Problems of digital diagnostics for prospect of autonomous vehicles implementation

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Abstract. This article outlines the principles and problems associated with the development of intelligent transport systems and, in particular, new trends in the creation and implementation of unmanned vehicles (autonomous vehicles). The alliance between technological evolution and the automotive industry allows us to highlight emerging and future challenges for smart vehicles. In the context of autonomous vehicles, there are a number of issues that need to be addressed. It is assumed that such vehicles must be reliable; therefore, real-time diagnostic issues are relevant. At the beginning of the article, a global vehicle model is considered. Further discusses a management strategy that provides recommendations for the development of diagnostic measures for AV. The results of high-precision joint modeling shown in the article prove the effectiveness of the proposed control technique and new opportunities.

1. Introduction
The automotive sector is constantly evolving. Every day we are getting closer and closer to the revolution of autonomous vehicles, which is one of the most complex systems. This topic still requires solving a large number of problems. Decision-making algorithms should still cover more critical scenarios, sensors should still become more reliable, control strategies should still increase their reliability and adaptability, etc. In the field of land vehicles, the only effector is the bus. Its potential varies with friction and vertical loading. In addition, it must be taken into account that the longitudinal and transverse forces are connected, and their behavior is very nonlinear. The dynamics of the roll can affect the dynamics of the speed of movement, and the lateral speed can inhibit the longitudinal, etc.

In addition, the dynamics at low speed differs from the dynamics at high speed. To prove the safety of autonomous vehicles, it is necessary to ensure dynamics control at the limit of vehicle controllability. Another problem is related to the uncertainty of vehicle parameters. The total weight can be uncertain and can vary, tire stiffness in corners can be uncertain, and it can also get old and so on. The management strategy should be constant regardless of how many passengers are in the vehicle alone or whether the road is dry or wet, whether the tires are new or already worn out, etc. [1, 2].

Diagnostics – this is the determination of the technical condition of the car, its components and components without disassembly and the conclusion about the need for repair, maintenance or serviceability, is an integral part of the technical process of maintenance and repair and is intended to improve the quality of work at minimal cost.

There are two types of technical diagnostics – general and advanced.
In general diagnostics (D-1), the technical condition is determined according to a common criterion – an object is “suitable” or “unsuitable”, can it be operated further without preventive or repair actions [3, 4].

With in-depth diagnostics (D-2), step-by-step diagnostics of the technical condition of units and assemblies is carried out, and places and causes of hidden malfunctions and failures of these nodes are identified. As a result, a diagnostic report is made with an accurate diagnosis and the amount of necessary adjusting and repair actions [5–7].

There are classifications of diagnostic methods according to various criteria.

Diagnostic methods are divided into subjective (organoleptic) and objective (instrumental).

Subjective diagnostic methods:
• visual inspection;
• listening;
• check by touch and smell.

An external inspection determines the condition of the seals, fuel, oil, electrolyte leakage, damage to external parts; listening – knocks, noises and other sounds that differ from normal workers; tapping – threaded, rivet, key and welding joints; touch – places of heating parts, vibration, run out, fluid viscosity; sense of smell – the state of the clutch by a characteristic odor, gasoline leak, etc.

In order to establish quantitative modifications of the parameters of the technical state of the vehicle, an objective diagnosis is established, that is to say with the aid of equipment and special devices. The hardware can be integrated into the machine or connected to it. Built-in sensors include sensors, light signals, operating hours counter, filter clogging indicator, and more. Connected sensors include media, peripherals, etc.

Almost all modern cars are saturated with a variety of electronic systems. This determines the appearance, as well as the demand, of a type of diagnosis such as the computer, able to identify efficiently and quickly all the main problems of a car.

Computer diagnostics of a car is a process in which the codes of possible malfunctions are read on the main nodes, the erasure of these codes and their subsequent correction. For this, dealership scanners and other systems can be used. These include OEM, multifunctional stands, portable readers. Modern diagnostic equipment and software allow you to read and detect the slightest changes in the operation of engine control systems, transmission, instrument panels and others.

All current data is displayed on a single channel multimeter in real time. At the same time, you can plot up to 4 technical parameter calendars, choosing the most convenient form of display. Modern diagnostic systems, which can only be provided by a certified car service, also allow the recoding of parameters. This is done to increase the power characteristics of the automatic chip setting.

For example, the control unit is often reconfigured to optimize it for a given vehicle. It includes idle adjustment or fuel system adjustment. And by downloading additional plug-ins, you can reprogram the car's electronics on the interface of the most recent models in that line and those about to leave the assembly line. The system automatically identifies the differences without the need to manually set the initial and final parameters.

As a general rule, the computer diagnosis of a car is made either when the system itself diagnoses malfunctions on the dashboard (error icons come on), or when the motorist himself observes the incorrect operation from some nodes / systems, you need to make sure (for example, before buying a used vehicle) what technical condition is really the vehicle. You can also perform computer diagnostics, at least once a year, according to the recommendations of the experts (depending on the technical condition of your vehicle).

In fact, computer diagnostics is a very effective and modern way to carry out the most complete verification of the electronic systems of a motor vehicle in order to identify and prevent malfunctions. With this, it is possible to obtain true information on the current state of the control units, parts and components of the vehicle.
The computer diagnosis of the vehicle is performed on embedded systems, via special diagnostic connectors. A rather complicated scanner with serious software is connected, which reads all the codes transmitted by the vehicle.

The codes received are deciphered by specialists, using special programs as well. On the basis of the information received, it can be concluded that there are certain failures. The computer diagnosis itself can be divided into several operations, including skip diagnostics. This is necessary if the motorist detects uneven rubber wear, shocks or buzzing during sharp turns or when driving at constant speed on rough roads. In addition, if a demolition of the rear or front axles is observed during sharp turns, ABC triggers prematurely or an increase in the free wheel of the steering wheel is noted.

A computerized diagnosis of the engine is carried out if the motorist begins to notice that the engine heats for a long time, that fuel consumption has increased, that the engine is unstable or that it starts badly, that it has lost power, exhaust, there is outside noise, the idle is lowered / increased. During the diagnosis, the following elements are checked: injection system; Power source; measured compression.

A computerized diagnosis of automatic transmissions must be carried out if one of the reports does not start, jerks, noises or slips are visible when shifting gears, fuel consumption is increased, oil leaks are noted. During the diagnosis, the error codes of the automatic transmission control unit are read, the sensor readings for the working fluid temperature and the throttle position are evaluated, as well as the position of the selector lever.

If we compare the computer diagnostics of the car with more traditional diagnostics, the first can most likely be considered the pinnacle of diagnostic technology, because it quickly and effectively detects almost all malfunctions and does not require much time and effort.

There is also another diagnostic method, such as:

- **ALDL** (assembly line diagnostic system) – a car diagnostic system developed by General Motors and preceding the OBD-I standard. Prior to minor changes, ALDL was called Assembly Line Communications Link or ALCL. These two terms are synonymous. This system was not a clear standard and was therefore accepted as a specification for communication with a vehicle. There are three different ALDL connectors: 5-pin, 10-pin, and 12-pin – the latter is more common on GM vehicles. Earlier versions used 160 bits per second, while later versions used 8192 bits per second and used bidirectional communication with the traction control module (PCM) [8].
- **OBD-I** (On-Board Diagnostics) – On-board diagnostics that regulate intentions to motivate automakers to develop a reliable emissions control system.
- **OBD 1.5** is a partial implementation of the OBD-II, which General Motors used on some cars in 1994 and 1995 (General Motors did not use the term OBD 1.5 in the documentation of these cars; called OBD and OBD-II sections). in the user manual).
- **OBD-II** (Embedded Diagnostics) – Embedded diagnostics, a standard developed in the mid-1990s, allow complete engine control. Allows you to monitor additional body parts and peripherals and diagnose a car control network. In this standard, manufacturers use various vehicle connection protocols.
  - ISO 9141-2
  - ISO 14230 Keyword Protocol 2000
  - SAE J1850 VPW
  - SAE J1850 PWM
  - ISO 15765-4 CAN (Controller Area Network)
  - OBD-II Socket contacts. Max. 0.6m from the steering wheel.

The OBD-II specification provides a standardized hardware interface and is a SAE J1962 compliant diagnostic link connector (DLC) with 16 contacts (2x8) for connecting diagnostic equipment to the vehicle in the form of a trapezoid. Unlike the OBD-I connector, which is sometimes under the hood of a car, the OBD-II connector must be near the steering wheel or within reach of the driver. SAE J1962 determines the location of the pins on the connector:
In the context of autonomous vehicles, a number of issues need to be addressed. It is assumed that these vehicles will perform multiple maneuvers and may be overloaded.

At the beginning of the article, a global vehicle model is considered. What follows is a management strategy that, according to the authors, should be used in the context of sufficiently activated vehicles.

The results of the high precision assembly modeling presented in the article prove the effectiveness of the proposed control technique and new features [9, 10].

The article is structured as follows: Development of a global vehicle model that can help control engineers learn more about dynamic vehicle couplings. The traffic control is synthesized using a very congested vehicle. A discussion of the outstanding issues in terms of reliability and quality objectives is presented. Findings and future work are described.

The authors believe that car manufacturers and equipment manufacturers will join forces to develop and standardize the proposed control architecture for future passenger cars.

2. Analysis

It is important to study: maneuverability by following the speed of movement and lateral stability by minimizing the lateral slip angle. The four-wheel vehicle model was subsequently examined in the case of a low-level direction for ESP. The clutches were not controlled to a high level of control since two different vehicle models were considered. In addition, no lateral speed adjustment was provided, whereas a vehicle equipped with active front and rear steering systems (AFS and ARS) can allow lateral transient movement, for example to avoid an obstacle.

The current state shows that we are using complex and reliable controllers based on unrelated simplified vehicle models, or that we are separating a complex vehicle model to use simplified controllers in each direction. The authors do not give priority to either the first or the second approach. The new approach has been sufficiently studied, in which a relatively sophisticated and robust high level controller is used, based on a relatively complex model of four-wheeled vehicle with an optimal coordination strategy. The objective is to evaluate dynamic coupling at the vehicle level to justify the structure of the high-level controller.

A twin longitudinal transverse control requires a paired longitudinal transverse vehicle model.

Future autonomous vehicles (AV) must simultaneously drive longitudinal, lateral and, ultimately, vertical controls. These speakers are connected because they are connected to the same system. For global chassis control (GCC), the vehicle’s internal dynamic clutches must be considered. These connections may be more restrictive or, conversely, more relaxed depending on the chassis systems integrated in the same vehicle. For example, with two-wheel steering (2WS), a vehicle can avoid an obstacle only by changing its course (angle of movement). Unlike the vehicle 2WS, vehicle 4WS, four-wheel steering in one direction, you can bypass an obstacle without changing its direction. Since it is impossible to know the future hardware design of cars, and since the design of cars may differ from different manufacturers, the authors of the article are developing a new detailed global car simulation.

In order to replace the driver and make cars autonomous, it is necessary to introduce additional embedded systems. In addition, in order to distinguish a car brand from competitors, various subsystems can be implemented by various manufacturers. One thing is certain, future vehicles can be heavily overloaded.

A layered architecture is a good option for future automotive control tasks. This architecture provides, in particular, the following criteria: adaptability, fault tolerance, dynamic reconfiguration, extensibility and modularity.

The car is equipped with an Active Rear Steering (ARS) system, a vehicle-based braking dynamics control system (VDC) and two rear wheel electric motors for vectorizing rear torque (RTV). The generalized efforts required to move the vehicle can be optimally distributed using optimization strategies based on optimization (CA) on four buses. Then, such bus forces can be converted into actuator commands and activate the corresponding system, avoiding any internal conflicts.
Figure 1. Vehicle axis system ISO 8855-2011

Figure 2. The decay of sprung and unsprung masses.
There are three types of control:

- **High level control**
  The goal here is to calculate the required forces on the vehicle propeller to track the desired speeds. Dynamics at this point is characterized by inertial parameters such as mass and moment of inertia. These parameters are usually uncertain, which requires a certain degree of reliability. A multi-input multi-output (MIMO) controller is required to account for various connections. Since the vehicle is equipped with ARS, VDC and RTV and access to active suspensions is not permitted, only a flat vehicle model can be considered at a high level. However, when evaluating tire potential, the importance of vertical dynamics should be considered.

\[
\sum = S_s + S_{uf} + S_{ur}
\]

\[
\sum: \text{total body mass } M \text{ and center of gravity (CoG) } G, S_s: \text{spring-loaded mass } M_s \text{ and CoG } G_s, S_{uf}: \text{front unsprung mass } M_{uf} \text{ and CoG } G_{uf}, S_{ur}: \text{rear unsprung mass } M_{ur} \text{ and CoG } G_{ur}.
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- **Medium level control** [8].
  This intermediate level aims at coordinating the wheel systems in order to avoid differences and to generate high level general forces. To do this, all the forces must be distributed optimally on the four tires in order to activate the system with the desired level of effort. Since the number of forces on the tires exceeds the total forces that must be applied to the propeller of the vehicle, the system is over-activated, which leads us to the CA problem.

3. Conclusion
Diagnostic issues for future autonomous vehicles are considered. These vehicles need several built-in systems to work efficiently and therefore need an optimal intersystem coordination strategy. In addition, as the driver becomes a passenger, motion sickness should be avoided, creating new driving behavior to provide comfort and confidence in the senses.

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