INFORMATION IN THE MOTOR VEHICLE SAFETY SYSTEM WITH THE "e-Call" FUNCTION

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Summary

A concept of the motor vehicle safety system (MVSS) with the e-Call automatic accident notification function has been discussed, with the issues of generation, transferring, and analysis of information in the system having been particularly taken into consideration. According to the concept presented, the MVSS includes set of sensors, digital camera (or a system of cameras), GPS-type vehicle positioning device, processor with read-only memory (ROM) and interface to connect the processor with a data processing system, manual accident notification switch, and sending-receiving unit of the GSM telephone system used for communication with a monitoring centre, where actions to help accident victims would be organized. An essential part of the MVSS is an autonomous measuring module, which includes sensors capable to detect the sinking, fire, or other dangerous situations with the vehicle, apart from the sensors used as standard equipment of the e-Call systems for recording the time histories of decelerations related to collisions. The information provided by the sensors of the measuring module may be supplemented with data obtained from other sensors installed elsewhere in the vehicle outside of the module. In the proposed general model of the structure of the data characterizing the accident, special synthetic indicator signals are to be used; the indicator signals would be generated on the grounds of the classified signals sent by the MVSS sensors. This would facilitate the quick making of a correct decision by the operator at the monitoring centre. A set of data generated by the MVSS has been also presented as an example.

Keywords: intelligent transportation systems; intelligent car; motor vehicle safety system; e-Call; MSD package; generation, transferring, and analysis of information

1. Introduction

The information generated in a motor vehicle safety system with the e-Call function is a key to the effectiveness of automatic accident notification.

This paper is to elucidate the issues concerning motor vehicle safety systems with the e-Call function, especially the theoretical problems related to the generation, transferring, and analysis of information.

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The scope of this study may be defined as an introduction (with giving some literature references) to these topics together with description of a concept of the system where an original method is used to generate information that is based on output data of measuring sensors and sent to the monitoring centre.

2. Motor vehicle safety systems

The hazards to road traffic safety that are associated with the motor transport stimulate the development of systems aimed at improving the active (pre-accident) and passive (post-accident) safety of motor vehicles and vehicle users. This is fostered by technological development, especially achievements in the field of mechanical quantity sensors, radars, lidars, digital cameras, positioning systems based on the Global Positioning System (GPS) technology, radio data transmission systems (especially GSM, i.e. Global System for Mobile Communication), signal converters, microprocessors and computers with real-time data processing software, data transmission networks (especially the local network referred to as CAN, i.e. Control Area Network), as well as precisely operating servomechanisms and other actuators. Varieties of mechatronic devices and systems have been built around the elements mentioned above to carry out fragmentary monitoring and automatic control tasks in a vehicle [1, 6, 9]. It is noteworthy that these systems have various brand names although in fact they perform identical functions. As an example, the driving stability system predominantly known as ESP, which is a Bosch's registered trademark, also occurs under the name of ESC, ASC, etc. One of exceptions is the name ABS used for various proprietary solutions of the systems that prevent road wheels from locking up during the braking process.

The mechatronic devices and systems used to improve vehicle safety undergo integration to an increasing degree. An example may be the ESC II system [10], which not only performs the basic driving path stabilization functions by appropriately controlling the braking and driving of specific wheels but also is coupled with controllers of the active steering and suspension systems. The integration of motor vehicle safety systems is facilitated by the fact that the same measurement signals are often used by different systems.

The integration of fragmentary vehicle safety systems makes a basis for the devising of comprehensive systemic solutions of driver assistance systems or even automatic vehicle driving systems. An example of the comprehensive motor vehicle safety systems is the one named APIA (Active Passive Integration Approach) [11]. It connects together the active and passive automatic safety systems. A car provided with the APIA system can avoid an accident by automatically applying brakes or, when a collision cannot be avoided, it will protect vehicle occupants by carrying out in advance such operations as preparation of safety belt tensioners and air bags, bringing of vehicle seats to their optimum positions, and closing of windows if open. The main part of the system is a danger control module, where all the data sent by sensors and cameras are collected and analysed. For all the time when the vehicle is moving, the module continually calculates the instantaneous degree of risk and determines the probability of a collision. Along with increasing collision risk, successive elements of the safety system are actuated, from warning the driver to actuating the safety belt tensioners and air bags.

When the on-board devices are supported with telematic systems, which would provide "signal coupling" between the vehicle and other traffic participants or road infrastructure, referred to as V2V (Vehicle-to-Vehicle) or V2I (Vehicle-to-Infrastructure) systems, respectively, complete implementation of the "intelligent vehicle" idea will be enabled, where not only the vehicle could be automatically driven but also full ride comfort could be achieved and in case of emergency, the negative effects of a possible accident would be minimized. Works on such vehicles are being carried out at various research and development centres within such projects as PATH of PROMETHEUS [8].

The notion of "intelligent vehicle" is undoubtedly connected with the notion of "artificial intelligence" introduced more than half a century ago in automatics and robotics and with the term "Intelligent Transportation Systems (ITS)," which comprehensively covers the issues of application of telecommunications, computer science, sensorics, and automatics to transport facilities and is a term accepted at the first World ITS Congress in Paris in 1994.

The "intelligent vehicle" (also referred to as "autonomous vehicle") is popularly defined as a vehicle capable to move on the road with no or very little driver's involvement. The possibility that such vehicles would appear on the roads in the not distant future is signalled not only by numerous successful prototype solutions [8] but also by certain governmental and administrative decisions. It may be expected that in not more than two decades, autonomous vehicles will become something more than merely a subject of technical interest and in several decades, manual driving will only be permitted on specially marked roads, which will resemble the similar restrictions having been imposed on the horse-driven transport.

From the point of view of the road traffic safety taken as a whole, the term "intelligent vehicle" should not only be related to automatic driving but also cover the automation of other areas connected with vehicle operation. The automation of neutralizing negative consequences of such road events as collisions, accidents, fires and the like situations (which in the more distant future will obviously be extremely rare thanks to the intelligence of active safety systems) appears as a top priority issue at the current state of development of automotive technology and mass motorization. The motor vehicle safety system (MVSS) with the function of automatic notification of a road accident with severe consequences is a concept that is perfectly consistent with the idea of an "intelligent vehicle."

For the purposes of this paper, the "intelligent vehicle" is defined as a motor vehicle that is not necessarily a vehicle "totally automated" but is provided with means for automatic accident notification.

3. Accident notification with the use of a mobile telephone system. The e-Call system

The accident notification is an important element of the safety system that is to protect vehicle occupants and other traffic participants. In the existing solutions, the road accident notification procedure is carried out by using the mobile telephony technology in a standard way (through the emergency phone number 112). Some motorcar manufacturers provide their vehicles, especially the luxury models, with special systems that automatically notify emergencies to rescue service centres. As an example, BMW in cooperation with the Vodafone mobile telephone network offers the world's first Internet portal for its vehicles where various on-line services are provided, such as assistance, navigation, and on-board telephone communication, including the function of automatic accident notification. Other manufacturers, e.g. Volvo, GM, PSA, or Fiat also propose their own solutions. In 2008, the company Subaru Import Poland introduced a system named ISR (Intelligent System for Rescue) to all the Subaru cars imported to Poland. The system is automatically actuated when the decelerations (measured by a 3D system of deceleration sensors) exceed acceptable limits, thus indicating a frontal or side collision or a rollover accident. The accident scene is located by means of the Global Positioning System (GPS). Then, three SMS messages are sent in succession with the use of the GSM transmission system to the monitoring centre with a package of information data (vehicle make, colour, registration number, owner's name, and pre-set mobile telephone numbers), which initiate the further procedure. The ISR system is also provided with a console with a hands-free car kit, which ensures independent voice contact with the monitoring centre and connection with the emergency phone number 112. Having received the SMS messages, the on-duty monitoring centre operator tries to establish voice contact with the driver and initiates action of the rescue service. The examples mentioned here represent fragmentary solutions and are still rather unpopular (in Europe, only about 0.5% of cars is connected with rescue centres).

An alternative solution is a single automatic accident notification system, common for all countries and vehicle makes. Such a system, named e-Call (which stands for Emergency Call) has been developed under the auspices of the European Commission since 2008 within the e-Safety initiative aimed at improvement of safety on the roads of Europe. It is

Fig. 1. Schematic diagram of functioning of the e-Call system

to be implemented in the EU countries in 2014, according to plans. From that year on, all the motor vehicles newly registered in the European Union will be obligatorily provided with this system. Thanks to the e-Call system, the time of waiting for help is to be shortened by half, according to estimates; this would also make it possible to reduce the losses incurred in result of road accidents by about 15%. The e-Call system is treated as an important supplement to the E112 system of emergency voice connections with the user's location, which is already functioning and which is maintained by operators of the GSM network and by public authorities of individual EU countries.

The principle of operation of the e-Call system is similar to that of the ISR system mentioned above (Fig. 1).

In case of a road accident, the system will establish a GSM connection between a special IVS (In-Vehicle System) module of the vehicle having met with the accident and the nearest Public Safety Answering Point (PSAP) operating within the system of the E112 emergency telephone network. When the emergency connection is started (manually, by means of a pushbutton, or automatically, by means of a processor, based on an analysis of the sensor data), a direct voice connection with the PSAP operator via the emergency number 112 is set up and an MSD (Minimum Set of Data) information package, which contains such data as geographical position (longitude and latitude) of the vehicle, direction of drive, time, VIN (Vehicle Identification Number) with vehicle data according to ISO 3779, and connection status (manual or automatic), is sent. It is planned that the MSD package might also include some additional data to supplement the basic information. The MSD format has been specified in details in the EN 15722 standard (see Table 1).

Table 1. MSD format

Name	*Size (bytes)*	*Type*	*Validation*	*Description*
Control	1	Integer	no	Bit7: Automatic activation Bit6: Manual activation Bit5: Test call Bit4: No confidence in position Bit3-Bit0: Reserved
Vehicle identification	20	String	The number consist of 17 characters not including the letters I, O or Q.	VIN number according to ISO 3779
Time stamp	4	Integer	value >= 0	UTC seconds
Location	4	Integer	-324000000 ≤ value ≤ 324000000	Latitude (WGS-84) in milliarcseconds
	4	Integer	-648000000 ≤ value ≤ 648000000	Longitude (WGS-84) in milliarcseconds
	1	Byte	0 ≤ value ≤ 255	Direction in degrees. The nearest integer of 360.0*value/255.0
Service provider	4	Byte[4]	IPV4 format or blank field	Service provider IP Address or blank field
Optional data	102	String	no	Further data (e.g. crash information) or blank field
Total bytes:	*140*			

When the voice connection has been set up, the PSAP attempts to strike up a conversation and arranges a rescue operation with the use of ambulance service, fire service, etc.

The voice notification of an accident with the sending of an MSD package requires that special technological solutions should be introduced in the GSM telephone system. Various detailed solutions are possible, from full data separation as it is in the ISR system to a solution where the digital speech signal and the MSD package are sent simultaneously in the same traffic channel. The solution with full separation is simpler but more difficult in organizational terms, due to the use of standard GSM networks for the transmission. In the innovative concept of simultaneous sending of the speech signal and the MSD package, described inter alia in [2], the use of the "in-band modem" is assumed. Such a solution is very advantageous from the point of view of network organization (this is very important in consideration of project costs) because, in terms of operators' services, it actually does not differ from ordinary telephone connections. From the technical point of view, however, this solution requires the use of special modems that would enable the coded MSD package to be "superposed" on the digitally coded speech signal at the vehicle and then the two signals to be separated from each other at the monitoring centre. The solution based on the "in-band modem" technology is already available in the market and has already been introduced into the standardisation documents of the e-Call system.

An important issue related to the technical and organizational aspects of the impact notification is the ensuring of adequate reliability and accuracy of transmission of the data having been digitally coded. Therefore, the e-Call standards include a requirement that the transmission should be automatically repeated several times until the monitoring centre becomes absolutely sure that the data transmitted are perfectly correct.

More details that might elucidate the technical issues concerning the transmission and reception of signals in the e-Call system can be found in publication [2], where prototype modules built to the "in-band modem" standard for both the IVS and PSAP have been presented as well.

The e-Call issues (covering the legal, organizational, and technical aspects, including the topics related to standards and specifications) have been comprehensively discussed in numerous publications and on the Internet. The works cited here [2, 4, 5, 7] are examples of interesting publications by Polish authors, as the multiple topics related to the e-Call system are explored at a number of Polish research and development centres.

This paper is to be chiefly dedicated to the issues related to the on-board elements of the e-Call system in an "intelligent" vehicle. Therefore, we will not go into details regarding the technology of information transfer; instead, our attention will be focused on the information contents of the MSD package.

4. Motor vehicle safety system with the e-Call function in an "intelligent" vehicle

The motor vehicle safety system (MVSS) with the e-Call function is a set of technical means and software used for automatic detection of accident situations and for automatic accident notification with generation of an MSD package.

The MVSS includes set of sensors (both incorporated in the measuring module and installed additionally), digital camera (or a system of cameras), GPS-type vehicle positioning device, processor with read-only memory (ROM) and interface to connect the processor with a data processing system, manual accident notification switch, and sending-receiving unit of the GSM telephone system (Fig. 2).

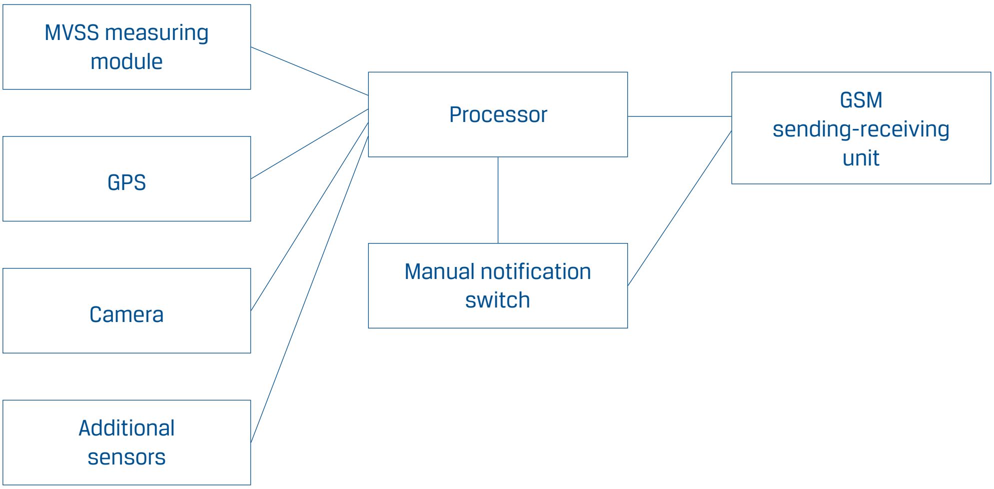

Fig. 2. Schematic diagram of the MVSS with the eCall function

The sensors are to provide the basic data for the accident situation to be identified and additional data to be included in the MSD package. The sensors intended to initiate the notification process are to be doubled, thanks to which the reliability of the information provided by the system will immeasurably improve. The digital camera provides frame-by-frame video information. The GPS-type device makes it possible to precisely locate the vehicle with specifying the direction of drive. The MVSS processor, providing computer control over the MVSS as a whole, carries out on-line a few specific tasks. First of all, it performs the functions of a data analyser and comparator, which continually checks the current values of measurement signals in order to switch on the GSM sending-receiving unit when any of the acceptable signal levels is exceeded and thus to initiate the automatic accident notification procedure. Simultaneously, it processes the data used to generate the MSD package. Within this scope, the MVSS processor directly cooperates with other components of the on-board telematic, computer, and automatic control systems (GPS unit, ABS controllers, ESP system, "black box," etc.). Thanks to the read-only memory, the data obtained from all the system sensors are recorded in the on-line mode and, if no accident notification signal is generated, they are deleted after a few seconds; the same applies to the successive camera pictures. In the off-line mode, the processor is used for system diagnostics purposes and for the generation of reports, e.g. for the preparation of post-accident documentation. The text data (VIN, additional information about the vehicle owner) are coded through the user's interface or a data processing connection. The manual accident notification unit that initiates a telephone connection set up with the emergency phone number 112 is a special switch protected from unintended use. The GSM sending-receiving unit is a specialist mobile telephone set provided with an "in-band" modem and a hands-free car kit.

The accident identification and the information contents of the MSD package will be discussed later. These issues are essential for the MVSS concept.

To ascertain the fact that a collision or rollover accident has taken place, data from the three-dimensional deceleration sensors installed in the separate MVSS measuring module will be used. Such an autonomous solution is easily implementable and does not require disturbing the connections of sensors of other existing monitoring and measuring systems of the vehicle. The use of signals generated by the sensors that are already used to serve other purposes in the vehicle may cause problems. Let us note that many cars of the older model years do not have equipment of this type at all and the vehicles manufactured at present are obligatorily provided with lateral acceleration sensors only (the longitudinal deceleration used by the ABS system is merely estimated rather than measured), but this is insufficient for the identification of decelerations in the three-dimensional system. In practice, only luxury cars provided with advanced (but not obligatory) active safety systems such as "Cruise Control" or "Rollover Protection" might meet such requirements. The use of airbag actuation signals for the initiation of the accident notification procedure seems to be incorrect, too, especially in consideration of the fact that vehicles have different airbag systems, more or less sophisticated, or have no airbags at all and, apart from this, the cases of accidental airbag actuation are known to have happened. In general, in consideration of the capabilities of deceleration sensors, the presence of signals received from sensors provided in passive safety systems (airbags, safety belt tensioners, head restraint systems) in the e-Call initiation algorithm seems to be a side issue; this does not mean, however, underplaying the importance of this information at the stage of analysing the event, i.e. when this information is provided within the MSD package.

At the previous deliberations on the initiation of the accident notification procedure, the situations that ended in a collision or rollover of the vehicle were taken into consideration. However, dangerous road events may also have another form, not associated with very high deceleration of the vehicle. Such events may include the sudden action of "elements," e.g. vehicle fire, being blocked in a tunnel filled with smoke, or sinking in water. Therefore, the set of sensors in the MVSS module of an "intelligent" vehicle is supplemented with three additional sensors, i.e. fire detector, dense smoke detector, and flood detector.

In such a solution, the autonomous measuring module of the MVSS system would include 6 sensors (3 deceleration sensors and 3 "element" detectors) and their backup units and this would ensure detection of virtually every accident situation.

A separate issue, but of primary importance for this study, is the structure of the additional data to be included in the MSD package (as regards the basic data to be provided in the

MSD package and to cover the place and time of the accident, VIN, and accident notification method, their required structure has been precisely specified in the EN 15722 standard). The said additional information should facilitate the quick making of a correct decision by the operator at the PSAP monitoring centre. The PSAP operator decides which of the rescue services (ambulance service, fire service, etc.) should immediately intervene at the accident scene and what specialist equipment (e.g. for the extrication of vehicle occupants, fire extinguishing, diving, transportation of injured persons, etc.) should be at their disposal. Therefore, the operator should collect as much information as possible about the course and effects of the accident, especially about the number of the persons injured and their state of health. Obviously, this information should be chiefly obtained from a telephone conversation; however, it may happen in most dramatic situations that the information needed must be deduced by the operator from the additional information received with the MSD package.

The basic part of the additional information included in the MSD package should be the data obtained from the autonomous MVSS sensors that initiate the accident notification process. This does not mean, however, that the monitoring centre would receive values of the measurement signals recorded. Thanks to the MVSS processor, the data generated by the sensors initiating the notification process will be processed so that the MSD package includes synthetic information about the type and class ("severity") of the accident in the form of appropriate indicators. The value of the collision class indicator will be generated on the grounds of the known criteria assigning the collision class to the level of the decelerations measured. Obviously, both the main and backup sensor readings will be taken into account to determine the collision class. Should the sensor readings significantly differ from each other, a verification procedure would be started in the processor for the data of lower confidence level to be rejected.

Special sensors installed outside of the MVSS measuring module would also be helpful in determining the additional information data. Such sensors may include vehicle body crumpling sensors, seat load sensors, sensors of vital functions of vehicle occupants, etc. (the discussion of these issues will be resumed in a subsequent part of this paper). However, a digital camera showing the picture of the vehicle cab interior seems to be the simplest and, simultaneously, satisfactorily effective solution. A compressed picture (or a sequence of several pictures) sent as an MMS message to the monitoring centre should provide the operator with sufficient information about the course of the accident and the number and condition of the people involved in the accident. It should be noted here that possible identification of the number of vehicle occupants without using additional equipment (such as a camera or sensors installed in vehicle seats), merely based on the recorded time histories of readouts of the deceleration sensors installed in the measuring module, may only give a roughly estimated figure in the best case.

To justify this thesis, having been so strongly formulated here, let us use an example where an attempt is made to identify nothing but the vehicle mass based on an analysis of a record of the lateral vehicle acceleration. The analysis will be carried out with the use of the so-called "bicycle model." Such a model, although having a small number of degrees of freedom and model parameters, is relatively accurate; therefore, it is commonly used for describing the "lateral dynamics" of a motor vehicle. Such a model is also used as a reference model in the algorithms of stabilization and automatic controlling of vehicle motion. Please note that vehicle stabilization systems require the lateral acceleration, angular velocity of yaw, as well as steered (road) wheels and steering wheel turning angles to be measured. In the case described here, the lateral accelerations are to be measured, too; therefore, it would be interesting to identify the vehicle mass with making use of the pre-accident time histories of the measurement values recorded in the processor memory providing that the model applicability condition was met, i.e. when the drive speed was constant and the steered wheels were not turned too rapidly.

Let us adopt the following symbols:
x,y – coordinates in the local coordinate system attached to the vehicle
θ – vehicle yaw angle
φ – steered wheels turning angle
V – linear velocity of the vehicle
M – vehicle mass (driver, passengers, and luggage inclusive)
J – moment of inertia of the vehicle relative to the axis of vehicle rotation
L_A, L_B – distances between the front and rear wheel axes and the projection of the centre of vehicle gravity
K_A, K_B – coefficients of resistance to slip for the front and rear axle wheels

The equations of motion have the following form [3]:

$$M\ddot{y}(t) + \frac{K_A + K_B}{V}\dot{y}(t) + \frac{K_A L_A - K_B L_B + MV}{V}\dot{\theta}(t) = K_A \varphi(t)$$

$$J\ddot{\theta}(t) + \frac{K_A L_A - K_B L_B}{V}\dot{y}(t) - \frac{K_A L_a^2 + K_B L_B^2}{V}\dot{\theta}(t) = K_A L_A \varphi(t)$$

The equations of motion make it possible to generate time characteristics of the model variables for various time histories of the $\varphi(t)$ function and various values of parameters V, M, J, L_A, L_B, K_A, and K_B. Based on the equations above, the transmittances representing relations between the transforms of the response signals and the transform of the control signal may be determined. The transmittance parameters present in the transmittance formulas (amplification factors, time constants, etc.) have the form of relatively complicated functional dependencies on physical parameters V, M, J, L_A, L_B, K_A, and K_B. The model transmittances do not depend on the form of the input $\varphi(t)$; therefore, they are particularly useful for the identification of unknown parameters. The identification of this type may be carried out with the use of frequency characteristics of specific transmittances, i.e. the amplitude vs. frequency and phase vs. frequency curves, and with applying the standard calculation procedures used in automatics.

Let us assume that the time histories of model variables have been recorded and that the frequency characteristics corresponding to transmittances of the "bicycle model" of the motor vehicle are known. Seemingly, it should not be a difficult computational problem to determine the correct value of mass M if only appropriate procedures of parametric identification were applied. Alas, the moment of inertia J as well as the K_A and K_B coefficients also depend, directly or indirectly, on the mass M, which means that actually J = J(M), $K_A = K_A(M)$, and $K_B = K_B(M)$. We should also remember that apart from the resultant mass M, the distribution of the mass in the vehicle is also important, because the distribution affects the parameters L_A and L_B as well as K_A and K_B. At identical total mass M, the parameters L_A and L_B as well as K_A and K_B will be different in the cases where the load is placed on the front seats only, on the front and rear seats simultaneously, or in the luggage compartment. Obviously, it is possible to make an assumption that appropriate reference characteristics corresponding to a number of combinations of various mass values, different variants of spatial distribution of vehicle mass, and various vehicle drive speeds might be stored in the memory of the MVSS processor in an "intelligent" car. With such an assumption made, an appropriate program executed in the MVSS processor might estimate (e.g. in a cycle following every opening of a vehicle door) the hypothetical mass of the vehicle occupants and the luggage transported and, taking this as a basis, might estimate different variants of the number of people involved in an accident. However, the information thus compiled, of high degree of uncertainty, seems to be of little use for the PSAP operator.

Another piece of information of considerable importance for the PSAP operator seems to be an answer to the question whether the driver actively controlled the vehicle or the vehicle moved without control before the accident. The passive driver's behaviour gives grounds to a suspicion that the driver fell into a faint, e.g. due to a stroke or heart attack. The inference of this kind might significantly contribute to the arranging of the optimum medical assistance. To obtain information about driver's activity, signals of other vehicle control systems, in particular ABS and ESP, might be used, as signals indicating the applying of brakes or the use of the steering wheel occur in the signal channels of these systems. Obviously, this information must be synthesized to a significant degree (i.e. to the form of an indicator) because of limitations of the MSD package.

In the case of a "highly intelligent" version of the MVSS, the MSD package might include direct information about the state of vital functions of vehicle occupants, obtained from special sensors installed in vehicle seats, head restraint systems, or safety belts. In certain cases where vehicle occupants (especially driver) suffering from specific diseases were involved, the MSD package might also include data about the type of the disease.

In the preceding deliberations on the additional information in the MSD package, much attention was paid to the state of health of the vehicle driver and passengers. The determining of the vehicle status just before and after the accident seems to be of somewhat less importance for the course of the rescue operation. When the camera (and especially a system of cameras) is appropriately positioned, the visual information should fully meet PSAP operator's expectations and make it easier for him/her to make correct decisions regarding the availability of adequate rescue equipment for the emergency services. At good quality of the picture recorded, the information provided by the sensors would be more useful rather for the police. However, the use of information obtained from the automatic vehicle control systems is worth being borne in mind, especially because this information might additionally help in verifying the correctness of operation of the MVSS measuring module. From the accident analysis point of view, the information about the linear velocity of the vehicle just before the accident, apart from the readings of the deceleration sensors, comes to the fore. The linear velocity value is present in many on-board automatic control systems. Let us note that if the accident notification procedure is initiated by a deceleration sensor at a relatively low speed, this may indicate an impact against a hard obstacle (e.g. a wall). On the other hand, an impact at a high speed with a relatively low deceleration value (for the specific speed) will indicate a collision with an object of good energy absorption characteristics. The information considered important for the assessment of collision effects will undoubtedly be that obtained from vehicle body crumpling sensors (if installed) and that about the actuation of airbags, safety belt tensioners, and head restraint systems. In consideration of the contents of the MSD package, this information should be provided in the form of indicators rather than values of specific quantities.

In authors' opinion, other data about the vehicle status just before the accident, e.g. lights being on or off, ABS or ESP operating or not, engine running or not, etc., may be included in the MSD package (providing that adequate space is available) as information of secondary importance.

Here, provisions of the EN 15722 standard should be cited. The total length of the MSD package is 140 bytes (1 byte = 8 bits), with 38 and 102 bytes of that being allocated for basic (obligatory) and additional (optional) data, respectively (Table 1). The additional data have the form of alphanumeric text chains and are not subject to program validation.

Bearing in mind, on the one hand, the MVSS concept presented and, on the other hand, the limitations regarding the format of the MSD package, efforts should be made to achieve the most effective allocation of the "free" 102 bytes so that the PSAP operator receives the best information and is thus enabled to organize appropriate rescue operations as quickly as possible. The additional information included in the MSD package in the form of synthetic indicators might significantly supplement the camera picture and facilitate operator's work at the PSAP monitoring centre.

5. Model of the additional information for the motor vehicle safety system with the e-Call function

A formalized model of the additional information in the MVSS is indispensable for both more precise defining (or even automation) of the synthesis of the additional data in the MSD package at the IVS and better subsequent reading and interpretation of the data at the PSAP monitoring centre.

The model is composed of the following elements:

- Signals generated by the measuring sensors at the moment of the accident (S_i, i = 1, 2, ...), defined by their classes;
- Synthetic indicators characterizing the accident (W_k, k = 1, 2, ...), defined by their classes and statuses;
- Mathematic relations between the characteristics (classes, statuses) of the signals and indicators.

The synthetic indicators are generated through certain mathematic (chiefly logic) relations based on the analysis and classification of appropriate signals.

The MVSS considerably depends on the set of the signals available. The MVSS is to cooperate with vehicles representing different automation levels (i.e. provided with sensor systems of various development degrees); therefore, the model adopted should be designed with adequate "margin," i.e. it should be applicable to vehicles with both more and less sophisticated equipment. Should data from a sensor unavailable in the system be required to determine the value of an indicator, the indicator value would be zero, which would be appropriately marked in the MSD package.

Below is shown a selected variant of the model, suitable for a car provided with measuring module (with doubled deceleration sensors and "element" detectors), standard ABS and ESC systems, and standard system of four airbags protecting vehicle occupants at frontal collisions, and additionally equipped with vehicle body crumpling sensors (on the front, rear, and both sides) and seat load sensors.

A list of the input information data, compiled for the sensor system adopted here, has been presented in Table 2. The division into classes has been given as an example. For the appropriate number of classes to be determined and for the limit values to be correctly assigned, additional research and analyses are required.

Table 3 shows a list of the indicators that have been set up as an example of the output information finally provided in the MSD package, with the data format having been specified as well. In the model proposed, an assumption has been made that three bytes would be assigned to each indicator, with the first and second bytes to represent the coded name of the indicator and the third one to be used by the coded class and status values (1 – reliable information; 0 – unreliable information). As it can be seen, the available 102 bytes may be used for the placing of as many as 34 indicators together with their coded names in the MSD package at the assumption as above.

Table 2. A list of the measurement signals S_i, i = 1, 2, ..., 32 (example)

i	Name	Description	Classes allowed
1	MAX1	Longitudinal deceleration, from sensor 1 of the module	0, 1, 2, 3, 4
2	MAX2	Longitudinal deceleration, from sensor 2 of the module	0, 1, 2, 3, 4
3	MAY1	Lateral deceleration, from sensor 1 of the module	0, 1, 2, 3, 4
4	MAY2	Lateral deceleration, from sensor 2 of the module	0, 1, 2, 3, 4
5	MAZ1	Vertical deceleration, from sensor 1 of the module	0, 1, 2, 3, 4
6	MAZ2	Vertical deceleration, from sensor 2 of the module	0, 1, 2, 3, 4
7	MB1	Fire signal, from sensor 1 of the module	0, 1
8	MB2	Fire signal, from sensor 2 of the module	0, 1
9	MC1	Smoke signal, from sensor 1 of the module	0, 1
10	MC2	Smoke signal, from sensor 2 of the module	0, 1
11	MD1	Sinking signal, from sensor 1 of the module	0, 1
12	MD2	Sinking signal, from sensor 2 of the module	0, 1

Table 2. A list of the measurement signals S_i, i = 1, 2, ..., 32 (example) cont.

i	Name	Description	Classes allowed
13	PLP	Airbag actuation signal, left front	0, 1
14	PPP	Airbag actuation signal, right front	0, 1
15	PLT	Airbag actuation signal, left rear	0, 1
16	PPT	Airbag actuation signal, right rear	0, 1
17	ZLP	Vehicle body crumpling, left front	0, 1, 2
18	ZPP	Vehicle body crumpling, right front	0, 1, 2
19	ZLB	Vehicle body crumpling, left side	0, 1, 2
20	ZPB	Vehicle body crumpling, right side	0, 1, 2
21	ZLT	Vehicle body crumpling, left rear	0, 1, 2
22	ZPT	Vehicle body crumpling, right rear	0, 1, 2
23	V	Linear velocity just before the accident	0, 1, 2, 3, 4
24	OMEGA	Angular velocity of yaw just before the accident	0, 1, 2, 3, 4
25	H	Brake pedal depressing signal	0, 1
26	K	Steering wheel turning signal	0, 1, 2, 3, 4
27	ABS	ABS operation signal	0, 1
28	ESC	ESC operation signal	0, 1
29	OSLP	Seat load signal, left front	0, 1
30	OSPP	Seat load signal, right front	0, 1
31	OSLT	Seat load signal, left rear	0, 1
32	OSPT	Seat load signal, right rear	0, 1

Table 3. A table of indicators Wk, k = 1, 2, ..., 21 (example)

k	Name	Description	Class	Status
1	ZDERZ C	Frontal collision	1	1
2	ZDERZ B	Side collision	0	1
3	ZDERZ T	Rear-end collision	0	1
4	WYWR	Rollover	0	1
5	POŻAR	Fire	0	1
6	DYM	Smoke	0	1
7	ZATON	Sinking	0	1
8	POD LP	Airbag, left front	1	1
9	POD PP	Airbag, right front	1	1
10	POD LT	Airbag, left rear	0	1
11	POD PT	Airbag, right rear	0	1
12	ZGN LP	Vehicle body crumpling, left front	4	1
13	ZGN PP	Vehicle body crumpling, right front	4	1
14	ZGN LB	Vehicle body crumpling, left side	3	0
15	ZGN PB	Vehicle body crumpling, right side	3	0
16	ZGN LT	Vehicle body crumpling, left rear	0	1
17	ZGN PT	Vehicle body crumpling, right rear	0	1

Table 3. A table of indicators Wk, k = 1, 2, ..., 21 (example) cont.

18	OPÓŹN	Deceleration	8	1
19	PRĘDK	Velocity just before the accident	8	1
20	AKTYW	Driver's activity just before the accident	1	1
21	OSOBY	Number of persons involved	4	1
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				

In this example, 21 of 34 indicators available have been used. The information sent has indicated uncertainty regarding the vehicle body side crumpling values on both vehicle sides.

The determining of the indicator class and status will be presented with the ZDERZ C indicator having been taken as an example:

The class of ZDERZ C = 1 if MAX1 > 3 or MAX2 > 3
The status of ZDERZ C = 1 if MAX1 > 3 and MAX2 > 3
The status of ZDERZ C = 0 if MAX1 > 3 and MAX2 < 3 or if MAX1 < 3 and MAX2 > 3

The logical formulas for determining the class and status values are formulated in a similar way.

6. Final remarks

The concept of modelling the additional information generated in the motor vehicle safety system (MVSS) with the e-Call function and analysed in the PSAP monitoring centre requires that the division of values of the signals measured into appropriate classes should be more precisely defined. This may be accomplished on the grounds of additional research and analyses, with making use of computer simulation techniques.

In consideration of international nature of the e-Call system, the names of signals and indicators should be changed into terms derived from the English language.

The MVSS concept proposed may be easily extended to include additional functions, e.g. assault notification etc.

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