Possible scenarios of autonomous vehicles’ testing in Russia

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Abstract. This article represents out point of view on what is happening in Russia in the field of autonomous driving technologies development, testing and implementation. A method for addressing the issue of autonomous vehicles (AVs) testing and critical testing scenarios detection is proposed. Road tests of ADAS Autonomous Emergency Braking System (AEBS) were performed in winter conditions at a proving ground and in virtual environment with simulation techniques, practical results are presented.

1. Introduction

Autonomous driving is a global trend and no automakers, suppliers, or technological companies will be able to pass it by [1, 2, 3, 4]. The rapid worldwide attempts to implement autonomous driving technologies with ADAS (advanced driver assistance systems) functionality at the first stage and the lack of legal regulation in Russia have led to the situation when we have a lot of modern passenger cars with ADAS systems on public roads. These ADAS systems (autonomous emergency braking, lane keeping, automated parking, etc.) have not been tested and may not have been adapted for use in Russian conditions [5]. It’s a potential threat to national road safety.

Russian government has established the association of “Autonet” in 2016 with the aim of new market consolidation (AVs, cooperative transport, electric vehicles, and transport services). This association has a road map for ADAS regulation deployment, and it consists of the next stages:

- A choice of appropriate ADAS systems to be tested;
- A development of national standards on safety requirements and testing methods;
- A creation of national AVs’ testing system on the basis of previously developed standards;
- Amendments to the Technical Regulations of the Customs Union TR CU 018 [6] (type approval level).

The third item in the above list sounds good, but seems to be tremendously hard to be solved. At the same time, deployment of automated and autonomous vehicles can lead to the next negative technical and social problems [5]:

- inadequate car’s behavior due to imperfection of control algorithms;
- inadequate car’s behavior in the events of failures, malfunctions, connection with infrastructure lost, after road accidents, vehicle’s parameters change (tires change, software modification);
- malfunction due to the conflict of driver’s actions and automated system operation;
- operation in conditions, which are not specified by car manufacturer;
- lack of cybersecurity;
- moral and ethical problems;
- contradiction with existing national legislation.
The above negative technical and social problems of AVs’ implementation should be solved with appropriate national testing system.

2. Foreign Experience
The UNECE/WP.29 on automated/autonomous and connected vehicles discusses the following grading of AVs operating conditions with respect to different road types: highways, city roads, other roads, parking areas, closed areas. Testing methods in this case are divided into several categories: virtual and real testing of typical scenarios; tests on public roads; manufacturer's audit (ISO 26262); software validation; etc.

Another example is the list of road situations, developed by researchers in the USA [7, 8], to which car’s automated control systems should respond adequately. AVs should:

- detect and respond to speed limit changes;
- perform high speed freeway merge;
- perform low speed merge;
- park on the shoulder or transition the vehicle to a minimal risk state;
- detect and respond to dangerous oncoming traffic;
- detect permitted and restricted zones for driving on a road, and perform maneuvering in permitted areas;
- perform car following including ‘stop and go’ and emergency braking;
- detect and respond to stopped vehicles;
- detect and respond to intended lane changes;
- detect and respond to static obstacles;
- detect and respond to traffic light signals, road signs of stopping and giving the way;
- navigate intersections and perform turns;
- perform driving at roundabouts;
- detect free parking slots and perform parking;
- detect and respond to prescriptive and prohibitive road signs;
- detect and respond to traffic-controller’s signals;
- follow the priority rights of driving;
- respect other requirements of national traffic rules;
- follow other road requirements (temporary road signs, marking, etc.);
- detect and drive safely in road repair areas;
- react to the situation in the area of road accident;
- detect and respond to emergency vehicles;
- detect and respond to cars with activated light alarm;
- give way to pedestrians and cyclists on pedestrian crossings;
- ensure safe distance between vehicles, pedestrians, cyclists on roadside;
- detect and respond to temporary changes in traffic patterns.

This testing pattern can be extended with the next situations, actual for Russian operating conditions:

- perform overtaking on two-lane roads with oncoming traffic;
- choose a safe cornering speed;
- detect and respond to dangerous defects of road pavement (roughness, ruts, etc.);
- detect and respond to road areas with poor adhesion characteristics;
- navigate a vehicle on a road without lane markings or with lane markings of poor quality;
- perform operation in inclement weather conditions.

3. Proposals for Critical Testing Scenarios Detection
Fundamentally, the AVs’ testing system should cover the whole life cycle of AVs, beginning from the stage of design and ending with utilization. At the same time, methods of testing consist of simulations, proving ground tests, public road tests and further data monitoring of automated systems in use.
The very important question is how to localize critical testing scenarios for proving ground and public road tests from the enormously great variety of all possible states, modes, internal and external conditions?

We suggest using the next sequence of actions for this case:

1. Definition of the test’s purpose, which may include: the task of functional or operational safety monitoring; determination of operating conditions, reliability metrics, fault tolerance, performance variation between the same cars, as well as during the whole life cycle, etc.

2. Creation of test scenarios or selection from the existing ones (e.g. EuroNCAP, ADAC, ISO):
   a. Definition of ranges of changeable parameters of the system “driver—car—road—environment” [9].
   b. The choice of evaluation criteria and their permissible values.

3. Flow simulation of all possible variations of the developed test scenarios in a virtual environment performing:
   a. Critical testing scenarios detection with respect to the test’s purpose.

4. Critical scenarios’ field tests performing:
   a. Virtual model’s parameters validation, the above cycle repetition.

5. Changing the design or control algorithms to achieve goals of testing.

4. Experimental Research – Road Tests
This section provides some experimental results of Autonomous Emergency Braking System (AEBS) testing in winter conditions [10]. Vehicle under test is Subaru XV of 2018’th model year with technical vision system based on stereo cameras (Subaru EyeSight). The following measurement equipment has been used: MSW – measurement steering wheel (Kistler); CPFTA – braking pedal sensor (Kistler); WPT – external wheel speed sensor (Kistler); TANS – Tri-Axial Navigational Sensor (Kistler); CS 1016 FAMOS Online – data acquisition system (IMC); GPS antennas (IMC, JAVAD); internal camera for dashboard AEBS warning signal detection; external camera for tailgate stop signals detection; on-board CAN bus data monitoring system [11]. Road tests were conducted at Dmitrovskiy proving ground (NAMI).

Figure 1 illustrates the results for AEBS winter testing on dry asphalt. Initial host car velocity was set to be approximately 35 km/h. The stationary target looked like a soft wall covered with thin reflective metallic coating. The first vertical line in Figure 1 indicates the in-vehicle AEBS warning signal, this moment corresponds to the distance of 28.8m between host car and stationary target, and TTC (time to collision) of 2.63s. The second vertical line indicates activation of the tailgate stop signals, this moment corresponds with the beginning of automated partial braking process with the approximate value of calculated TTC of 0.82s. We can mention, that then in the control strategy of tested vehicle the next stage of more intensive braking was activated with deceleration of up to 8 m/s² (see the graph of deceleration in Figure 1). The third vertical line indicates full vehicle stop in front of a stationary target with free space of 0.3m between them. Collision was avoided.
Figure 1. AEBS winter test – stationary target, dry asphalt, daylight.

Figure 2 illustrates the results for AEBS winter testing of the same car and the same scenario as above, but on snow road. Initial host car velocity was set to be approximately 35 km/h. The first vertical line indicates the in-vehicle AEBS warning signal, this moment corresponds to the distance of 37.7m between host car and stationary target, and TTC of 3.52s. We can mention, that these values of distance and TTC has been increased for snow conditions in comparison with dry asphalt. The second vertical line indicates activation of the tailgate stop signals, the braking process begins, it also has two stages and the maximum deceleration achieves values of 4 m/s², but it is also clear that it was the maximum possible deceleration on such a road (see the graph of wheel velocity in Figure 2 with ABS cycles). The TTC of braking process start approximately equals to 1.44s, and this value is also higher than the TTC value for dry asphalt (0.82s). The third vertical line indicates collision of a host car with stationary target. The velocity equals to the value of 6.8km/h, collision was not avoided.

Figure 2. AEBS winter test – stationary target, snow road, daylight.
We can say, that it seems, that AEBS of Subaru XV adapts to the road friction conditions because TTC values of the above road tests are essentially different. The other side of this is that we don’t know the actual control algorithms of vehicle under test, as well as the actual characteristics of vision recognition system. Perhaps in other lighting and weather conditions this AEBS will demonstrate other results. The task of AEBS control algorithms decompilation (reverse engineering) seems ambitious and non-effective for further virtual testing of all possible variations of test scenarios and weather conditions.

5. Experimental Research – Virtual Tests

We have used standard software for ADAS virtual testing. We simulated straight driving of a host car with initial velocity of 60 km/h with a stationary object (Euro NCAP car target) on a way. Ideal road conditions have been used (dry asphalt, daylight). The AEBS control algorithm gave a warning at 2.6s TTC, then it applied 40% of braking at 1.6s TTC, and 100% of braking at 0.6s TTC. Virtual vehicle under test was equipped with long range radar (LRR – 120m range, 9 degrees narrow beam) and short range radar (SRR – 30m range, 90 degrees wide beam). The test scenarios were as follows: 1) driving with idealized radar sensors; 2) driving with characteristics of real radars (Continental ARS510 as a LRR, and Continental SRR510 as a SRR with characteristics from the official web site).

Figure 3 illustrates virtual AEBS operation with idealized sensors and ideal road conditions. Collision was avoided.

![Figure 3. AEBS virtual testing – stationary target, dry asphalt, daylight, idealized sensors.](image)

Figure 4 illustrates virtual AEBS operation with characteristics of real radars and ideal road conditions. Collision was not avoided, collision speed equals to 37.07km/h. Warning and partial braking TTC of the both experiments are the same, but in the second case we see malfunction of AEBS control algorithm (the graph of deceleration in Figure 4 – it stopped braking). Perhaps, this situation has occurred because of target tracking fail. In any case, we see that the results of virtual tests are essentially sensitive to the adequacy of ADAS control algorithms and sensors characteristics.
The information of exact ADAS control algorithms and vision recognition system characteristics is very important for virtual tests and critical scenarios detection. This type of information can be provided by car manufactures or their OEMs only. Of course this information is essentially confident, but it can be provided as a hardware or software “black boxes” for testing purposes.

6. Conclusion
A comprehensive approach with the use of virtual and field tests is needed to assess the safety of autonomous road vehicles with respect to the peculiarities of road and weather-climatic conditions in Russia.

It is impossible to assess the complete ADAS systems safety without the use of exact control algorithms and vision recognition system characteristics, which can be provided by car manufactures or their OEMs as a hardware or software “black boxes” for testing purposes.

A clear statement of the acceptable operational conditions and the functionality of automated in-vehicle control systems should be declared in the instruction manual. AVs legal permission to access public roads should be done after comprehensive tests only.

We have proposed a method for addressing the issue of autonomous vehicles testing and critical testing scenarios detection.

References
[1] Eskandarian A 2012 Handbook of Intelligent Vehicles (Springer) p 1628
[2] Saikin A M, Bakhmutov S V, Terenchenko A S et al 2014 Tendency of creation of "driverless" vehicles abroad Biosciences biotechnology research Asia 11 (Spl. Edn.) pp 241-46
[3] Ruparel T, Yonten K and Eskandarian A 2014 Analyzing roadside safety implications of future vehicle designs ASME International Mechanical Engineering Congress and Exposition Proceedings (IMECE)
[4] V V Gaevskiy and A M Ivanov 2018 Problems of the application of intelligent driver assistance systems on a single-track vehicles IOP Conf. Ser.: Mater. Sci. Eng. 386 012021
[5] A M Ivanov and S S Shadrin 2018 Development of autonomous vehicles’ testing system IOP Conf. Ser.: Mater. Sci. Eng. 315 012011 (doi:10.1088/1757-899X/315/1/012011)
[6] Technical regulations of the Customs Union “On the safety of wheeled vehicles” TR CU 018/2011
[7] Christopher Nowakowski et al 2014 Development of California Regulations to govern the testing and operation of automated driving systems California PATH Program (University of California, Berkeley, available at http://docs.trb.org/prp/15-2269.pdf)
[8] Federal Automated Vehicles Policy. Accelerating the next revolution in roadway safety U.S. Department of Transportation (NHTSA, Sept. 2016, 12507-091216-v9) p 116

[9] Shadrin Sergey Sergeevich and Ivanov Andrey Mikhailovich 2016 Technical aspects of external devices into vehicles’ networks integration International Journal of Applied Engineering Research 11(10) pp 7003-06

[10] Ivanov A M, Kristalniy S R, Popov N V, Toporkov M A and M I Isakova 2018 New testing methods of automatic emergency braking systems and the experience of their application IOP Conf. Ser.: Mater. Sci. Eng. 386 012019

[11] Shadrin S S, Ivanov A M and Karpukhin K E 2016 Using data from multiplex networks on vehicles in road tests, in intelligent transportation systems, and in self-driving cars Russian Engineering Research 36(10) pp 811–14