Measuring method for function and quality of automated lateral control based on high-precision digital ”Ground Truth” maps

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Abstract

Advanced driver assistance systems (ADAS) of longitudinal control are widely used. In contrast to longitudinal controls, lateral controls are a growing market since this technique plays a major role in a successful introduction of automated driving. Customer and benchmark studies conducted by the University of Applied Sciences Kempten and Consline AG have clearly shown that the vehicle behavior and customer experience such as tracking performance, driver-vehicle interaction, availability, degree of stress and the sense of security of today’s lane keeping assistance systems are consistently rated as extremely unsatisfactory [14]. As a consequence, there is a moderate level of trust and low customer acceptance. A new measuring method based on high-precision and accurate digital maps (ground truth) was developed. With this method, analysis of the entire chain of action, from sensor to tracking is possible. Position, direction and motion of the vehicle and its reference distance to road markings can be precisely measured in the digital map using a high-precision inertial measurement system (IMU) with RTK-DGPS and SAPOS correction service. The measuring method can be used in particular on public routes, since test areas are still insufficient due to the very small tracks and driving maneuver variations for lane keeping assistance systems. For a precise assessment of the sensor, planning and control performance as well as the overall driving characteristics, a very precise knowledge of the routes and the route excitation is required. For this purpose, high precision and accurate digital maps (ground truth) of real tracks were generated. A roof mounted stereo camera system combined with an RTK-DGPS IMU was used to provide offline-generated digital maps with high precision in the OpenDRIVE or OpenStreetMap format, as well as other common simulation formats like IPG CarMaker. In order to be able to carry out the dynamic driving evaluation as well as the simultaneous evaluation of the sensor, planning and control performance in the digital maps in real time, a route format with a regular grid, based on OpenCRG (Curved Regular Grid), was further developed. An IMU with RTK-DGPS and correction service (e.g. SAPOS) provides in real time the highly accurate position, direction and movement of the ego vehicle of up to two centimeters in the lateral and longitudinal direction. In addition, a special measuring steering wheel was built to objectify the driver-vehicle interaction, in particular the steering torque curve and the tracking. Particular attention was paid to the reuse of the original steering wheel with all functions, such as airbag, operation and hands-off detection. The novelty is the ability to measure the recognition, planning and control performance of environmental sensors, algorithms and controllers compared to the reference ”Ground Truth”. In addition, the driving characteristics of the entire vehicle can be assessed in terms of its tracking performance, driver-vehicle interaction, availability, degree of relieving and a sense of security. Another novelty is the consistent use of digital maps in driving tests as well as in the MIL / SIL / HIL simulation as a digital twin.

1 INTRODUCTION

Advanced driver assistance systems (ADAS) classified into SAE-level 1 and 2 support the driver in its task to control the vehicle in lateral and longitudinal direction [15]. For that a lanekeep assistant system (LKAS) which is already used in field, keeps the car in the actual lane by actively intervene in steering. The information about localization are provided by camera or LIDAR (light detection and ranging) [19]. Different customer and benchmark studies, conducted by the University of applied science Kempten have shown that customer's stress level increases while driving with activated LKAS [14]. To enhance customer‘s approval for ADAS and autonomous driving (AD) it is strictly indispensable that the drivers safety feeling increases, while his stress level decreases simultaneously. To transform common ”fun to drive” into ”fun to be driven” it is necessary to fulfill the following hypothesis, shown in figure 1.

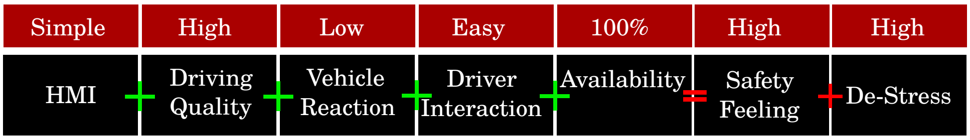


Figure 1: Hypothesis to convert ”fun to drive” into ”fun to be driven”.

Only a system which enhances drivers' safety-feeling and reduces the stress level, confidence will increase and the driver will use such systems. If functions are not fulfilling these criteria, users will continuously drive without using ADAS [1]. Thus, it is necessary to define objective parameters on which a system can be evaluated on. At numerous expert workshops, benchmark tests and measuring campaigns, relevant attributes for the LKAS (type 2) were systematically and structurally developed. The subjective and objective characteristics of such were transferred and linked to a so-called level model, consisting of subjective customer evaluation, subjective expert evaluation and objective characteristic key performance indicators (KPI). At the top customer level the main criterias are lane tracking quality, edge guidance, driver-vehicle interaction, availability, de-stress, sense for safety and human-machine-interface (HMI). These criterias are more detailed on an expert level. The objective level describes the subjective parameters of the abovementioned levels in a mathematically way, which can be used as input for the common V-model [2]. A schematic representation is shown in figure 2.

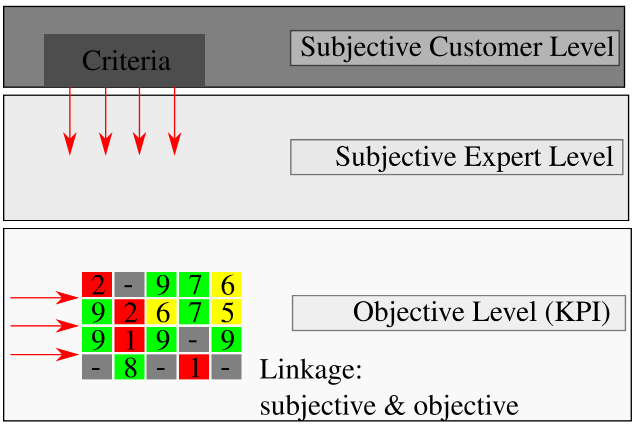


Figure 2: Layer based evaluation model from subjective to objective level.

1.1 Formulation of the problem

Unfortunately, there is still no proving ground available that is needed to evaluate a realistic behavior of ADAS. For the evaluation of LKAS, a high knowledge of the road is essential. While increasing the complexity of ADAS, test effort has risen to a level that can no longer be performed in real driving tests [18]. For that it is strictly necessary that a digital proving ground including realistic attributes such as downward slopes, declensions, shadows etc. is still used for simulation. Stringent definded quality-requirements for ADAS/AD functions are required for developing and homologation. In 2018, there is no law that describes the minimum quality requirements for an ADAS in SAE-level 2. A deeper look on the system reveals that the systems react and behave unpredictably. One reason for this may be that the sensor does not sufficiently detect the given situation/environment. For this purpose, a reference measurement must be carried out under real conditions using sensors with factor n higher resolution than the system under test.

1.2 Solving of the problem

A new format for ultra high precise maps were developed which can be used for the real driving test as well as for the simulation in a so called ”digital twin”. Digital twins of any road can be created whilst being offline. Additionally, it is possible to rate sensor performance and the quality of detection by using merged information from map and intertial measuring unit (IMU). For an estimation of the sensor performance, comparison of the sensor output and reality can be made. All used driving maneuvers to evaluate ADAS as a system have been developed, that a test drive can be carried out under real traffic conditions. Unpredictable events and real (critical) situations can be measured.

2 STATE OF THE ART

2.1 Lane Keeping Assistant Systems

Two categories of lane keeping assist systems are available. The non-steering system (e. g. LDW) provides visual, acoustic and haptic feedback if an unwanted lane departure might happen. On the other side, the second category are lane keeping assistant systems (LKAS), which can be devided into two subtypes. Type 1 does not support active steering in the center of the lane however the steering torque strongly increases at the edges of the lane – known as edge guidance. Due to that, a large control free corridor is created and the vehicle is returned only when approaching the lane boundary. In contrast to that, type 2 LKAS provides continuous support-steering-torque even if driving in the center of the lane. The provided torque increases slowly as a function of distance to the center of the lane – known as center guidance. Here, the control corridor is kept narrow and the resulting torque distribution is similar to a bathtub. Figure 3 shows the expected steering behavior for different LKAS types. The information about ego-localization as well as lane-information are provided mainly by using a monocular camera. The functionality of an LDW is given in both LKAS-types as well [4].

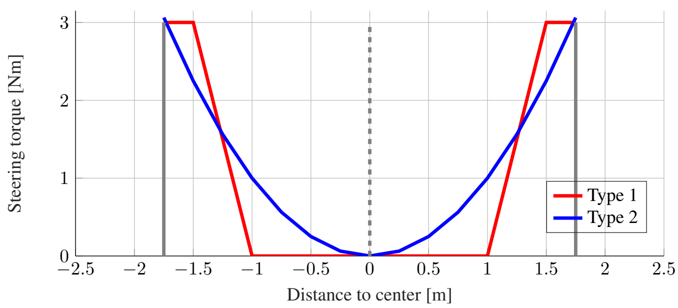


Figure 3: Steering torque behavior of different LKAS-types.

2.2 Digital Maps

Three dimensional digital map data is widely considered as cornerstone of future highly and fully automated vehicles. An environmental model of the immediate vicinity of the ego vehicle is the basis of control and decision making of such systems. The static part of this environmental model typically comes from high accuracy 3D map data with model of lane geometry, road signs, edges and many more. In addition, maps can also be used for routing, navigation and localization.

Sourcing these high fidelity maps on a vast scale, however, is a Herculean task - let alone maintaining them at short turn around times. Building a first version of these maps with highly complex mapping hardware which is consisting of multiple lidar and camera systems is the current approach. Multiple lidar and camera systems are combined/equipped with extremely expensive global navigation systems for designated mapping vans.Updates from a connected crowed of vehicles and will be fused into existing map data fully automatically. Current progress in artificial intelligence eventually pave the way to such technology. The race towards fully automatic map building with low-cost senors might soon separate the wheat from the chaff.

Notable players in the 3D mapping race are the European and Chinese map providers which pour money into the research of the swiss-army-knife of map building mentioned above. TomTom and HERE are competing in Europe, US and Japan whereas Navinfo and Autonavi cover the Chinese market. In addition the two web search giants Google and Baidu have entered the market.

The challenge of building 3D map data from low-cost sensors has given fertile ground to various startup companies which all focus on the crowd sourcing approach and follow different approaches. DeepMap, Carmera and Civil Maps from the US, DeepMotion from China and atlatec from Germany are to be mentioned. In contrast to the other companies, Carmera and atlatec do not require Lidar for high fidelity 3D mapping.

2.3 Vehicle Dynamic Measuring

Inertial Measurement Units (IMUs) are a standard for vehicle dynamics measurement for decades. For detection of an exact position (of a body) on the earths surface, the inertial technology has already been used in 1958 by the US submarine Nautilus for navigation under the North Poles ice. The IMU comprises the inertial sensors, three gyroscope channels to measure rotational speed (e.g. yaw rate) and three acceleration channels to measure linear acceleration in three dimensions. The accelerometers are also used to keep the system analytically leveled in steady state, accounting for the orientation of the earths gravity vector. Gyros are used to calculate the pitch, roll and yaw of the vehicle at any instant under motion. From the accelerometer channels, velocity and position are continuously calculated in real time by numerical integration. The main properties include, for example, high bandwidth ($100 \dots 1000$ Hz), low data latency and low noise. The main disadvantage of any IMU is the fact that the internal calculated motion states like position and velocity show an inaccuracy, the so-called drift, which increases over time, due to imperfections of the inertial sensors. In contrast, Global Navigation Satellite System (GNSS) receivers, e.g. GPS receivers, provide velocity and position data, as well. They do not have a drift, but signal noise, high data latency and measurement errors due to signal reflections and signal blackouts when passing bridges or tunnels. The GNSS measurement can be improved through the differential approach (DGNSS), engaging a local GNSS base station or using a GNSS base station network service (e.g. the German AxioNet or SAPOS). This results in position accuracies in global coordinate frame down to centimeter in real-time with so-called Real Time Kinematik (RTK) DGNSS corrections. Additionally, precise time measurements are derived from GNSS signals. Consequently, the combination of DGNSS and IMU leads to a highly accurate measurement device which describes all dynamic movements of the vehicle. The data fusion is done using an extended Kalman filter in the navigation computer of the DGNSS/IMU system. As a result, typical jumps or outages known from purely GPS-based measurements are perfectly suppressed.

Figure 4 shows an example for speed signals, recorded on a public road under realistic conditions with GNSS signal distortions: The velocity over time plot with a velocity scale up to 80 kph shows the signal of a GPS receiver (black) with noise of up to 10 kph and total signal loss over several seconds, the inertial velocity (blue) calculated from acceleration with the signal drift and the output of the Kalman filter (red) which is the smoothed inertial signal, compensated for drift by the Kalman filter using the GPS signal.

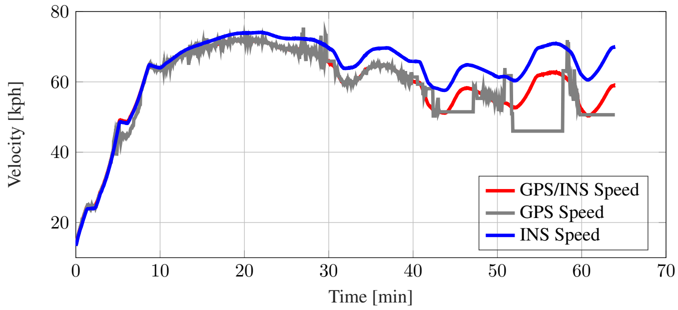


Figure 4: Speed signal comparison between INS and GPS.

The steering wheel is an important interface between the vehicle and the driver. In order to be able to evaluate the steering behavior, it is important to measure parameters such as the steering wheel torque (SWT) and the steering wheel speed (SWV) objectively and independently from the internal vehicle bus. Commercially available steering wheels can be devided into three classes. First, the replacement steering wheel, which involves loss of airbag and control elements. It is mainly used for driving dynamic measurements. Control elements on this steering wheel and airbag functions are no longer available due to so-called top-mounted steering wheels (category II). These top-mounted steering wheels are placed on the original wheel itself. Due to the mechanical change, a moment detuning cannot be ruled out here. Only with the so-called insert measuring steering wheel the original function of the steering wheel with all elements of active safety remains available and a detuning of the original moments, friction and hystereses can be minimized. Above all, the functionality of the so-called hands-off detection plays an essential role here. Between the steering wheel and the steering column (attachment on the steering teeth) a measuring socket is installed. All types of construction offer a incremental measuring method (optical, inductive, magnetic or interferential). The force measurement is based on strain gauges with a measuring bridge.

2.4 Quality Evaluation

Systems available on the market from SAE levels 1 and 2 are not subject to any legal minimum requirements in terms of quality and accuracy. To this end, the OEMs are driven by their own responsibility with suppliers and service providers. The so-called European New Car Assessment Programme (Euro-NCAP) emerges as a non-governmental institution that defines and evaluates test measures. The Euro-NCAP, was founded in 1996 for the Department of Transport in UK, with the aim to investigate the behavior of assistance systems in new vehicles. First and foremost, the emergency brake assistant (AEB) is the best-known example. The latest regulations (as of 11/2017) define not only objective assessment criteria and quality measures for LSS (Lane Support Systems) but also maneuvers containing traffic participants. In addition to maneuvers and speed profiles, information on road conditions can be found here. Euro-NCAP specifies a fixed curve radius of 1200 m for the LSS test [6, 5]. A further test definition is given in the ISO 11279 guideline. This guideline includes information and definitions, for instance testing conditions [11].

With the draft of UNECE-78, stringent, objective evaluation criteria for LDW have been published. The regulation defines hard limits for dynamic parameters such as jerk (max. $5\ \frac{m}{s^3}$, lateral). UNECE also defines the speed profile for test runs. Among other things, a lateral acceleration of $0.9 \cdot \max(a_y)$ is required. Due to this definition, there must be a different curve radius on the test tracks due to their dependence on lateral acceleration and speed as well as curve radius [16].

The tool AVL-Drive developed by AVL in 1998 was already expanded in 2017 to transform and evaluate subjective system properties of an LKAS into objective parameters. The ADAS extension, which refers to common ISO rating scale, finds defined events by the so-called ”event collector” within the test run and describes, among other things, the lane guidance quality using distance to lane limits. Measurement data can be generated in two ways. On the one hand, the vehicles internal sensors can be accessed via bus access and the measured values can be fed to the evaluation routings; on the other hand, external sensors can also be used for ego localization. *Holzinger et al.* showed that the evaluation should take place on test tracks in order to meet efficiency and reproduceablity. According to the authors, it is also possible to use the tool for software testing during development [9].
In 2018 *Fen* published a simulative methodology for the determination of KPIs for transverse and longitudinal ADAS. The test scenario presented is a combination of Full Speed Range ACC (FSRA) and LKAS. The author focuses on the description and evaluation of vehicle-independent parameters such as jerks or accelerations. In constrast to that, vehicle-specific indicators such as torques from the powertrain are not considered. The description of the KPI itself is based on the information obtained by evaluating extremes and averages of given signals [7]. The methods presented here determine the quality characteristics without defined route knowledge. This makes it impossible to locate the vehicle on the track with high precision and to evaluate it in accordance with the criteria.

3 PROPOSED METHOD

3.1 Measuring Setup

Vehicle dynamics must be recorded in all six degrees of freedom for the evaluation of LKAS. Even with bad GPS-signals, highly precised values are recorded with the help of GeneSys’ ADMA G-Pro. The built-in fiber optic gyroscopes enable high-precision movements to be detected. Using so-called dead reckoning navigation, it is possible to record stable trajectories under real-time even in case of GPS failures. GPS coordinates are represented by the SAPOS HEPS (high-precision real-time positioning service). A static accuracy of ± 2 cm and a dynamic accuracy of ≤ 10 cm is achieved. It is possible to correct the measured values for the direction of movement by means of a downstream forward-backward in order to avoid undesired reset jumps. Atlatec’s roof mounted box (atlabox) is a good example for a stereo camera system which is able to generate the measuring section in a later process. A cross calibration between atlabox and GeneSys’ platform can be realized by synchronization via master clock. DEWETron LT-02, for instance, takes over the synchronization at this point. By this coupling it is possible to provide and correct the atlabox, equipped with own RTK-GPS, with information about pitch, yaw and roll. The built-in measuring steering wheel makes it possible to measure mechanical driver-vehicle interaction independently of the vehicle bus. All steering wheel functions can still be maintained at this point. Figure 5 shows a schematic structure of a measuring vehicle.

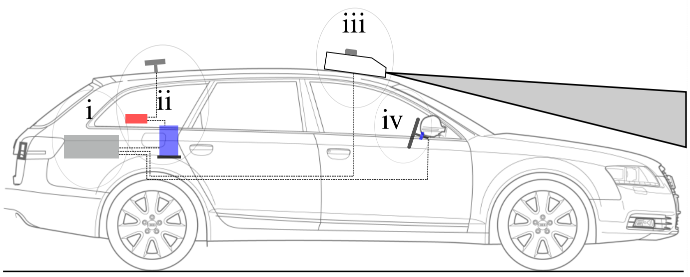
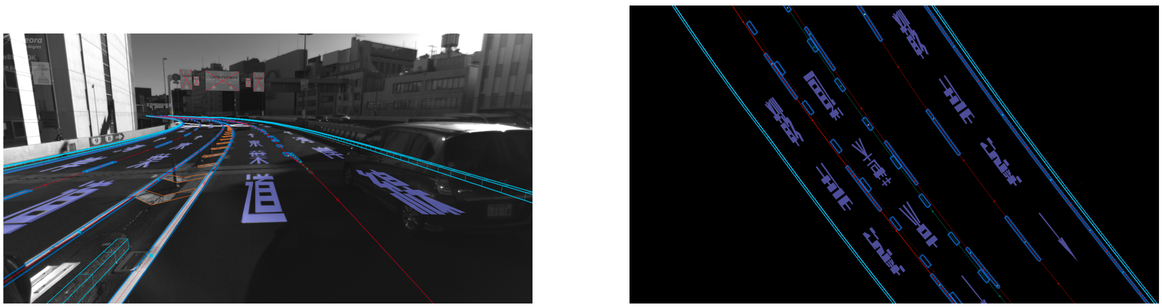


Figure 5: Builted-up test vehicle with (i) Measuring-Computer, (ii) ADMA combined with RTK-GPS, (iii) Atlabox, and (iv) insert-steeringwheel from [13].

3.2 Ground Truth Maps

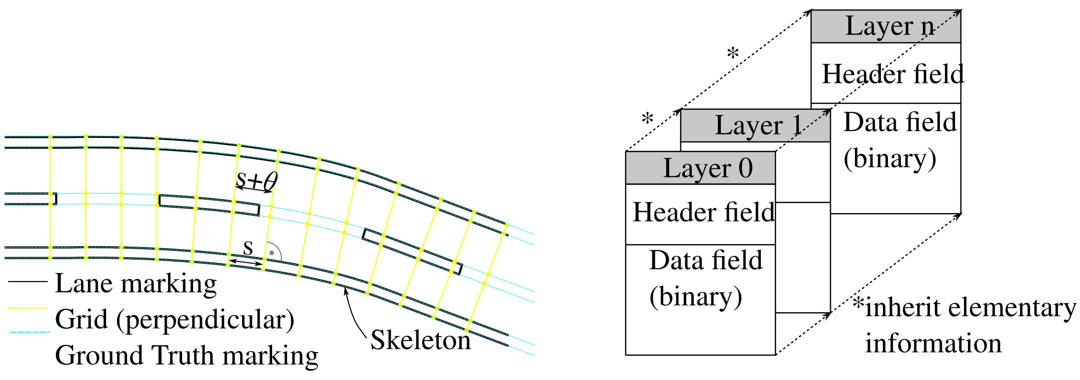
Atlatec has developed a method to create high accuracy 3D maps with nothing but two cameras, a low-cost IMU and GPS. The imagery, inertial measurements and GPS data are fused in large nonlinear systems of equations relating the sensor measurements to the trajectory of the sensor pod. These systems of equations are solved by means of least-squares optimization. Areas of self-overlapping trajectories are robustly detected and fused into the optimization process to assure a high degree of map consistency. Finally objects are detected and a reconstruction process is launched to translate the object detections (e.g. road signs) into 3D. An example of 3D map is shown in figure 6.



(a) (b)

Figure 6: 3D map created by atlatec.

In order to be able to precisely locate the ego vehicle in the lane in post-processing as well as online, a description format (CRO, Curved Regular Objects) was developed based on OpenCRG. Based on different layers, an orthogonal grid can be stretched over the entire measuring section. Layer 0 describes the base layer, whose header contains general information about the number of grid lines, increments, etc. A regular point trajectory with the distance s between the respective points forms the baseline (skeleton) for the network structure (given in figure 7(a)). Along this skeleton line, the normal vector generates the grid line over all lanes. The grid cells are located perpendicular to the skeleton line. By superimposing



(a) (b)

Figure 7: Scheme of the used road structure (CRO) (a) and based grid-map (b).

the layers it is possible to set up different constructions in positive z-direction (ISO 70000). For example, information such as the position of crash barriers, bollards, traffic signs or (sign) bridges can be placed above the base layer. In figure 7(b) a schematic representation of the layer model is given.

By the aid of an orthogonal network structure, it is possible to reference the respective grid cell after initial positioning belong to ego vehicles position, so that no computationally effort for global positioning has to take place at runtime. This format has the advantage that the information can be inherited between the layers. Thus it is possible to provide all traffic signs to a waypoint T_i within a radius of x meters. The basis of the highly accurate map is the measurement of lane markings. Following semi-automatic annotation, individual road points are assigned to a high-precision GPS position via stereo camera. This processing step allows to create a map (Ground Truth, GT) with high accuracy. The resulting map is converted to the defined input format for CRO generation by optimization and preparation (spline interpolation of the individual lines, outlier handling, ...). By transferring to the OpenDRIVE format, the resulting highly accurate map can be used in the simulation. Further tools such as Trian3DBuilder are used to create hyper realstic environments.

3.3 Quality evaluation

By transferring the vehicle dynamic measurement data into a uniform time-discrete input signal, it is guaranteed that measurement channels can be processed from simulation as well as real driving tests. The signal filtering based on ISO 4138 and UNECE R79 eliminates noise and external excitations. Therefore, a phase-corrected 4$^{\text{th}}$ order Butterworth with 3 dB cut-off frequency of 0.2 Hz and 10$^{\text{th}}$ order Butterworth with half power frequency of 12 Hz were used. A central step in quality determination is to locate the ego vehicle on the road. To find related start and endpoints of the car in the basic layer (see chapter 3.2) a N-D nearest point search is started initial [3]. Fundamental is the determination of lateral deviation from the center line (d_s) as a mathematical measuring channel for later evaluation at every timestamp. Determine d_s as the minimum distance between vehicle position at time t_i and ground truth position. Due to the definition of the grid structure for used GT maps, there are asynchronous occurrences of location point (X_i) of the GT road and GPS-measurements at this point. After corresponding value pairs are found in the GT line (see perpendicular foot), the distance in metric dimensions can be determined by using the calculation rule according to *Vincenty* or using the Haversine-method (see below) [17, 10].
To calculate the distance in meters (d_s) the inverse haversine formula has to be applied.

$$d_{s_i} = r\,\mathrm{hav}^{-1}(\mathrm{hav}\,(\Theta)) = 2r \arcsin\left(\sqrt{\mathrm{hav}\,(\Theta)}\right) \tag{1}$$

with

$$\begin{aligned} \mathrm{hav}\,(\Theta) = \\ \mathrm{hav}(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\,\mathrm{hav}(\lambda_2 - \lambda_1) \end{aligned} \tag{2}$$

where $\varphi_{1|2}$ represents latitude of point $1|2$, $\lambda_{1|2}$ longitude of point $1|2$ and r represents world‘s radius [10].

By analyzing the mathematical channel d_s, objective parameters such as the drift velocity can be determined by deriving the distance respect to time $\left(\frac{dd_s}{dt}\right)$. Further channels like lateral acceleration (a_y) and steering wheel torque/angle are the inputs for rating driving quality, vehicle reaction and stress-level. Jerks (derivation lat. accel. respect to time) are indicators for smooth vehicle reaction whereby the so-called steering reversal rate (SRR) represents how often the driver needs to interact while driving with activated LKAS. The steering torque can be used to evaluate the driver interaction e.g. how much the driver has to intervene to stay in the lane.
Caused by bus communication (if desired) and external sensors (approx. 1 GB/s, [12]), this concept can be integrated on a big data platform, for instance on a Hadoop cluster. The KPIs are evaluated on any number of nodes simultaneously, which results in efficient fleet evaluation.

4 EXPERIMENTAL RESULTS

4.1 Cross calibration ADMA

The following experiment was conducted to test the fusion of the high accuracy of the ADMA system with the fidelity of the atlatec mapping device.

Data from the atlatec atlabox was recorded time synchronously with data from the ADMA. Time synchronization was solved by harnessing the pulse-per-second (PPS) signal of the two respective GPS receivers. The pulse is perfectly in sync as it is radio transmitted to both receivers. The PPS signal also triggers the cameras of the atlabox to assure perfectly time synchronized datasets. Note that the image stream alone is used from the atlatec system, GPS and IMU data are replaced by the GeneSys ADMA.

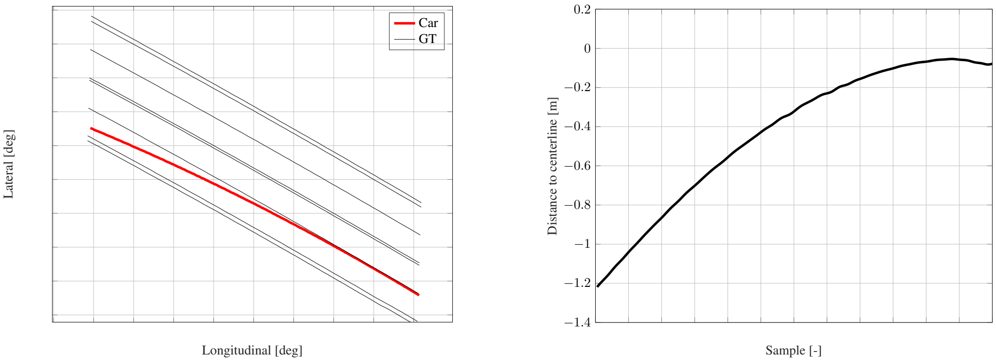
In principal the setup described above allows to simply use the pose information from the ADMA processing in the atlatec mapping tool chain. This, however, does require a careful cross-calibration of the two systems as both operate in their own reference frames. The origin of the ADMA coordinate system resides in the ADMA IMU (which is inside the test vehicle) whereas the atlatec reference frame is tied to the left camera of the sensor pod (which is on top of the vehicle). Both of these coordinate systems are rigidly linked to one another and cross-calibration procedures yield the coordinate transform from one to the other. This transform is finally applied to the ADMA IMU trajectory yielding a high accuracy atlatec camera trajectory which is then used for mapping.

Cross-calibrating the systems (e.g. estimating the abovementioned coordinate transform) is done as following. The trajectory of the atlatec camera is computed by modified bundle adjustment. The trajectory is a sequence of poses where each consisting of six-dimensional comprising position as well as orientation in 3D. The ADMA system delivers the same sequence of poses with same parametrization. An initial guess of the sought-for transform can now be applied to the ADMA trajectory which roughly aligns it with the atlatec trajectory. The difference of each pose pair (e.g. atlatec pose and corresponding ADMA pose after transform) is accumulated and summed into a scalar error value. This value indicates the quality of the fit of the two trajectories, hence the quality of the transform. Standard optimization techniques allow to successively improve the error value by varying the transform. Optimization is processed until convergence yielding a robust estimate of the cross-calibrating transform. An example of a map that is created from an ADMA trajectory is shown in Figure 8.

Figure 8: A map created with an ADMA trajectory after successful cross-calibration of the two systems.

4.2 Evaluation of LKAS

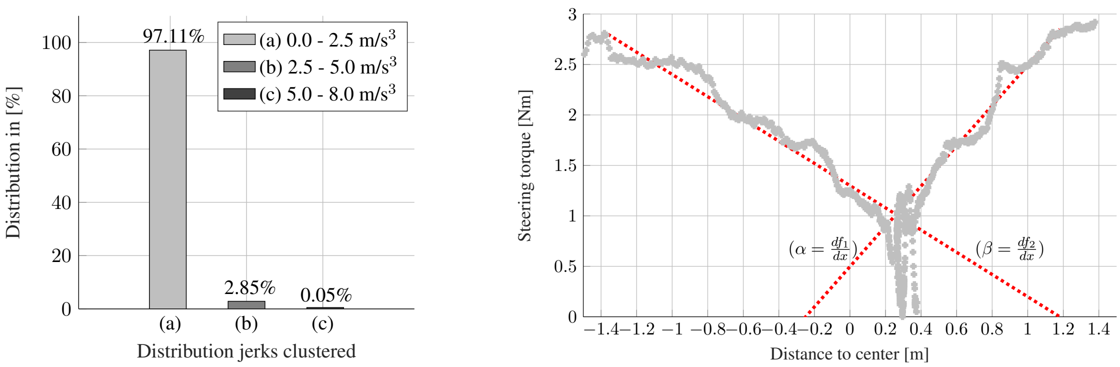
As described in chapter 3 special attention will be paid to the calculation of the distance to line. The required full automated localization into the GT road is the basic step in quality evaluation. A graphical example is illustrated in figure 9. Belonging to this localization the calculation of d_s is applied and shown in 9(b).



(a) (b)

Figure 9: Located Ego-vehicle in GT-road (9(a)) as well as distance to middleline (9(b)).

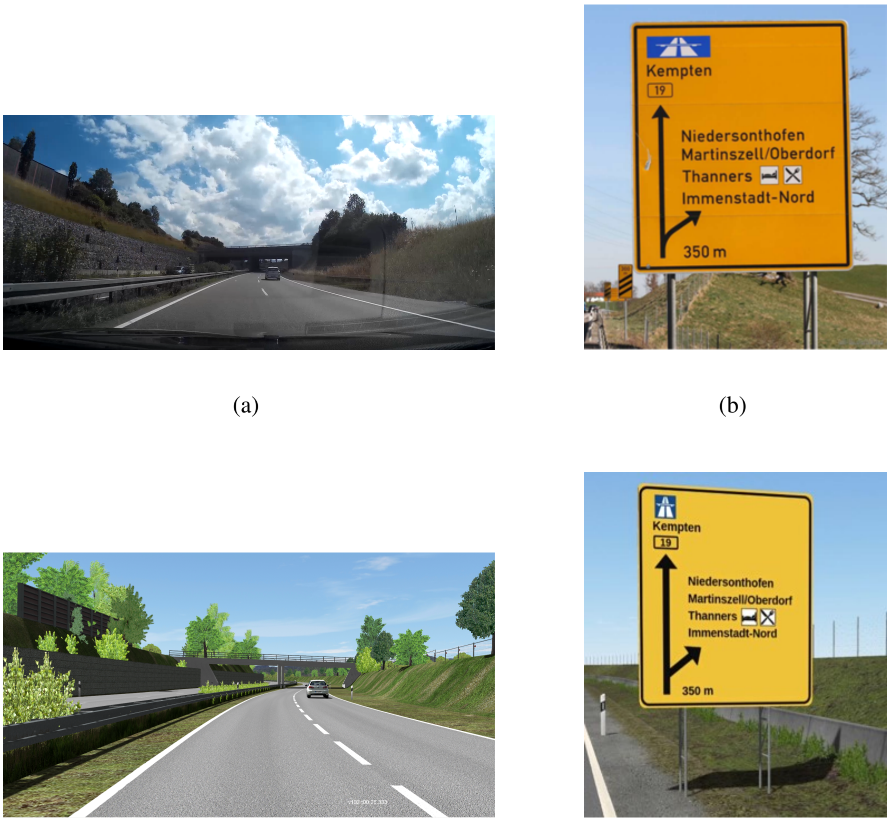
The change in lateral acceleration produces jerks, which are regarded as an indicator of vehicle reaction. The percentage distribution of jerks during a satistic test drive on German highway (more than 30 km in a row) shows that jerks larger than $5\frac{m}{s^3}$ occur. The distribution (clustered into 3 classes reffering to [8]) is shown in figure 10(a).
By analyzing the so-called bathtub-chart (given in fig. 10(b)) further information about steering behavior as well as localization offsets can be extracted. The slope of the branches (α and β in fig. 10(b)) is an indicator how fast and comfortable the system reacts. A general center-offset of vehicles localization within the lane can be figured out by analyzing the area around zero.



(a) (b)

Figure 10: Percentual distribution occurring jerks (a) and bathtub chart (b).

High precise simulation environment is essential to evaluate camera based ADAS in virtual test drive. The determination of the distance to centerline as well as evaluation of jerks and steering torque via the distance to lane marking can be integrated into the developed framework for ADAS evaluation. The determination of the KPIs is identical to the real driving test. DoE (design of experiments) makes it possible to apply parameter optimization based on the developed layer model. AVL Cameo offers the possibility of automated test execution and optimization. In figure 11 an example of the digital twin is given.



(a) (b) (c) (d)

Figure 11: Graphical comparison between real road (a,b) and simulation (c,d).

5 FUTURE WORK

The key factor for ADAS evaluation is the road-knowledge. Prediction of the ego position is needed for this evaluation, especially in absence of GPS signals or in presence of unprecise GPS signals due to so-called dead reckoning. One solution for this problem is the usage of landmarks. Landmarks, such as fixed traffic signs or bridges, are ideal for localization. By correcting the ego position, using visual odometry, the inexactly GPS position can be mapped to the ground truth. Thus, it is possible to evaluate the ADAS during driving in valleys and cities. In further working packages, the functionality using steady landmarks to correct the ego position on a highly precise level on embedded system will be presented by the group of UAS Kempten, GeneSys and atlatec.

6 CONCLUSION

Due to the upcoming test effort for ADAS and AD it is not possible to test and rate the functions only in real driving tests. For that, it is strictly necessary to use HIL/SIL/MIL simulation as well as test rides on real roads to develop and test ADAS. Common test methods and definitions relay to restricted proving grounds with non-real traffic situations and road behavior. This paper presents a new method to rate ADAS while driving on public roads. With the mounted stereo camera system, it is possible to drive on any road and to produce the needed ground truth information whilst post processing. By using the CRO ground truth map it is possible to run a prototypical function on a simulated environment (as digital twin) right before testing on real road. The proposed measuring method enables a quality rating without access to internal vehicle bus by using IMU combined with an RTK-GPS and insert steering wheel. The results presented in this paper shows the offline-localized vehicle in GT road, position-dependet calculation as well as the derivation of KPIs and system specific charts. It can be shown that available LKAS (series vehicle) interact with greater jerks than recommended.

7 ACKNOWLEDGEMENTS

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