Modern methods of field tests of driver assist systems

Ye I Toropov\textsuperscript{1}, Yu P Trusov, A S Vashurin, P S Moshkov, V I Filatov and M E Gnenik

\textsuperscript{1}Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Minin st., 24, 603950, Nizhny Novgorod, Russia

E-mail: \textsuperscript{1}evgeny.toropov@nntu.ru

In view of stringent vehicle safety requirements the automakers are urged to develop and implement electronic driver assist systems (ADAS). However, before starting the mass production, one has to make sure that these systems function correctly and efficiently. The current level of technologies, the simulation modelling allows debugging and testing of operation algorithms for electronic ‘assistants’ in laboratory conditions thereby reducing the costs of the prototype production. This approach is employed at intermediate development stages of the system. At the final stage the ‘traditional’ approach (field tests) is used by the automobile manufacturers, the reason being that the algorithm operation has to be tested in real conditions, and the certification of vehicles with ADAS functionality using methods of simulation modelling is not provided in current state standards. Keeping this in view, the problem arises of creating a measuring unit for geolocation of the vehicle with precision accuracy and synchronized video recording from multiple cameras simultaneously. This article presents the solution developed by employees from NNSTU n.a. R. E. Alekseev as regards the development of such a test system: a schematic diagram of the system is developed; the system is installed on a light commercial vehicle being tested; the system efficiency is checked. The system performance was checked when testing blind spot detectors, lane departure warning system and parking assistant.

Introduction

Over the recent decades, vehicle manufacturers are focused on the development of electronic active safety systems: anti-lock braking system (ABS), traction control system (TCS) and electronic stability control system (ESC). These functions allow the driver to maintain and exercise control over the vehicle in critical situations. However, given the advance of microelectronics and reduction in prices, access to technologies earlier unavailable to civil industries (radars, lidars, ultrasonic sensors, cameras, digital vision), the automakers are urged to implement the vehicle control automation. This research and development work resulted in the manufacture of mass production samples of auxiliary active safety systems, so-called assistants (DAS/ADAS). These systems can warn the driver of negative changes leading to a critical situation, and also interfere ahead in the vehicle control including the steering, braking, engine and transmission control systems \cite{1, 2}.

In the passenger and freight transport segment where light commercial, medium-duty and heavy-duty vehicles are used, the development and implementation of intelligent driver assist systems holds the highest potential; these systems are designed for monitoring ‘blind’ spots which is most critical for trucks, as well as preventing driving mistakes due to inattention, temporary distraction and physical fatigue of the driver \cite{2-4}. The following systems meet these requirements:
– Lane Keep Assistance system (LKA). Its main function is to alert the driver to the vehicle departure from the lane, and adjust the vehicle motion path if the driver’s actions are inadequate or none.
– Park Assist System (PAS) assists the driver in searching for a parking spot, and also controls the steering system [5].
– Blind Spot Monitoring (BSM) alerts the driver if the vehicle is a blind spot, and prevents collision with preceding traffic [6].

Implementation of these systems allows improvement of the traffic safety and brings down the costs of transportation companies related to vehicle idle time due to traffic accidents.

Today the technologies of software-based simulation Model-in-the-loop (MIL), Software-in-the-loop (SIL), and software and hardware-based simulation Hardware-in-the-loop (HIL) are most commonly used for testing of electronic systems thereby reducing the prototype production costs and helping to avoid mistakes at early stages of development. Despite all the benefits virtual tests cannot in full measure substitute ‘full-scale’ trials therefore for many years field tests have been the main development phase, and results of the tests a key factor for a decision whether or not the vehicle is ready for the market [7,8].

In this regard, the field testing methods of electronic driver assist systems as well as the necessary measuring equipment are still relevant.

**Regulatory documents on functional characteristics of ADAS system**

As of now, there are a number of documents in the Russian Federation regulating the requirements for electronic systems functions and describing the methods of their testing. Let us analyse each system separately:

1. Lane departure warning system. The system functioning is described in GOST R 58807-2020 whereby the following parameters are to be recorded:
   – travel speed of the vehicle;
   – speed of the vehicle leaving the traffic lane;
   – time of the optical sensor actuation;
   – position of the test object relative to the marking line;
   – time of actuation of the malfunction indicator [9].

2. Assist the driver to decide on changing travel lanes. The system functioning is regulated by GOST R 58803-2020 (the relevant part is taken from UN Regulation No. 130 Uniform provisions concerning the Lane Departure Warning System).

To evaluate the system efficiency, the following parameters are recorded:
   – travel speed of the vehicle;
   – steering effort;
   – lateral acceleration;
   – time intervals;
   – time of actuation of the optical sensor activating the function, and the malfunction indication;
   – video recording of the driver’s actions (operating the turn signal lever);
   – distance between the auxiliary (approaching) vehicle and the test object [10].

3. Lane keep assistance system (LKA) is regulated by GOST R 58804-2020. Measured parameters:
   – travel speed of the vehicle;
   – steering effort;
   – lateral acceleration;
   – time intervals;
   – time of actuation of the optical and acoustic sensors activating the function, and the malfunction indication;
   – video recording of the driver’s actions [11].

4. Blind spot monitoring - GOST R 58808-2020. Measured parameters:
   – travel speed of the vehicle;
   – approach speed of the test and auxiliary vehicle vehicles;
   – time intervals;
– longitudinal distance and lateral separation between the test vehicle and auxiliary vehicle;
– time of actuation of the optical sensor, and malfunction indication;
– video recording of the driver’s actions [12].

5. Park Assist System is regulated by PNST 381-2019 (associated standard ISO 16787:2017 - Intelligent transport systems - Assisted parking system (APS) - Performance requirements and test procedures). Measured parameters:
– travel speed;
– lateral separation from parked vehicles;
– course angle distance between the test object and parked vehicles;
– time of actuation of the optical sensor, buzzer, and malfunction indication;
– test vehicle position given the parking spot geometry;
– time intervals;
– time of actuation of the optical sensor, and malfunction indication [13].

As can be concluded from the above requirements, the measuring unit installed on the test vehicle should have the following functionality:
– geolocation of the test object with precision accuracy including the auxiliary vehicle for a number of some tests;
– connectivity to on-board data bus CAN for recording time delays in human-machine interface operation;
– receiving video imagery with an option of synchronizing the recording with third-party equipment.

Development of measuring unit

Distances between moving test vehicles that is travelled distances, separation and intervals, cannot be measured with precision accuracy using ‘traditional’ equipment (e.g. optical travelled distance sensor, ‘fifth wheel’, linear laser distance sensor). The growing demand of the automakers for ADAS functions testing equipment urged the developers of measuring equipment to use the technologies earlier employed in the civilian sector only for geodetic measurements.

For maximum precision and convenience of ADAS-functions testing, advanced GNSS technologies are currently used by manufacturers of measurement systems. The vehicle positioning with 2 cm precision is achieved by using real-time kinematic technology (RTK). It is common knowledge that a single satellite device of any class cannot provide high precision positioning due to a large number of negative factors (atmospheric inhomogeneities, interference from stationary and mobile objects, indirect reflection or multipath propagation of signals), therefore, more accurate coordinates are determined by applying so-called ‘RTK corrections’ which are computed and transmitted by another GNSS-receiver (base station) the exact position of which is known (figure 1) [6, 14].

There are several ways to transmit RTK corrections from the base station to the receiver (rover):
1. GPRS channel – the downside of this method is that each receiver should have Internet connectivity which is not available everywhere;
2. GSM connection – it allows only 1 rover to be connected, other drawbacks are similar to the first method;
3. A radio channel is the preferred option as the number of connected rovers is not limited, and the radio channel is not affected by the quality of cellular communication. The only downside of this option is that in the Russian Federation (as in many other countries) restrictions apply to the power rating of a radio frequency signal source for unlicensed use: for operating frequency 433 Mhz the maximum power rating shall not exceed 10 MW, for 2.4 Ghz frequency – 100 mW, given the maximum antenna suspension height of 10 meters. As evidenced from the experience, these power characteristics allow the coverage of a 500-600-meter radius area (subject to line-of-sight availability). A larger radio signal coverage area involving the application of a more powerful transmitter would require going through the procedure to obtain a license for the radio frequency and register the radio frequency signal source that can take as long as 6-8 months. It is practical if tests are always performed in the same location (vehicle test track); if the test track location is changed, all permits shall be renewed.
Acquiring the exact coordinates from each of the rover receivers is not sufficient for testing and validating ADAS systems; it is necessary to calculate the test vehicle dynamic parameters (shortest, longitudinal distances and lateral separations, approach speed etc.) relative to auxiliary vehicles or the marking line. For this purpose, each vehicle is equipped with an additional set of telemetry equipment for synchronizing GNSS data on the target object (figure 1).

The specialists of the Nizhny Novgorod State Technical University were set a task to develop and implement a measuring unit for testing and validation of ADAS functions of a light commercial vehicle. The schematic diagram is shown in figure 2.

The main components of the measuring unit include:
1. High-precision measuring GNSS device Racelogic Vbox 3i 100 Hz (item 3, figure 2). It is installed on each vehicle for computation of the exact position, dynamic characteristics and ADAS functions evaluation parameters.
2. GNSS base station (item 12) is required for updating the position of the measuring instruments (with 2 cm accuracy). A local radio communication link is set up for transmission of RTL-corrections, that is the base station and all rover receivers are equipped with radio modules operating at 2.4 GHz frequency (item 6).
3. Additional 2.4 GHz telemetry (item 4) synchronizing GNSS data is required for calculation of ADAS parameters such as the relative distance between test vehicles, approach speed etc.
4. Racelogic CAN02 interface (item 1) is connected to the tested vehicle data bus to record the operation status of ADAS functions as well as a number of other parameters (engine rpm, operating brake and accelerator pedals, turn signal indication, engaged gear number etc.).
5. Speed display (item 8) showing the actual speed of the vehicle.
6. Multifunctional display MFD (item 9) allows displaying any of the measured parameters. For example, it is required for monitoring lateral separation between vehicles.
7. Racelogic Video Vbox Pro (item 10) is a GNSS device that can record a video streams from 4 video cameras simultaneously; it is required for recording the operation of light indicators, the vehicle crossing the marking line, video recording of the driver's actions etc. It is connected to Racelogic CAN bus (item 11) for synchronizing the recording with Vbox 3i.
8. Measuring steering wheel MSW (item 2). It is mounted right on a standard steering wheel and required for measuring the steering angle, rotation speed and torque. The measured data is transmitted to Vbox 3i via Racelogic CAN bus as well.
Figure 2. Schematic diagram of the measuring unit. a – component to be installed on the test vehicle; b – component to be installed on the auxiliary vehicle; 1 – CAN-interface to be connected to on-board data bus; 2 – measurement steering wheel (MSW); 3 – measuring GNSS device Racelogic Vbox 3i 100Hz RTK; 4 – telemetry 2.4 GHz for synchronizing GNSS data between the vehicles; 5 – radio communication link 2.4 Ghz for synchronizing GNSS data; 6 – radio receiver for RTK corrections; 7 – radio communication link 2.4 Ghz for transmission of RTK corrections; 8 – vehicle speed display; 9 – multifunctional display MFD; 10 – Video Vbox Pro; 11 – Racelogic CAN-bus; 12 – GNSS base station with 2.4 GHz telemetry for transmission of corrections.

The measuring equipment is mounted on the main and auxiliary vehicles as shown in figure 3 (a-e). Figure 3f. Location of GNSS base station with 2.4 GHz radio transmitter and the antenna mounted on a telescopic rod. It is to be noted that given the maximum power 60 MW and the antenna suspension height 5 m, this radio frequency signal source can be used without any additional licenses.

Testing of ADAS lane detection functions require no auxiliary vehicles. In place of an auxiliary vehicle, lane marking lines are traced with geodetic accuracy using the ‘lane marking system’ (figure 4) and subsequently uploaded into measuring device Vbox 3i mounted on the test vehicle. This allows the calculation of driving parameters as required for assessment and validation the ADAS function: the distance from the wheels to the marking line and the speed of the vehicle leaving the lane.
Figure 3. Mounted measuring equipment. a – Racelogic Vbox 3i 100Hz mounted in the main vehicle cabin; b – GPS/GLONASS equipment and telescopic antennae; c – Racelogic Vbox 3i 100Hz mounted in the auxiliary vehicle cabin; d – Video Vbox Pro cameras recording the right front wheel crossing the marking line; e – measurement steering wheel (MSW), Vbox display, Video Vbox cabin camera; f – GNSS base station with telemetry package.

Figure 4. Tracing of marking line
Testing of ADAS functions
The developed measuring system was tested during trials of the light commercial vehicle prototype equipped with driver assistance systems. The tests were conducted at the test ground of Berezovaya Poima Joint Research Center including the following functions:
- lane departure warning;
- blind spot monitoring;
- searching for a parking lot.

Some results of blind spot monitor function (BSM) testing are presented for the purpose of clarity. Test mode: the test vehicle travels at a speed of 30-35 km/h, the auxiliary vehicle accelerates to 40-45 km/h and overtakes on the blind side of the test vehicle. The objective of the test is to determine the time of actuation and operation of BSM assistant light and sound alarms. In addition to statistical data, video imagery was recorded using Racelogic Video Vbox Pro equipment. A video frame sample is shown in figure 5. As you can see, in addition to the option of synchronous video recording from 4 cameras at the same time, the software allows the application of virtual markings for evaluation of external objects’ location. It is to be noted that Video Vbox features CAN interface with an option to record 32 additional channels received via the data bus: all numerical values in the video frame (figure 5) (BSM sound-optical indicator status, location of test vehicles relative to one other as well as contact points, i.e. the points around the vehicle outline corresponding to the minimum distance between test objects) are acquired using this method.

Figure 5. Vbox Pro video frame
Racelogic Vbox 3i 100 Hz measuring instrument is used for computation and recording of ADAS parameters including:
- travel speed of both test objects (figure 6a);
- distance between the vehicles: shortest and longitudinal distances and lateral separation (figure 6b);
- contact points of both vehicles (figure 6c). When setting up the measuring system, the contour of the test vehicles is marked (so-called contact points), i.e. the arrangement of markers around the outline of the vehicle relative to the GPS/GLONASS measuring antenna. In our case, these 4 points are arranged as follows: the first marker in the left front corner, with other markers numbered counter-clockwise;
- approach speed and accelerations of the objects relative to one another;
- angular distance between courses of the vehicles.

According to the test results, a set of statistical material is generated that allows ADAS system algorithm operation to be assessed (accuracy of functioning absence of false positives), validate the algorithm operation, check for compliance with high international and domestic requirements which is an integral part of development of any product.
Figure 6. BSM system test graphs. a – travel speed graph of the main and auxiliary vehicles; b – distance and lateral separation between the vehicles; BSM operation status; c – shortest distance between the vehicles; contact points
Summary
The developed measuring system was successfully test run when testing the driver assistance systems of the first series prototype. The results obtained in the course of the tests will be used for fine-tuning and debugging of the high-level algorithm of the electronic assistants. Also, these results will be again used for testing second- and third-series prototypes.

It is to be noted that this measuring system is compliant with international and domestic regulatory documents therefore the system can be used for certification tests of ADAS systems.

This measuring equipment potential is not limited to testing of the systems reviewed in this article; it can also be used for testing the Adaptive Cruise Control system (ACC), Autonomous Emergency Braking system (AEB), both with moving and stationary objects, Forward Collision Warning (FCW) and Traffic Sign Recognition (TSR).

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