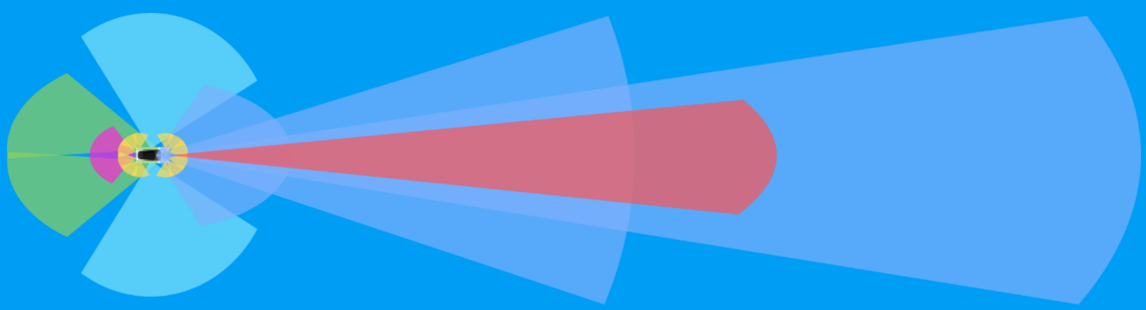
HOCHSCHULE RUHR WEST
UNIVERSITY OF APPLIED SCIENCES

INSTITUT **INFORMATIK**

Internal Report 17-04

Functionality, Advantages and Limits of the Tesla Autopilot

Thorsten Tatarek, Jan Kronenberger, Uwe Handmann



Functionality, Advantages and Limits of the Tesla Autopilot

Thorsten Tatarek, Jan Kronenberger and Uwe Handmann

Abstract—Autonomous driving is one of the future visions in which many vehicle manufacturers are working with high pressure. Nowadays, it is already supported partially by high-class vehicles. A completely autonomous journey is indeed the goal, but in cars for the public road traffic still not available. Automatic lane keeping assistants, speed regulators as well as shield and obstacle detections are parts or precursors on the way to completely autonomous driving.
The American vehicle manufacturer Tesla is not only known for its electric drive, but also for the fact that high-pressure work is carried out on the autonomous drive. Tesla is thus the only vehicle manufacturer to use its users as so-called beta testers for its assistance systems. The progress and the function of the currently available Model S in the field of assistance systems and autonomic driving is documented and described in this paper. It is shown how good or bad the test vehicle manages scenarios in normal road traffic situations with the assistance systems, e.g. lane keeping assistant, speed control, lane change and distance assistant, and which scenarios can not be managed by the vehicle itself.

Index Terms—Tesla Motors, Autopilot, Advanced Driver Assistance Systems, HRW.

1 Introduction

This technical report describes the features and limits of current advanced driver assistance systems exemplified by a 2016 Tesla Model S with the v8.1 firmware (more at section 4.1). This electric car is equipped with a lot of sensors (section 4.2) and uses highly advance algorithms to solve several tasks autonomously like automated cruise control, lane-changing and parking (more see in section 6).
Advanced driver assistance systems and autonomous cars are getting more and more important. In 2016 nearly 400.000 people were injured in car accidents in Germany (3206 of them deadly) [1]. Although the number of accidents and (deadly) injured people is decreasing over the last years [2], there are still a lot of accidents which could have been prevented. Most of the last years reduction is due to passive safety systems like more stable cars or multiple airbags. Modern cars already have some active assistance systems like autonomous emergency brake. To further reduce this high amount of accidents these systems have to be develop even more leading to autonomous driving cars. In 2014 a standard has been released to measure the autonomy of cars.

1.1 Autonomous driving levels

The levels are defined in the SAE INTERNATIONAL STANDARD J3016 (updated January 2014) and shown in figure 1. They describe the amount of autonomy and what tasks are done by the car itself.
Current cars can reach level 2 . They are capable of self driving on country roads and highways in normal situations. The human driver still has to control the systems and may overwrite the control inputs. But there are level 3 cars coming in the near future [3]. They will be capable of driving same special situations without the driver being in charge to monitor the road. The complexity to reach the next higher level increases exponential.

	Name	Description
Human driver monitors		
0	No Automation	The driver is performing all driving events.
1	Driver Assistance	The system can steer or accelerate/ decelerate, but the driver is expected to do all other aspects of driving.
2	Partial Automation	The system can steer and accelerate/ decelerate, but the driver is expected to do all other aspects of driving.
Automated system monitors		
3	Conditional Automation	The system can perform automatic but can expect the human driver to intervene if needed.
4	High Automation	The system can perform automatic and has to continue being automatic even if the driver does not react.
5	Full Automation	The system can perform automatic under all conditions a human driver can do.

Fig. 1: Autonomous drive levels defined by SAE INTERNATIONAL STANDARD J3016 [4]

2 Development

1925: Francis P Houdina via Radio Control traveled up Broadway and down Fifth Avenue through the thick of the traffic jam. The so called American Wonder a 1926 Chandler was equipped with a transmitting antennae on the tonneau[1]

1. hard or soft cover used to protect unoccupied passenger seats

and was operated by a second car that followed and controlled the car by radio impulses.

1939: GM Pavillion Futurama at the NY Worlds Fair, future of autonomous driving by automated highways for electric cars through inductive electromagnetic fields embedded in the roadway [5].

1953: RCA Labs built a miniature car guided by wires on the laboratory floor, 1958, a full size system was successfully demonstrated in Nebraska. Also, 1958 GM showcased a Firebird III with electronic guide systems by inductive highways.

1980s vision-guided Mercedes-Benz robotic van, designed by Ernst Dickmanns and his team at Bundeswehr University Munich, Germany developed and built the VaMoRs (**V**ersuchsfzg. für **a**utonome **Mo**bilität und **R**echnersehen / engl. Test-vehicle for auto-motive mobility and computer visualization). Steering, acceleration and brakes are controlled by computers, 5kW generator and hydraulic power unit. Two computer racks are built in the Kastenwagen Daimler-Benz L 508 D [6].

1987: First autonomous high speed driving tests with max. speed $96^{km}/_{h}$ on closed highways near to München-Dingolfing. They drove 20 km without operator intervention.
At the same decade DARPA-funded **A**utonomous **L**and **V**ehicle (ALV) project started in the US.

1987-1995: EU Project Prometheus (100 years of automotive) **Pro**gra**m** for an **e**uropean **t**raffic of **h**ighest **e**fficiency and **u**nprecedented **s**afety started with about 749 Million Euros [7] support money. Stop and Go driving behind other cars, start of autonomous driving on real driving scenarios. DB Car Vita built in Bundeswehr University Munich Vision-Software.

1994: Two Mercedes 500 SEL equipped with cameras front and back (each two, 1 wide and 1 tele objective) tracking of 5 vehicles, called VaMP Project

1994: Final presentation of Prometheus in Paris, autonomous driving in one lane up to top-speed $130^{km}/_{h}$, autonomous following (ACC) and autonomous lane change.

2004: DARPA Challenge founded by the US military with no car reaching the finish-line.

2005: Robotic vehicle ”Stanley” made by Google's self driving car project leader together with the Standford University won the DARPA Grand Challenge.

2015: Tesla Model S starts with semi autonomous piloting.

2016: Tesla builds hardware into cars with the capability of full self-driving [8].

3 State of the Art

There are currently two different ways to go when developing (semi-)autonomous cars. The first option, which is currently done by Tesla and the most established car manufactures, is to keep the human driver as a central aspect of the driving process but to continue helping the driver while he is driving or to manage some specific situations autonomously when the driver wants to (but still with the human driver as fall-back possibility). The other way is to completely take any control from the human driver by for example removing the steering wheel and pedals and letting the car be driven completely by itself. One example company trying to accomplish this is Waymo[2].
For the first option with many subsystems there are multiple car suppliers which develop currently used hardware for semi-autonomous driving. Some examples are MobilEye[3], Continental[4], Bosch[5], Tesla[6], Kostal[7], ZF[8], Hella[9], Delphi[10] and Valeo[11]. They all develop sensors and functions which are used in current cars. In 1999 Handmann et al. [9] presented a system covering the whole surroundings of the vehicle. Their algorithms for classification and tracking are mostly adapted for today driver assistance functions. The functions include automatic lane keeping, adaptive cruise control, emergency braking and driver observation. But these are some sort of sub-functions of autonomous driving. In order to drive completely autonomous as mentioned in the second way the car has to know its whole surroundings and should plan its path of driving based on this instead of only the lane markings or leading cars.
The Google self-driving car does this by using a 360° Laser scanner on its roof. Google is working on the future vision of autonomous driving cars since 2009. Since December 2016, Waymo is the autonomous car development company spun out of Google's parent company, Alphabet Inc. It took over the self-driving project with the called mission ”a new way forward in mobility”.
As said, Google (or Waymo) is equipping cars e.g. a Lexus RX450h with 360° LIDAR systems [10] with a Velodyne 64-beam laser. The laser generates 3D maps of its surrounded environment [11]. Waymo is doing fleet tests with several cars as of June 2016, Google had test driven in autonomous mode for a total of $1,725,911$ miles (2.777.585 km). So far with ”only” 14 involved collision, in which human drivers were at fault 13 times [12]. Google is trying to allow public access to the prototypes to let public people test there systems on their way to work and home.
Conventional car producers focus on making the driving task for humans easier. Recent driver assistant systems include helping on a evasive maneuver [13] or Efficiency assists [14]. Daimler therefore equips their most advance cars with many sensors, even more than Tesla does [15].

2. https://waymo.com/
3. http://www.mobileye.com/en-us/
4. https://www.continental-automotive.com/
5. http://products.bosch-mobility-solutions.com/
6. https://www.tesla.com/autopilot
7. https://www.kostal-automobil-elektrik.com/
8. https://www.zf.com/
9. https://www.hella.com/
10. https://www.delphi.com/
11. http://www.valeo.com/

But they do not focus only cameras, they mainly use radar systems. The most advance system has a stereo camera and is called *6D Vision* [16].
Currently the cars are learning from the driver and share their experience with the other cars [17]. This will help building a near live map of the world to help autonomous car react to situations they can't even see or measure.

4 Technical Data

The car is capable of full autonomous driving using the NVIDIA DRIVE PX 2 AI computing platform. Equipped with eight cameras (positions mentioned in figure 4), a radar sensor facing to the front and ultra sonic sensors at the front and back, the Tesla is theoretically capable of a full self-driving mode.

4.1 The car we used

Our test vehicle for this paper was a Tesla Model S 60D which is illustrated in figure 2. It is equipped with the Autopilot 2.0 hardware and uses software *v8.1*.

Fig. 2: Our Tesla Model S

4.2 Sensors

Tesla equips all their current and future cars with basically the same sensors. They use 8 cameras, one radar and 12 sonar sensors (See table 1). The Autopilot is mainly based on the vision systems, but the radar is capable to view on difficult weather conditions like fog, rain or dust.
Their first cars were equipped with less sensors (see figure 3). There were only one front-facing camera and radar as well as 12 ultrasonic sensors.

Sensor	Application	Range
Radar	Cruise Control, AEB [12]	160m
Forward Main Camera	LKA[13], AEB, TSR[14], ...	150m
Forward Wide Camera	Traffic Lights	60m
Forward Narrow Camera	Cruise Control	250m
Forward Side Camera	Side Collision Warning	80m
Rearward Side Camera	LCA[15]	100m
Rear-view Camera	Reverse Driving	50m
Sonars	Parking, LCA	8m

TABLE 1: List of the used sensors [18]

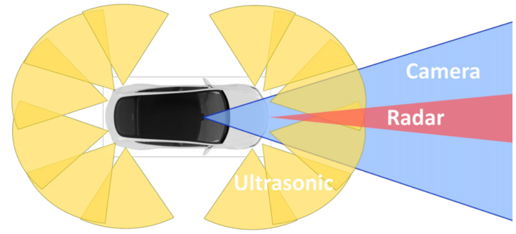


Fig. 3: Sensors at the Tesla Autopilot 1.0

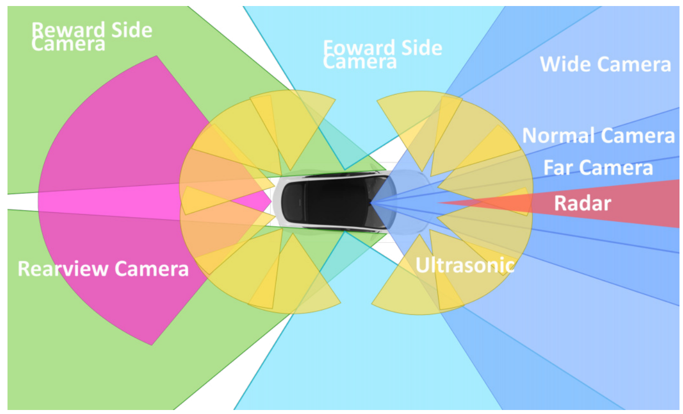


Fig. 4: Sensors at the Tesla Autopilot 2.0

5 Test environment

Here we describe how the car was set-up to perform out tests and what kind of tests we made.

5.1 Documentation

In order to reconstruct our test results we recorded them and written down everything that happened. This also helps to keep track of changes in the cars performance.

5.1.1 *Video*

For the documentations, we started with one GoPro Hero 3+ mounted at the roof in the inside of the car looking forward. We filmed the steering wheel, the street directly in front of the car and the display behind the steering wheel.
We planned to use more cameras from the start of the project, but had to wait for the deliveries.
When they arrived and after some test with one camera, we installed the planned setup seen in figure 5. This setup uses four GoPro Hero 5 Sessions and one GoPro Hero 5 Black. Two of the GoPro Sessions are mounted next the the back mirror at the front window looking forward left and right seen in figure 6 the two lower pictures. One Hero Session is filming only the instrument cluster behind the steering wheel. The last GoPro Hero 5 Session is filming our test scenarios during target tests from the outside.
The GoPro Hero 5 Black, is mounted at the roof in the inside where the single Hero3+ was mounted to film the

interior. We decided to use a better GoPro here, for better dark light videos and for the possibility to use the internal GPS signal for gauges and documentation of the test-routes. Like mentioned before, the view of the cameras in our setup is shown in figure 6.
For the environment around the vehicle we use a Garmin VIRB360 360° standalone camera mounted on top of the Tesla (see figure 7).

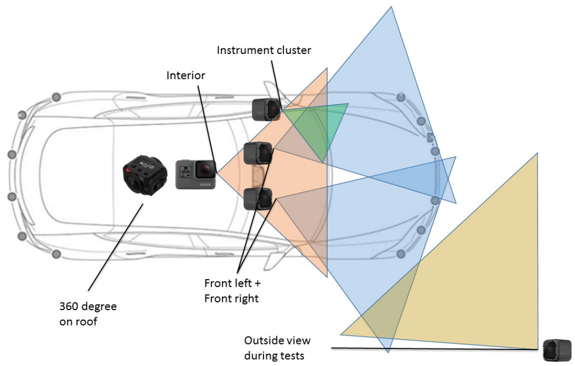


Fig. 5: Our camera setup


Main Display


Overview


Front left


Front right

Fig. 6: View of the GoPro Cameras

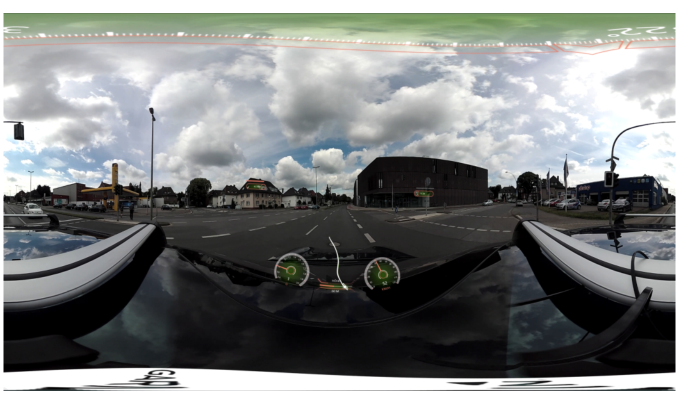


Fig. 7: 360° camera on the roof

5.1.2 Forms

We created two forms (Figure 8) which could be filled out during driving on the road by the co-driver to keep track of the latest happenings.

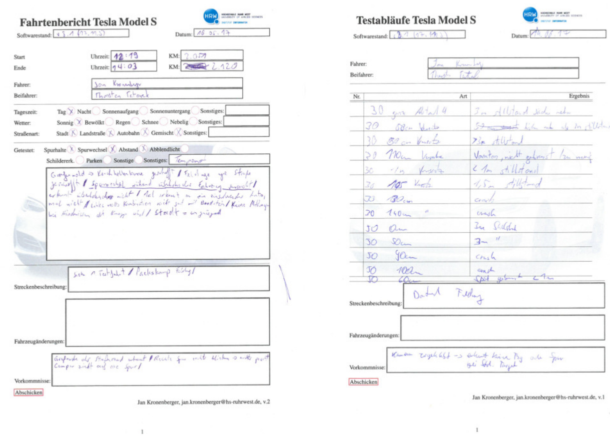


Fig. 8: Our Formulas

5.2 Target

As our target we used some foam with a poster glued onto it (see figure 9). The poster was a photograph made of the back of the Tesla printed at original size. We use the foam target for breaking and identification/detection tests of "standing cars" without damaging other cars or the Tesla itself. We planned several test scenarios for these tests and filled up our test-list notepads. For example we use the activated autopilot mode driving with different speeds ($10, 20, \ldots {}^{km}/_{h}$) and different angles to the car (directly behind/shifted half/shifted only mirror). Same without autopilot mode.

Fig. 9: The target in front of our car

5.3 Test Scenarios

For testing different scenarios in various environments we created some diversified routes (see figure 10). For some scenarios which should or can not be tested on public roads we had to find straight roads with no traffic.

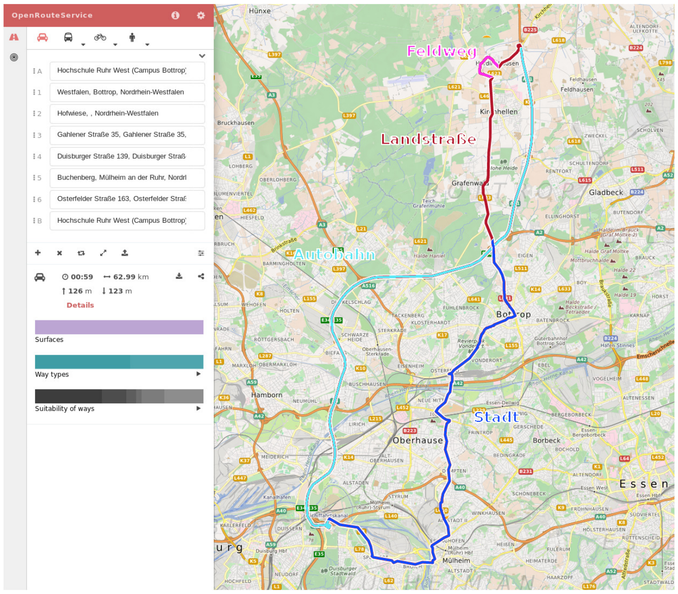


Fig. 10: Our main testroute

5.3.1 *Highway*

Our highway route is 28 km long and contains two highway intersections and two entries/exits. Half the time the route has three lanes, the other half with two lanes each direction. Most times there is no speed limit but at the end there is a section limited to $120^{km}/_{h}$. This makes the route perfect for testing scenarios with cars driving different speeds.

5.3.2 *City*

We drive through the cities Mühlheim, Oberhausen and Bottrop. The whole trip is 24 km long. There are some special places like a tram in the center of the road, very tight curves, cars parking on the road and interesting lane changes.

5.3.3 *Countryside*

In the north of Bottrop we drive on countryside roads for about 16 km. This includes a small track across the fields where are no lane markings and rapidly changing lightning conditions.

5.3.4 *Braking*

For test with our foam-target (section 5.2) we selected a route in Oberhausen where there is no traffic. The surface is very new which is perfect for braking.

6 Driver Assistance Systems

Due to Tesla's OTA[16] updates the software can get new features any time. The first tests were done with version v8.1 (17.11.3). In the subsections for every function the possibilities are divided by the software version.

16. Over the air

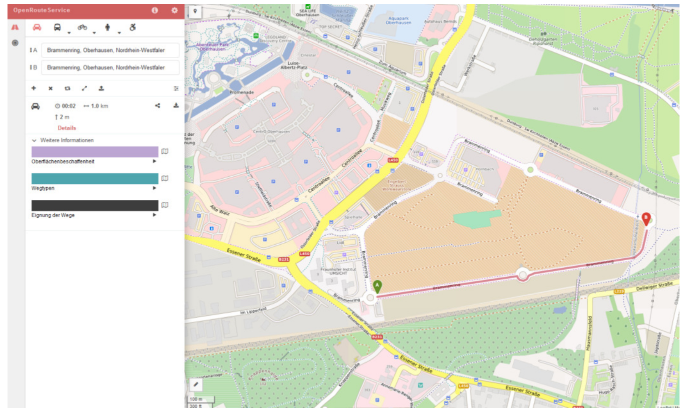


Fig. 11: Test-route for braking tests

6.1 Lane Keeping

The Lane Keeping System is activated by pulling the cruise control lever towards the driver twice. It is only possible to activate when lanes are detected which will lead to a gray steering wheel being displayed in the instrument panel. When activated the icon will get a blue background and a notification sound will be played.

v8.1 (17.11.3)

The detection of the lanes works very well when there are clear markings. But even when the markings are not that clear the lane can be detected. Even grass scars can be detected. When a curve is to tight (mainly on highway entries and exits) the lanes cannot be detected for sure. We experienced some strange behaviors which we will explain in the results.

v8.1 (2017.28.4 cf44833)

The lane keeping is more stable now and seems to follow leading cars if the lane markings are bad. The leading car in the dashboard will become blue then.
The distance to curbstones is much bigger now which increases the trust in the system.
But now grass scars are now longer detected. This worked perfect in the versions before.

6.2 Lane Changing

This system can automatically change lanes on highways when the driver actives the indicators and a stroked lane marking is detected in direction of the indicators.

v8.1 (17.11.3)

In this version the lane change works quite well, but the Model S uses only the ultrasonic sensors to observe its surroundings. Traffic which approaches from behind with a much higher speed won't be detected. This behavior is explained in section 7.5.
Other cars driving the same speed next to the Model S will be detected through the ultrasonic sensors which will prevent the lane change.

v8.1 (2017.28.4 cf44833)

In this version the lane change seems to work more smoothly and faster. The oncoming traffic is still not detected.

6.3 Cruise Control

The cruise control adapts the speed of the Model S to the traffic. It uses to forward-looking camera to detect obstacles in front. The distance to the leading vehicle can be selected by the driver. In the instrument panel a car icon will be displayed if one is detected. The visualization depends on the distance and offset. Multiple vehicles can be displayed as well.

v8.1 (17.11.3)

On clear conditions cruise control works very reliable. But there are two main situations where the car reacts not as expected. Because the Tesla reacts only vehicles which are on the ego lane the performance depends on the lane detection. On sharp curves on the highway/autobahn the Tesla sometimes incorrectly recognizes cars from the neighbor lane in its own. The results to unexpected braking.
One special occurrence is described in section 7.5.

v8.1 (2017.28.4 cf44833)

The maximum speed in cities can be set to more than $50^{km}/h$ (if allowed). But limit sign are not detected, the car gets the maximum speed based on a map information.

6.4 Sign recognition

Sign recognition is not supported yet.

6.5 Parking guidance

v8.1 (2017.28.4 cf44833)

We briefly tested the automatic parking system for parallel and lateral parking spaces. It worked quite well for both. After driving past the parking space, the Tesla shows a P-symbol in the cockpit. To activate the automatic parking system, its necessary to shift into the reverse gear and press "start" on the display during full screen rear-camera mode. The Tesla drives automatically into the parking space, steering and speeding by itself. To adjust the position the Tesla drives back and forth till standing straight.

6.6 Front Collision warning

The front collision warning system warns about slow or still standing traffic in front of the car only. Because we used a Target made of foam the radar cannot detect it. For the front collision warning, the autopilot is not necessary to be activated.

v8.1 (17.11.3)

When approaching another still standing car, the Model S will detect it and visualizes it in the display. At a certain TTC[17] the car in the instrument panel will be colored red and a warning sound is played.
With an activated autopilot mode, the Tesla recognizes the target car and slowly reduces the speed by itself.
But the system is limited for different speeds and offsets to the target. When driving very slow speeds lower than $20^{km}/h$ the car is capable to brake even if there is an offset about 100 cm. When there is more offset (but the front lights still overlap) the Tesla can't stop safely during auto-piloting and approaching to the car. Increasing the speed this possible offset decreases. At $50^{km}/h$ a maximum of 50 cm is possible.
When driving faster than $80^{km}/h$ the Tesla might not stop completely but it will reduce the amount of the impact while approaching to an "standing" car like traffic jam. Above $90^{km}/h$ sometimes no braking occurs, only a warning sound appears.

6.7 Side Collision warning

v8.1 (17.11.3)

As seen in section 6.2 the rear and side cameras do not work in this version. The side collision warning will only rely on the ultrasonic sensors.

6.8 Automatic Emergency Braking

This function is to decrease the amount of a frontal impact. It may can prevent a crash but this shouldn't be trusted. Its focus is on the manual drive mode because the Autopilot will decrease the speed much earlier when a leading car is detected. Some test-results are explained in section 7.6. This feature is currently deactivated [19].

v8.1 (17.11.3)

Does not work in this version. The ego car just reduces the speed in case of an activated piloting mode.

v8.1 (2017.28.4 cf44833)

The Emergency braking was introduced in this version. In the manual it is mentioned that the emergency braking system works between $8^{km}/h$ and up to $150^{km}/h$ speed. The Tesla recognized the possible upcoming collision, warns the driver with a sound and perform the emergency braking by itself. Test results are mentioned in 7.6.

6.9 Auto High Beams

This feature uses the front facing cameras to detect other cars and deactivates the high beams if needed. It works only in the night and was not tested.

6.10 Fleet learning

With the information gathered from the car every Tesla in the world will improve in certain conditions [20] and vise versa. Therefore every Tesla uses its radar sensor to build a point cloud map while driving. All point clouds from each Tesla are now combined to be accessibly to every Tesla car.

17. Time To Collision

7 Results

Because the Tesla Model S is sold with certain features we expected to work we only present some results where the systems failed or worked even we did not expect.

7.1 Detection failure

This failure happened only once with version *v8.1 (17.11.3)*. When approaching a standing Truck the Tesla did not detect it (no vehicle visible in the instrument display [see figure 12]) and continued driving with $50^{km}/_{h}$. The driver had to brake completely by himself.

Fig. 12: Truck scenario

7.2 Tram detection

As seen in figure 13 the Tesla can even detect the back of a tram, keep constant distance and follow it. The tram rails are no problem for the lane detection.

Fig. 13: Tram scenario

7.3 Expanding lanes

Sometimes the Tesla chooses the wrong path when there are expanding lanes. Especially when the ego lane does not go straight forward. One example is shown in figure 14. With the newest software version we cannot reproduce this behavior. This can relay on updates in the software or due to the learning process explained in section 6.10.

7.4 Merging lanes

When driving with the Autopilot activated the car cannot merge lanes automatically. Instead, it continuous driving straight forward through the keep-out area without any message or deactivating the autopilot. In figure 15 the driving paths are visualized.

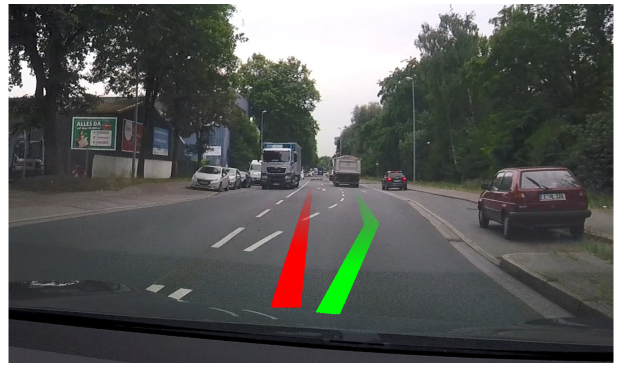


Fig. 14: Failure of expanding lanes. Red is the path the Tesla drove with Autopilot on, green is the path the Tesla should drive

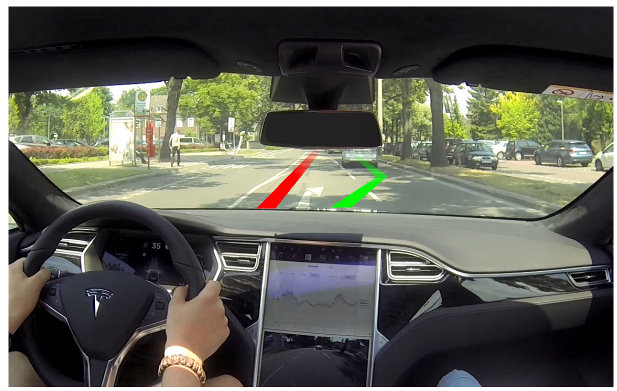


Fig. 15: Failure of merging lanes. Red is the path the Tesla drove with Autopilot on, green is the path the Tesla should drive

7.5 Detecting lane changer

To be recognized on the ego lane a car has to be on the ego lane with quite a high amount. When only one wheel is on the ego lane the Tesla Model S won't brake. If the driver does not intervene this can result with a collision.

7.6 Automated Emergency Brake

v8.1 (17.11.3)

The "automated emergency braking" and the approach on leading vehicles using the autopilot work only with a quite small offset to the target and only with an activated cruise control. When the offset between the ego car and the target are too big the Tesla Model S will not brake.

v8.1 (2017.28.4 cf44833)

With the software update, the Tesla is capable of a real automated emergency braking in case of an upcoming collision. We tested a frontal crash without offset on a not moving target. The results distinguish a lot on the ego cars speed. While the car could prevent every crash (we tested) driving at speeds lower than $25^{km}/_{h}$ or about $35^{km}/_{h}$ up to $50^{km}/_{h}$ speed. the Tesla could not prevent crashes at a speed of $30^{km}/_{h}$. At $30^{km}/_{h}$ and with $60^{km}/_{h}$ the automated emergency braking didn't work correctly and would lead to (mighty) damage on both cars. We didn't tested the system at speeds higher than $60^{km}/_{h}$.

8 Conclusion

As the software of the Tesla Model S is updated every few weeks this conclusion is only based on our experiences we made with the firmware *v8.1.*

The experiences during testing are extensive. During highway driving, most of the time the Tesla managed it quite well. Except the named problems with autonomous lane changing while a car is overtaking on the destination lane, there was no major incident.

But there is still some work to do. As there are many small mistakes possible at any given time the human driver has to be patient every time to act as fall-back system. So the Autopilot is a system which can help the human driver to keep distance or stay in lane but it does not work without an observer which can overtake.

Nevertheless the used systems show very good what the current state-of-the-art techniques are in advance driver assistance and how they could be applied. We are very excited about new features being released and how the whole market is evolving.

References

[1] S. Bundesamt. (2017) Polizeilich erfasste unfaelle. Website. [Online]. Available: https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/TransportVerkehr/Verkehrsunfaelle/Tabellen/UnfaelleVerunglueckte.html?nn=50922

[2] ——. (2017) Polizeilich erfasste unfaelle. Website. [Online]. Available: https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/TransportVerkehr/Verkehrsunfaelle/Tabellen_/Strassenverkehrsunfaelle.html

[3] M. Taylor. (2017) The level 3 audi a8 will almost be the most important car in the world. [Online]. Available: https://www.forbes.com/sites/michaeltaylor/2017/09/10/tthe-level-3-audi-a8-will-almost-be-the-most-important-car-in-the-world/#3caf07d0fb3d

[4] S. INTERNATIONAL, "Levels of driving automation," SAE INTERNATIONAL, Tech. Rep., 2014. [Online]. Available: https://www.sae.org/misc/pdfs/automated_driving.pdf

[5] R. OToole, *Gridlock: Why Were Stuck in Traffic and What to Do About It*, 2009, pp. 189–192.

[6] A.-F. Web. (2012) Geschichte des autonomen fahrens. [Online]. Available: http://www.autonomes-fahren.de/geschichte-des-autonomen-fahrens/

[7] A. Oagana. (2016) A short history of mercedes-benz autonomous driving technology. [Online]. Available: https://www.autoevolution.com/news/a-short-history-of-mercedes-benz-autonomous-driving-technology-68148.html

[8] T. full self-driving capability. (2016) Teslas software timeline for enhanced autopilot transition means full self-driving capability as early as next year. [Online]. Available: https://electrek.co/2016/10/20/tesla-enhanced-autopilot-full-self-driving-capability/

[9] U. Handmann, T. Kalinke, C. Tzomakas, M. Werner, and W. Seelen, "An image processing system for driver assistance," *Image and Vision Computing*, 1999.

[10] What is lidar? [Online]. Available: https://oceanservice.noaa.gov/facts/lidar.html

[11] E. Guizzo. (2011) How google's self-driving car works. [Online]. Available: https://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works

[12] C. Osborne. (2015) Google's autonomous car injuries: Blame the human. [Online]. Available: http://www.zdnet.com/article/googles-autonomous-car-injuries-blame-the-human/

[13] MercedesBenz. (2017) Intelligent drive next level as part of driving assistance package. [Online]. Available: https://www.mercedes-benz.com/en/mercedes-benz/innovation/with-intelligent-drive-more-comfort-in-road-traffic/

[14] Audi. Audi driver assistant systems. [Online]. Available: https://www.audi-technology-portal.de/en/electrics-electronics/driver-assistant-systems/

[15] M. Jordan. Die neue s-klasse: Vorab mehr details. [Online]. Available: http://blog.mercedes-benz-passion.com/2012/11/die-neue-s-klasse-vorab-mehr-details/

[16] U. Franke, S. Gehrig, and C. Rabe. 6d vision. Daimler. [Online]. Available: http://www.6d-vision.com/

[17] Fortune. How tesla is ushering in the age of the learning car. [Online]. Available: http://fortune.com/2015/10/16/how-tesla-autopilot-learns/

[18] Tesla. Tesla autopilot. [Online]. Available: https://www.tesla.com/autopilot

[19] P. Olsen. (2017) Tesla turns off automatic emergency braking in some newer models. [Online]. Available: https://www.consumerreports.org/car-safety/tesla-turns-off-aeb-in-some-models/

[20] Tesla. Upgrading autopilot: Seeing the world in radar. [Online]. Available: https://www.tesla.com/de_DE/blog/upgrading-autopilot-seeing-world-radar

Impressum

Internal Report 17-04

ISSN: 2197-6953

1. Auflage, 31.12.2017

Anschrift

Institut Informatik

Hochschule Ruhr West

Lützowstraße 5

46236 Bottrop