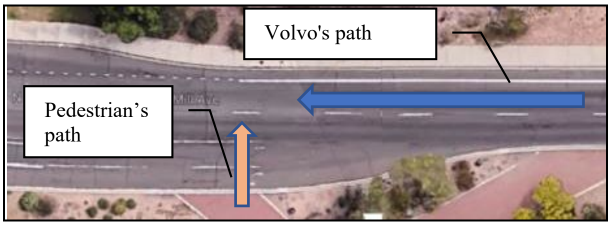

Fig. 1. The accident sites (Google Earth)

Figure 2 shows the street view, where the location of the collision was specified.

Fig. 2. The collision location (Google Earth)

Figure 3 is a screenshot from the video when the pedestrian becomes visible to a driver.

Fig. 3. The moment of pedestrian perception (Youtube, Abc Action News)

The second accident occurred on January 22, 2018, in the morning, in the day-time, dry road conditions. Based on the obtained data, the fire truck was occupying 2 internal traffic lanes of the motorway. The Tesla car in self-driving mode smashed into the back of a fire truck. A personal injury occurred, the case is investigated by NTHSA. The event happened in the US state of California, Culver City, on the 405 freeway.

3. Results and discussion

The calculation of the accidents process

Own accident calculations based on the data collected during the test were used (Burg, Moser, 2009).

The simulation calculation was conducted by the means of Virtual Crash 2.2 software (Virtual Crash Homepage, 2016). This application is intended for forensic experts working in the field of traffic, who specialise in elaborating technical expert reports about causes of road traffic accidents.

In the case of the first accident the process based on the recording of the on-board camera was synchronised. The pedestrian speed was approx. 6 $^{km}/_{h}$, the car was traveling approx. 64 $^{km}/_{h}$. The sync point is the location of the collision that ends the white separating line of the bicycle track. Analysing the video, it can be stated that the vehicle hit the person without braking. The impulse that caused the braking was the collision.

It can be concluded from the established speed that the pedestrian started crossing the road approx. 8.5 seconds before the collision. At that time, the car was 150 meters away from the point of impact. From this distance, the pedestrian is not yet expected to be seen, and the movement of the pedestrian does not pose an emergency as one can still change direction or speed. In the following pictures, typical situations connected with the assessment of hazard are presented.

Figure 4. shows the situation when the pedestrian walked to the middle of the road 4.5 seconds before the collision with the vehicle. The Volvo was 80-85 meters away from the point of impact. From this distance the pedestrian did not pose a dangerous situation because the vehicle with a normal brake manoeuvre can be stopped, before the hitting point.

Fig. 4. The mutual position of the participant's T – 4,5 sec

Figure 5. shows the next situation when the pedestrian reached the lane along which the Volvo car was travelling. The vehicle is then approx. 43-47 meters, pedestrian approx. 4-5 meters from the point of hitting. In this case, a vehicle with an intensive brake manoeuvre can be stopped.

Fig. 5. The mutual position of the participant's T – 2,5 sec

Fig. 6 depicts a simulated moment corresponding to Fig. 5. The vehicle is then approx. 20 to 25 meters from the collision site. From this distance the vehicle with an emergency brake manoeuvre cannot be stopped before the pedestrian's travel path.

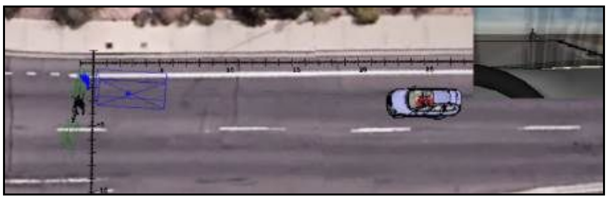

Fig. 6. The mutual position of the participant's T – 1,25 sec

Based on this, it can be stated that the pedestrian became visible to the human driver within the braking distance. The collision was inevitable with normal operation.

The next step was the investigation of the avoidance of the accident. On the basis of expert experience, a pedestrian who is in the area that is marked with different colours represents the danger to the driver. Figure 7 depicts a different area. The area of the vehicle which is marked with yellow, and the further area are the ones from which, in reality, it would be not possible for the human eye to detect a pedestrian, and in the case of an autonomous vehicle, an earlier detection, independent of the weather and visual conditions, is necessary. With proper detection, the vehicle could be halted by intensive braking before the path line of pedestrian.

Fig. 7. The expected detection distance

In the case under investigation, it may be established that the autonomous system was not functioning properly.

In the meantime, the preliminary report was completed. (National Transportation Safety Board, 2018). Based on the report, the system first registered the pedestrian about 6 seconds before the impact. First as an unknown object, as a vehicle, and then as a bicycle. At 1.3 seconds before impact, the self-driving system determined that an emergency braking manoeuver was attempted.

A significant part of new vehicles have an EDR (Even Data Recorder) system, from which accident data can be read with CDR Softwar. (Darts Group Homepage, 2018; Fourth Cdr User Summit Europe, 2017; Gazdag et al., 2018).

The braking did not happen because "according to Uber, emergency braking manoeuvers are not enabled while the vehicle is under computer control, to reduce the potential for erratic vehicle behaviour. The vehicle operator is relied on to intervene and take action. The system is not designed to alert the operator."

Based on the investigation of the avoidance of the accident, it can be stated that the detection and determining of the self-drive system was correct. According to own calcultions, the Volvo could have been stopped before the pedestrian's travel path, 2.5 to 6 seconds prior to the accident.

Fig. 8. The accident process in the case of adequate autonomous function

It can be calculated in case of 1,3 seconds before the occurrence, if, as a reaction point, the time when the pedestrian is seen on the video for the first time is chosen, or the self-drive system determined an emergency braking manoeuver, and 0.1-0.3 seconds of self-drive system "reaction time" and the slowdown of emergency braking is taken into consideration, then Figure 8 depicts the simulated moment. In the case under investigation, the pedestrian goes out of the path of the vehicle (time avoidance), but if the pedestrian had not even left the lane, then the speed of collision would have been one third of the real speed (about 18-25 km/h).

In the case of the second accident, before the collision, the Tesla was travelling at 104 $^{km}/_{h}$. Based on the damage pictures, the collision speed can be estimated - approx. 40-45 $^{km}/_{h}$. It follows that the vehicle decelerated before the collision. There is no information available that the self-drive system or the human driver brake the vehicle.

Based on the speed of travel and collision, the Tesla started breaking at approx. 45 to 55 meters before the point of the impact. Figure 9 shows the end position of the collision.

Fig. 9. The end position of the collision

Figure 10 shows the start of braking.

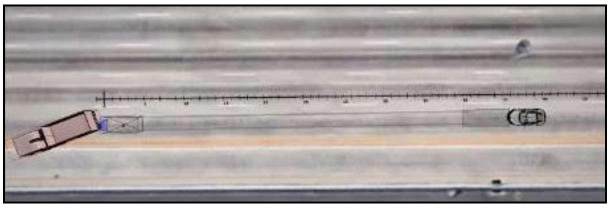

Fig. 10. The beginning of the car's braking T = -2,5 sec

Taking into account the reaction times, if the self-propelled system had started to brake, then the stationary car would have become recognizable 50-60 meters before the collision, if the human driver had recognized the emergency, then the reaction point would have been approx. 73 to 78 meters.

Following the breaking, the Tesla car collided with the left rear corner of the fire truck.

After the likelihood of the avoidance of the accident was calculated.

In order for the Tesla car to stop safely behind the fire truck the self-drive system should have recognized the danger before the point of impact approx. from 62 to 67 meter, the human driver approx, from 82 to 87 meter. Figure 11. illustrates the breaking process with human reaction time.

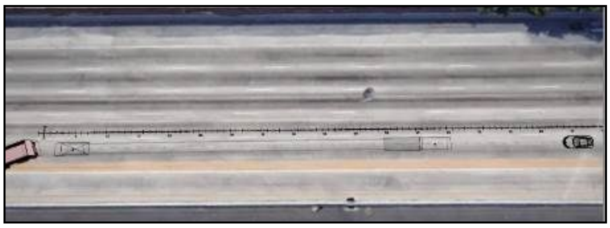

Fig. 11. The case of the safely standstill of the Tesla

It can be stated that the autonomous system detected the obstacle but approx. 15-20 meters, and approx. 1 to 1.5 seconds earlier would have been necessary to detect an emergency.

4. Conclusion

In the first case, the self-propelled system was detected in time but the system did not operate because the emergency brake function was switched off, in the second case, the delay of the detection could be calculated.

In the first case, a human driver could not have escaped the incident because the perceived of the bicycle – subject to visual conditions –was possible only within the braking distance. In addition to properly functioning self-drive vehicle function, the collision could have been avoided.

In the second case, either a human driver or a car with the properly functioning self-driving function could have avoided the collision. As the accident occurred, therefore the self-driving function of the vehicle did not work properly.

In addition to the steady increase in the number of vehicles, the reduction of traffic accidents can only be achieved by the means of the widespread introduction of driving support systems and autonomous vehicle functions. However, the marketing messages of vehicle manufacturers should not lead to excessive expectations with the vehicle's self-driving capabilities, thus creating a false sense of security for an average driver.

It is important to emphasize, that the autonomous vehicle functions have to be provided at least the spatial and temporal emergency expected of the human leader irrespective of conditions of weather and vision conditions.

Acknowledgements

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自动驾驶汽车的不规则操作

關鍵詞
事故重建，自动驾驶汽车
，
自驾车
紧急
车辆运动模拟

摘要
今天，随着车辆自主功能的普及，强调了引发事故的责任。自导功能在某些交通情况下起作用，但事故发生，因此，下面的文章提出了对该问题的分析。其目的是表明具有自动驾驶功能的车辆不能提供车辆制造商建议的驾驶员安全水平。在这篇文章中，最近的四个事件和一个分析是否可以避免这些事故是一个人类驱动因素，或者它们是如何发生的，具有适当的自我驱动功能。在每个调查的案例中，涉及具有自驱动功能的车辆。在对事故的评估和评估的基础上，得出结论，当前的自行式车辆是否提供了驾驶员和社会对这些车辆的期望。
在车辆模拟程序的帮助下说明事故过程的重建，特别强调所得到的参数，特别是避免事故。