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OVERVIEW OF AN ONGOING SCIENTIFIC RESEARCH ABOUT VEHICLE SYSTEM RELIABILITY WITH COMPLEX INTERCONNECTIONS

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Abstract
The aim of the research is to elaborate mathematical methods and procedures which support design of technical systems and system elements with increasing complexity introduced in autonomous vehicles and transportation systems taking operational safety and maintenance risk factors into account. This includes investigation of reliability and development of the joint risk assessment methods of vehicle sensor networks. This paper summarizes the main scientific approaches and gives a theoretical overview published during the project so far without being exhaustive.

1 Introduction

Nowadays one of the most important social issues is safety reliability and risk. These highly affect engineers and experts who design and operate different technical systems based on their specializations.

The main research aim of the authors is elaborating and studying applicability of different mathematical solutions and well-algorithmizable models for supporting decision making in reliability and safety engineering of vehicle systems with complex interconnections e.g. vehicle sensor networks. Beyond introducing the project the paper presents the topics mentioned above.

The rest of paper is organized as follow: Section II. Shortly describes the project. Section III. Discusses the most important questions of reliability design taking more aspects into account. Section IV. Summarizes the project work.

2 Short project description

This paper is closely connected to EFOP project called Dynamics and Control of Autonomous Vehicles meeting the Synergy Demands of Automated Transport Systems (EFOP-3.6.2-16-2017-00016), in which the following research consortium is taking part: Széchenyi István University, Neumann János University, Dunaújvárosi University and Óbudai University.

Determinate target of the project is to improve research and development conditions in human resources and services. In order to provide proper dissemination and long term financing strong cooperation with economic sphere is inevitable thus it is need to be strengthened and facilitated.

Long term goal of common research of the consortium partners is that with common force they can have a more active and initiative role in creating knowledge based economics and enhancing research and development potential in Hungarian higher education. Based on the created new knowledge bases participation and cooperation in international networks is initiated. Short term goals are cooperation in network and forming common research groups by harmonizing capacities of which synergic effects can multiply the actual individual potentials of the institutions.

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Concrete goal of the research is that the partner institutions gain significant results in control and communication of autonomous vehicle and vehicle systems. Seven joint re-search areas were assigned by the partners, which are structured in three main research directions. The method is based on integrated approach and interactions of related research problems focusing on cooperation based on mutual strengths and common human resource development.

According to different technical-economic analyses the following prerequisites are needed for autonomous transport with reliable and available operation:

• On-board environmental observation technologies working properly in different conditions

• High precision localization technologies, which can complete sensor data with geographical information during decision making and organize, select and prepare them for the perception system according to their spatial connection

• Communication technologies which make information connection among traffic players, the related infrastructure and the environmental elements in general

• Perception methods, which enable to analyze decision making situations in real time based on sensor and communication data and support control system adapted to the given situation

• Low level vehicle control algorithms with complex, local controlling operation of each vehicle including actuator operation by real time decision making based on perception algorithms in order to fulfill the transport mission safely determined for the vehicle at a required performance

• High level vehicle control making vehicle group control possible along general aspects by and in the interest of real time complex traffic control solutions and achievement of global optimum conditions

• Application of innovative materials, vehicle drive and fuels with better adaptability to total automatization

The goals are defined by the scientific application and they are unambiguously determined also adjusted to concrete project goals.

3 Applied approaches and methods

Today one of the most urgent issues is cyber security concerning reliable communication, making decisions, having complex interconnections while protecting human lives. Regarding intelligent autonomous vehicles, safety is meant so that a certain vehicle should be in such a condition which provides top level of human life protection. “Safety describes the effort to prevent mistakes in the core functions of a vehicle or, in a worst case, to protect the occupants and other persons involved from harm. Components such as brakes, steering, airbags, and the crumple zone of a car, but also electronic assistants such as ESP or ABS are critical to safety”.

Ground vehicles are main items of intelligent transport systems (ITS). At safety planning or review of intelligent autonomous ground vehicles, Society of Automotive Engineers (SAE) International defined the upcoming features: functional safety, active safety (e.g. Advanced Driver Assistance System), safety and reliability (e.g. electronics and electrical systems; hardware and software verification and validation), safety and human factors. All data, warning, control, intervention, effect reduction or rescue systems providing actively or passively vehicle’s road safety, should be taken into consideration from cyber security aspect.

Bus system has been implemented to lessen complexity and enhance flexibility of electronics in motor vehicles. Since there are more and more functionalities the amount and range of bus systems have grown. Safety and comfort functions have been separated from each other. Comfort functions are rarely given appropriate protection and several of them are implemented without protection at all.

These security gaps make access possible to certain security functions, to disturb their operation or take over the control even with no direct physical connection. Thus at intelligent autonomous vehicle design these cyber security questions must also be considered.

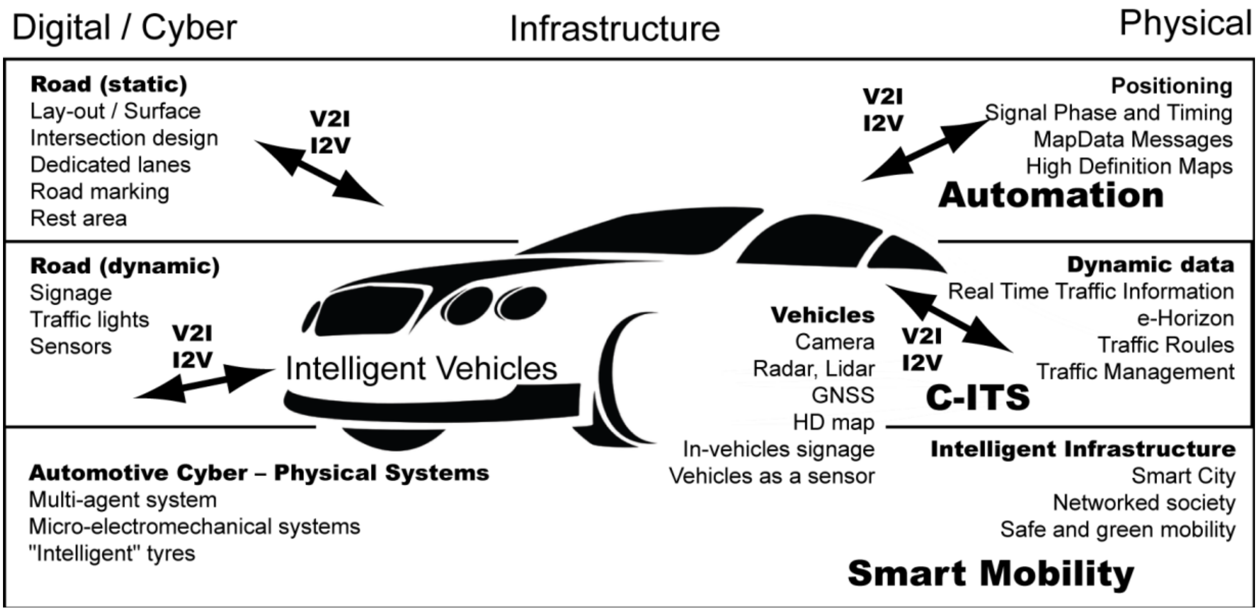

Figure 1. Strategy model of Cyber-Physical Vehicle Systems and Infrastructure [9]

Figure 1 presents an interaction&communication example of autonomous intelligent vehicle with physical and cyber infrastructures. Far-reaching automation also goals to lessen of human risks transportation process. [9]

Since technical systems are featured by network structures they can be determined if there are interconnections between components and subsystems by mathematical model-based analysis. Taking an integrated system into consideration the layout of interconnections may be a hard task due to its complicated interconnections. Graph theory is a wide-spread mathematical solution to investigate network structured systems with interconnections between components. [5]

Safety has always been an actively researched area for automated vehicles, as the expected complexity of self-driving competences extends to traditional safety evaluation techniques. Safety standards are included and actual validation and verification devices are applied to specific components or driver assistance features of the car, supposing that vehicle control is followed by the driver with attention.

Collision Mitigation Systems (CMS) or lane-keep assistance, for instance, were tested and verified according to well-known processes like the automotive V-model or International Organization for Standardization (ISO) 26262. Nevertheless, concerning CMS, filtering and evading unintentional braking are properties named by the recently developed Road Vehicles Safety of the Intended Functionality standard.

Figure 2 shows a safety development workflow that reconsider customary automotive product development methods concerning system, hardware and software design with integration.

Since self-driving technologies are continuously being developed, society claim for comprehensive principles in operation and consequences of a growing number of autonomous vehicles on the road. While Artificial Intelligence (AI) has been a device used for e.g. forecasting and decision making for several professional fields, autonomous cars may become those safety-critical systems that will have a global consequence on society. Even though autonomous cars enhance traffic safety and ensure a significant fall in road injuries, a strong ethical discussion will still go on self-driving car’s decisions regarding moral questions. This demands an educated public dialogue getting to an ethical code of conduct or robot manifesto. The Massachusetts Institute of Technology (MIT) carried out an interesting way of decision making of autonomous vehicles called moral machine, which generates moral dilemmas and gets data regarding the choices participants make between negative consequences. [8]

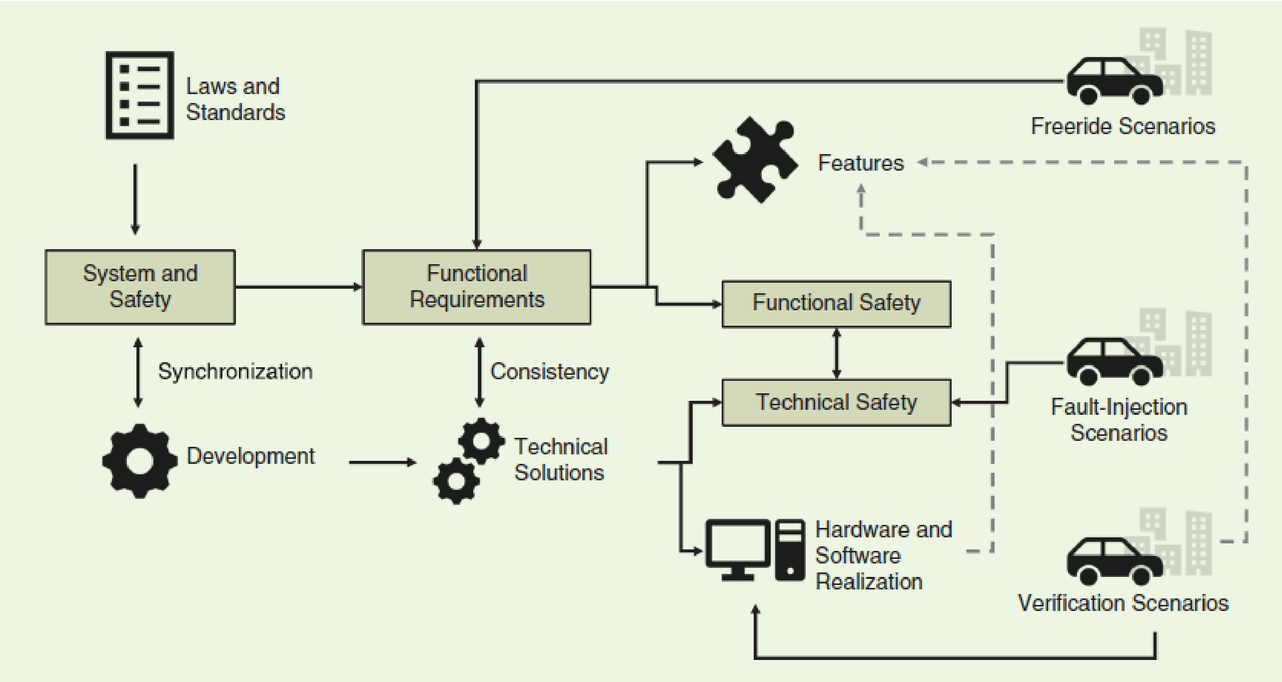

Figure 2. An alternative safety-development workflow that better fits the extended requirements of highly autonomous cars [8]

As today transportation plays a crucial role in our lives car manufacturers not only make continuously vehicle design and performance better and better but also increase automotive safety on the road. Development of Vehicular Ad hoc Network (VANET) system is one of the prospective solutions to lessen a big number of vehicle crashes and lethal accidents. In VANET system vehicles can give information to each other and to the infrastructure, which is called vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. This solution can enhance road safety, help in efficient transport services and reduce environmental effects.

It is important to remark that when vehicles connect the Internet and wireless networks cyber-attack risks are increasing in vehicle communication. VANETs are linked to mobile ad hoc networks (MANETs) communication for sending data between the cars. Furthermore, VANETs includes V2V and vehicle to road side units (RSU) or V2I communication. The main components in VANETs structure are the RSU, the Application Unit (AU) and the On Board Unit (OBU). Whereas the RSU's application gives services, the AU is in the vehicle, which is used by the providers to interconnect with OBU either wireless or wired mode. OBU is operating via waves combined with on-board car to deliver data with RSUs or further OBUs. Moreover, VANETs is a basis of the intelligent transportation system (ITS) and smart city conception. In this system of connections, cars are capable of sending and receiving data from further vehicles or RSU via wireless moderate connection. Vehicles with appropriate hardware can get and deliver the position data in VANET like global positioning system (GPS) or other global positioning system (DGPS) receiver. Additionally, this solution ensures much benefit, for instance, warnings in case of danger (lights, road construction or maintenance, weather data, highway danger sector information, and stop or go road announcements), vehicle-road connection and communication inter vehicles. This approach can provide an improved outlook in transportation, more safety for the pedestrian, passengers and especially for the drivers. [1, 2, 3, 4, 7]

The Failure Modes and Effect Analysis (FMEA) has spread in wide range of modern automotive engineering, which means that in our days this method is also involved in manufacturing and development of vehicle systems.

Although, earlier the main focus was on the mechanical parts, today electronic elements and software components must be included because of system complexity. The shift pointed out above highlights the fact that complication and sizes of car systems result in a lower clearness and similar

Risk Priority Numbers (RPN). Thus a clear and transparent overview should help analysts in underlining the most dangerous parts of the whole system.

The suggested method should not demand further and long working time, but ought to count with the original values of FMEA. The method helps to identify the sensitive points in a complete system highlighting the meaning of dangerous comprehension behind. The goal of the sensitivity analysis is to represent how a modification in any system constraint influences the resultant reliability value of the entire system.

Diverse causes, such as lack of time or low field experience generate the necessity of a neutral summary of existent risks in system background. In general it is used as a basic risk approximation to direct all of RPNs in the whole FMEA Sensitivity Investigation of FMEA to a matching function. This may indicate where the top values refer to risks.

However, S(everity) × O(ccurence) × D(etection) = 10 × 10 × 10 = RPN = 1000 shows extreme risks in the system. Similar RPNs with diverse S (referring to failure effect), O (referring to failure cause), D (referring to failure cause) values e.g. 10 × 3 × 3 or 2 × 5 × 9 both RPNs equal to 90 and cannot be differentiated that easy. Consequently, the actual meaning of close and similar RPNs should always be checked and presented in a common overview. A sensitivity model is set up and two illustration modes, which review the single S, O, D values and the RPN compared to the whole system. Diagram results are very expressive providing a better overview. [6]

4 Conclusions

The Dynamics and Control of Autonomous Vehicles meeting the Synergy Demands of Automated Transport Systems (EFOP-3.6.2-16-2017-00016) project was introduced in this paper. Within the project the Óbudai University, Institute of Mechatronics and Vehicle Engineering is examining sensor networks and systems including their reliable and safe operation. The first results can be read in paper.

The aim of the project participants is to elaborate mathematical methods and procedures which support design of technical systems and system elements with increasing complexity introduced in autonomous vehicles and transportation systems taking into operational safety and maintenance risk factors into account. This includes carrying out and improving modular sensitivity analysis procedures of reliability and joint risks of vehicle sensor systems.

Due to research experience so far earlier “more simple” methods are not perfectly applicable, rather procedures with professional intuitions are needed to take into account, e.g. FMEA, fuzzy FMEA.

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