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Advanced surface vehicles collision risk reduction system

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ABSTRACT
An idea of the innovative enhanced vehicle collision preventing system is presented. The system is based on usage of real-time information about vehicles mutual positions, trajectories and movement, which will be collected by mobile sensor network created ad-hoc by vehicles entering a potentially colliding area. The system will particularly consider vehicles movements dynamics, procedures of secure approaching and passing-by processes as well as remote warnings about traffic obstacles ahead. Premises and assumption for possible procedures and algorithms referred to such a network functionalities involving dispersed mechanism of drivers behaviours coordination is analysed, taking into account also some possible and allowed level of automation of the autonomous control an steering of the vehicle. Moreover, a possibility of system cooperation with various brand contemporary equipment of ITS Advanced Driver Assistance Systems type is analyzed. Results of analysis will be presented first of all to traffic participants and to appropriate traffic management services.

KEYWORDS: Driver assistance, mobile networks, traffic security

1. Introduction

Common daily news and observations of traffic accidents and collision results and related economic and social costs strongly prove the importance of the traffic security problem. For example, in Poland, the number of traffic accidents of the category “moving vehicle collisions” in year 2015 reached 16 802, constituting 50.9% of the all road accidents. There was persons killed (1270, 43.3% of all) and injured (22 231, 55.9 of all) [1]. At the same time (data for 2013), the yearly social costs of accidents reached nearly 8.6 bln € and car crashes 3.7 bln € (in total 12.3 bln €) [2].

It is an evidently strong reason while one of the most important ITS applications is related to travel security, both related to traffic contributors, as well as goods and vehicles. Contemporary road vehicles, mostly cars, are equipped with various devices intended to support drivers in avoiding dangerous mistakes in car conduction. An overview of the previous solutions of ADAS types shows that all of them were constructed as autonomous systems, allotted to vehicle-own use and working on individually collected data, therefore concerning only one particular vehicle, as illustrated in Fig. 1 and in literature, e.g. [3]. Almost the sole external data used in this kind of driver’s support are those coming from GPS system.

In the Internet sources overview can be even found an important information about value of “vehicle-to-vehicle” (V2V) communication, allowing cars to ‘talk’ to each other and “vehicle-to-infrastructure” (V2I) to avoid crashes The source [4] estimates that “safety applications enabled by V2V and V2I could eliminate or mitigate the severity of up to 80% of non-impaired crashes, including crashes at intersections or while changing lanes.” There is shown that this direction of research in traffic safety area have to be nowadays a leading trend.

2. Contemporary driver’s support systems

As a rule, contemporary vehicle’s build-in or available as ad-on package safety equipments are designed to avoid collisions and accidents by automatic or semi-automatic control of the vehicle movement or to alert the driver about possible dangers. In several vehicle models we can find applied more or less advanced ADAS features. Most common ADAS types are listed in Table 1.

Table 1. Most popular ADAS applications [5]

Adaptive cruise control (ACC)	Forward Collision Warning
Glare-free high beam and pixel light	Intersection assistant
Adaptive light control: swiveling curve lights	Hill descent control
Automatic parking	Intelligent speed adaptation or intelligent speed advice (ISA)
Automotive navigation system with typically GPS and TMC for providing up-to-date traffic information.	Lane departure warning system
Automotive night vision	Lane change assistance
Blind spot monitor	Parking sensor
Collision avoidance system (Pre-crash system)	Pedestrian protection system
Crosswind stabilization	Rain sensor
Cruise control	Surround View system
Driver drowsiness detection	Traffic sign recognition
Driver Monitoring System	Turning assistant
Electric vehicle warning sounds used in hybrids and plug-in electric vehicles	Vehicular communication systems
Emergency driver assistant	Wrong-way driving warning

Many of ADAS applications work as autarchic ones, but actually more and more of new or improved solutions with advanced features, need communications with surrounding and road co-users, which is strongly facilitated by many various proven wireless telecommunications technologies.

Contemporary vehicular communication systems [6] are networks or links in which vehicles and roadside units are the communicating nodes or terminals, providing each other with important data, such as safety warnings and actual traffic circumstances information.

Vehicular communications is usually developed as a part of intelligent transport systems (ITS), which means that is build considering rules contained in typical ITS Architecture.

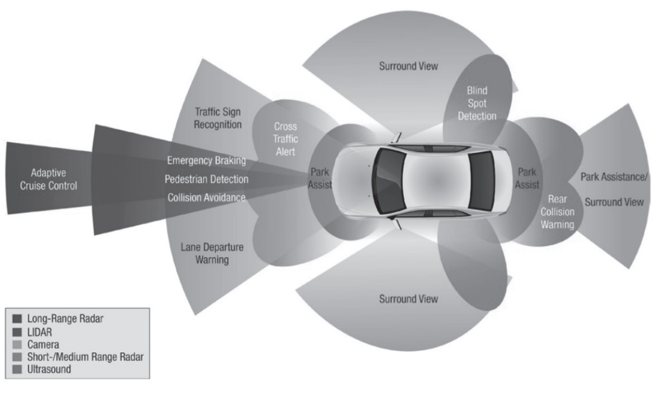

Fig. 1. Illustration of contemporary vehicles telematic sensing equipping [12]

3. A concept of innovative collision-preventive system

Almost all the contemporary solutions helping drivers to avoid collision, are working on the basis of own cruise and surrounding circumstances (road surface condition, markings and signs and co-users), through observations made by sensors of the single vehicle. This make only some automatic cruise corrections or warn the driver about dangers or incorrect vehicle behavior. In fact, actually no information is provided to vehicle security mechanisms about broader surrounding traffic area circumstances, especially about other vehicles than the ones directly ahead and rear. So just accessing to such information, can essentially improve level of traffic security. From this observation and from the willing to guarantee longer time available for driver's reaction, arose a concept of innovative collision preventive system (CPS), which – according to authors opinion – will substantially reduce probabilities of collisions.

3.1. CPS structure

The structure of the system shown on Fig. 1 concerns individual vehicle equipment and "intelligence" allowing cooperation in the group of similarly equipped vehicles. Hereinafter we call "hive" such a group of occasionally and temporarily gathered vehicles, and "risk area" the relevant limited road area with potential collisions danger, caused by the vehicles density.

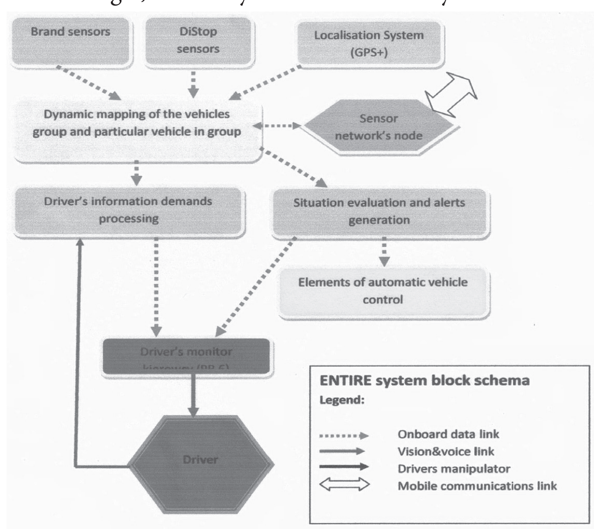

Fig. 2. A structure of vehicle's equipment of collision preventing system: ENTIRE ("Enhancing time for Reaction") and DISTOP ("Distance Stop") are acronyms of the research project undertaken by the Authors [own study]

As it can be seen in Fig. 2, there are few technical devices for data sources and means for data processing and communication, integrated with information transmission systems. While technical devices seem to be known, situation mapping (i.e. mapping of vehicle's locations in the hive) and situation of the given vehicle in potential collisions and consequent alerts generation, are crucial "intelligence" problems, which have to be solved during a research works planned from the Authors. Especially, is to be underlined that evaluation of the situation and alerts generation are to be basic, but complex and difficult questions.

To communicate into a hive, a sensor network technology must be applied, where all the members are equipped also with transmitting device, being a network node. In this way, the vehicles entering the risk area will be automatically included to the hive, as their communication network acts as an "ad-hoc network".

This assumption implies solutions for functional diagnosis of network traffic.

- All vehicles subject to protection are equally privileged. The system analyzes the situation for each vehicle individually and provides information in real time to drivers.
- The system must be equipped with tools to recognize the traffic situation in the neighborhood of every vehicle. This applies, of course, only to vehicles equipped with terminals of the system.
- The recognition of surroundings of the vehicle is able to follow all the vehicles, not only those belonging to the system.
- The system recognizes the dynamics of movement and is able to predict the trajectory of conflict and the course of events of collision.
- The system has the ability to inform the driver to potential collisions and propose appropriate driving behavior, and can be integrated also with action braking or acceleration of the vehicle (this type of operations should be subjected to separate analysis).

To meet the aforementioned functionalities, a unique architecture of wireless network will be designed, with a dedicated computing able to handle a system of distributed intelligence and cognitive elements.

3.2. Basic onboard equipment

As it arises from Fig. 2, onboard systems basic equipment consists of distance sensors, localisation sensors, network communication unit and driver's monitor.

Use of new enhanced distance sensors results from the idea of improvement of the vehicles drivers "reaction" time through visual/acoustic alerts in case of unexpected reduction of the distance between two vehicles. It can be achieved due to dedicated device (DiStop) composed by three newly constructed main elements:

- frontal proximity sensor device (PS)
- rear light indicator (LI),
- internal communication/processing system, integrated on microcontroller or embedded system (CS),

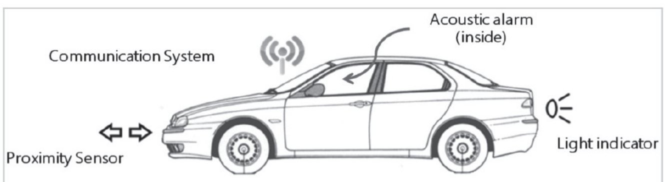

Fig. 3. DiStop system [own study]

supplied by rechargeable battery and connected to acoustic alarm. This internal acoustic alert avoids any distraction of the vehicle's driver_1, for example due to mobile phone or kids or people on board, while a rear visual alert forewarns the vehicle's driver_2 (which follows) about the oncoming braking, before activation of the brake lights from the vehicle's driver_1.

The system works as follows (see Fig. 4). The PS detects the distance from the vehicle ahead and send the distance numerical value to the CS. As soon as the system elaborates an anomalous distance reduction (as interpreted by a relevant algorithm), the CS gives an acoustic alarm and sends a command to the LI.

All the system communication is wireless and doesn't interact with the vehicle's brand infrastructure, neither technological neither mechanical.

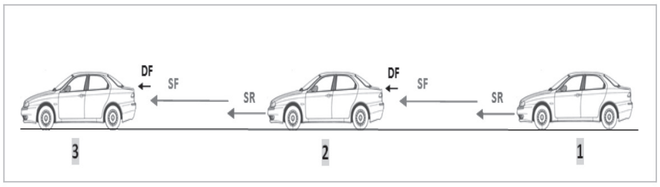

Fig. 4. Illustration of the early warning system (SR - reaction available space, SF - braking space, DF - no impact zone (blocked vehicle) [own study]

All the elements which composes the system is a topic to be developed into the whole discussed project, namely:

- proximity sensor, which must be improved referring to the existing performances;
- rear light, which can be either a „third stop" or a new integrated lamp for the rear flashing lights;
- internal processing/communication system (CS), based on a new algorithm.

Firstly, a deep research on existing technologies for proximity sensors must be developed. There are many types of distance sensors, which use several technologies, such as laser, ultrasonic, radar, etc. The goal in this stage is to research and develop a sensor with improved characteristics, as concerns range of distance measurement, accuracy, and ease to be integrated with embedded systems, microcontroller and others sensors.

Referring to range of distance measurement, measuring distance higher than 40 meters assures earlier warning and more braking distance. Proper measurement accuracy guarantees the value measured is correct within a delta value. And last but not least, the sensor should be easy to be integrated with many types of systems.

The main features of the unit can be defined as follows:

- distance till 40 ÷ 60 meters;
- accuracy 20 ÷ 80 cm;
- working ability also in bad weather conditions (rain, fog, high rate of humidity);
- possible integration of the sensor with acquisition system and other sensors;
- high durability;
- low consumption of energy;
- low cost.

Of great importance is to develop a new algorithm, mainly based on a mathematical formula which calculates the Distance's Reduction Speed parameter (DRS) and compares this parameter with limit values depending on speed, distance, weather conditions and other variables, on the basis of experimentations carried out during the research. To fulfill the CS calculations, the algorithm have to communicate with integrated PS and traditional sensors. The communication should be wireless, short distance ones, compatible with other inner-vehicle communications means, branded or installed for whole project means.

Obviously DiStop system can be installed as a standalone device or be a part of whole ENTIRE system.

A proper preliminary analysis of the DiStop concept and a specialized consulting show that foreseen solutions do not needs some broad basic researches, but necessary are deep researches of the possibilities of the construction of such systems with high level of reliability and efficiency of foreseen system functionality.

Other devices of ENTIRE system, i.e. localization set and driver's monitor, shall be developed from existing technologies, considering that in localization function it is important not the exact geo-localization as itself, but the mutual positions of the vehicles in a *hive* on a given *risk area*. In the project the *hive* shows some extended order, with regard mainly to situations of travel in two way routes with single carriage, passing road crossings and by pass maneuvers.

3.1. Inter-vehicle communication system

Inter-vehicle communication system (IVCS) has to connect all the vehicles which are hive's members, during the time they spend in the risk area. Obviously, the system has to be wireless and connect functionally all involved vehicles. The accessible proper communication technologies are well known [6].

Wanted functionality and architecture of the ENTIRE'S inter-vehicle communication system is similar to other known technologies coming from "ad-hoc" networks and sensor networks. Nevertheless it will be an innovative solutions, with new functionalities not yet fully applied, both in tracking systems, and in recognition of area of electromagnetic environment, and in remote observation (remote sensing).

Communication protocols applied in IVCS will be developed with reference to the needs emerging from real data, and the determination of vehicles position has to be calculated with advanced computational techniques, using correlation and cognitive methods. In order to reduce the risk of collisions, the needs of the surroundings recognition for each of the vehicles into the hive will influence the communication functionality, as it must be supported by advanced information technology [7].

It is assumed that proposed radio network will be adapted for communication of the vehicles traveling on public roads. Radio devices installed on board become a network nodes. These nodes will exchange information concerning the location of the vehicle, its movement parameters and detected traffic of the moving vehicles in the neighborhood. They will also inform the driver about road condition and potential hazards, even with the possibility to support the drivers in the reactions for adaptation to the requirements of traffic safety. Obviously, in such a specific case, network architecture should have the characteristics of "Ad-Hoc" networks, sensor networks, networks M2M type and similar.

This kind of networks is now shortly described as follows, even from the ENTIRE needs point of view.

1. **Ad-Hoc networks**

Like in all radio communicating systems, Ad-Hoc networks automatically establish communication between the different nodes. Node inherently will change their relative position and thus the network will be in a constant changing its geographical configuration. Notably distinguishing feature of the network is the fact, that in our case for each vehicle system will develop the traffic situation in the immediate area. So each vehicle will create a cluster of limited range in the centre of it, but in total covering the entire length of the risk area. This will require the development of a special protocol for division of the network into clusters.

2. **Sensor networks**

A characteristic feature of sensor networks is the organization sensors or sensors equipped with radio interface lower spontaneously pass through the adjacent sensor measurement data to the central system. Thanks the nanotechnology achievements sensors are built in a minimum volume in a mass and thus low cost dimension. They can therefore be used once for the fulfillment of a specific measuring task. Renewal of network becomes after adding a new batch of sensors with new energy resources.

The proposed network connecting vehicles will have features of sensor networks with the exchange of information between each vehicle and some "central" computing system also by some neighbors configured network. The feature that distinguishes the this network from the typical sensor network is requirement of the ability to process data from the scope of the cluster without a typical central system computer. Within the cluster will be solved the problem of predicting the risks of collision. Inevitably, each of the vehicles will make available part of their computing power to clusters in which it participates, may even participate in several.

So nodes of proposed network will differ from the typical sensor network nodes increased by computing power and enhanced functionality sensors.

It should be noted that in the present preferred embodiment is the communication node-to-node, that is able to communicate with each network node to a specific other node within the cluster network.

3. **MASTR network**

Communication in MASTER-network are organized in order to receive and transmit data within the entire network. This solution is dictated by the idea of building a network of autonomous operation of a distributed intelligence within a single cluster separately, but also the ability to monitor the situation in the environment over large areas [9], [10].

3.1. Outer world communication

In case of necessity to communicate driver with the outer world obviously for individual driver mobile communication services (phone, Internet etc) are accessible and usually sufficient, but for the discussed system it is rather useless. But it is highly probable that in further research some important needs for outer world communication may emerge, for example for communication with road infrastructural elements, or – what more important – for to get access to information processing means – for example in cloud ones. It could be critical condition for realization of the main system algorithms concerning *hive's* dynamical configuration and generating advices for drivers and those questions need some particular studies.

It is worth to remember, that some fortunate circumstances could emerge due to introduction of obligatory e-Call system [11], as in e-Cal dispatch format was left a free place for some short additional message. It may create an additional source of warnings about disturbances in road ahead of cavalcade. The importance of the travel security should justify to use this place it for this goal.

4. Conclusion

A solution is presented, which has been created on the basis of broad knowledge about transportation needs and risks, as well as modern means and methods to fulfill the users and market expectations. Some necessary for system means are known and probed, but several technologies need to be prototyped during the mentioned research project.

Comprehensiveness of the essentially innovative system planned with use of the above mentioned technical means and its infrastructural autonomy, as well as economic values of installation and exploitation, distinguish them favorably from other partially similar solutions actually used in individual branded applications.

The experience and the know-how gained during the project will be useful for a further development, especially related to applied methods of dispersed intelligence.

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